

Research on a Virtual Machine Mode Transfer Method Supporting Energy Consumption Optimization

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Abstract—In traditional cloud resource optimization scheduling, excessive pursuit of service performance and system reliability has resulted in low utilization of system resources and severe energy dissipation. In this paper, transfer target of virtual machines was taken into account with respect to the above problem, including virtual machine mode transfer method, hot mode sleep selection method and cold mode wake-up selection method that support energy protection. In other words, the operating mode and hot mode virtual machines are converged in a cluster of physical machines of minimum amount to reduce energy consumption by shutting down idle physical machines; the cold mode virtual machines are converged in another cluster of physical machines of as few physical machines as possible to reduce energy consumption through collective sleep. The experimental results show that the energy optimization resource adjustment strategy in this paper reduces the energy consumption of the system while ensuring the required system performance and reliability.

Keywords—Virtual machine mode transfer, Hot mode sleep method, Cold mode wake-up method, Energy consumption optimization;

I. INTRODUCTION

As the Internet technologies are developing rapidly, performance is often taken into account as the primary goal. A great number of cloud systems are constructed with a resource configuration for the maximum service performance. Nevertheless, such configuration programs can result in problems such as low resource utilization and energy dissipation in practices. With the expansion of cloud systems, these problems are becoming overwhelmed, forcing IT system managers to address energy consumption more seriously. However, there are numerous scenarios in which performance and energy consumption are not compatible due to the complex counteraction between performance and energy metrics. For example, allocating more virtual machines to a task can effectively improve performance, while consuming more energy. Therefore, it is necessary to make appropriate allocation of virtual machines to find an optimal balance between performance and energy consumption.

To address the above problems and reduce energy consumption, this paper focuses on the transfer target of mode

virtual machines, that is, when reducing the number of hot mode virtual machines, hot mode virtual machines are switched to the cold mode, for which a solution that reduces the most energy consumption is selected by using hot mode sleep selection algorithm that supports energy protection; when increasing the number of hot mode virtual machines, cold mode virtual machines are switched to the hot mode, for which a solution that increases fewer energy consumption is selected by using cold mode wake-up selection algorithm that supports energy protection. The effectiveness of the method is verified experimentally.

II. RELATED WORK

In terms of resource allocation strategy for mode transfer, there are three research approaches: virtual machine dynamic migration, virtual machine copy increment/decrement, and virtual machine resource dynamic scaling. Jiang et al.[1] described target virtual machine selection by user behavior and load characteristics based on the application history and analysis and evaluation of real-time performance data. Qiu et al.[2] analyzed dynamic storage resource optimization using genetic algorithms to achieve energy saving. Beloglazov et al.[3] proposed a resource allocation and distribution algorithm for energy management in the environment of cloud computing, of which the energy-aware distribution heuristic algorithm provides data center resources to client applications in a way that improves data center energy efficiency while providing negotiated quality of service (QoS). They used multi-objective programming algorithm without a violation of SLA to migrate virtual machines to less loaded servers while ensuring the minimum number of migrations. Xu et al.[4] analyzed the correlation between virtual machine running time and energy consumption, and proposed a method to optimize energy consumption by an effective arrangement of virtual machines. Yan et al.[5] proposed a comprehensive heat assessment method for virtual machines. Based on the availability and quality factors of services deployed on virtual machines, they established a heat index system, proposed an algorithm based on the subject weight of fuzzy analytic hierarchy process (FAHP) and the objective weight of maximizing deviation method, and provided rules for

determining hot and cold spots of virtual machines based on heat. Yuan et al.[6] addressed to virtual machine resource scheduling applying an improved particle swarm algorithm, mainly focusing on computing power of servers, which can reduce the service execution time to some extent. Shabeera et al.[7] proposed a meta-heuristic algorithm based on ant colony optimization (ACO) which selects a set of contiguous PMs to place data and virtual machines by taking the factors such as virtual machine arrangement and data placement into account. Huang et al.[8] proposed a virtual machine resource scheduling algorithm based on k-means, which uses the correlation of virtual machine resource allocation to cluster, in turn achieve virtual machine resource complementation and apply a greedy algorithm in resource scheduling.

III. MODEL DESCRIPTION

A. Virtual machine mode transfer algorithm based on energy protection

After activating a cloud service system, energy consumption, both basic and dynamic, is occurred. When the system is in standby, it will only produce basic energy consumption; when the system is running tasks, it will produce both basic and dynamic energy consumption. Table 3.1 shows the measured no-load power consumption of servers in the experiment. The data analysis results show that energy consumption generated by the sleep and shutdown state of servers is much smaller than that generated by the no-load and standby state of servers.

TABLE 1. NO-LOAD POWER CONSUMPTION OF SERVERS

Order	Server state	Power consumption
1	No-load running	0.1096
2	Server standby	0.1106
3	Server sleep (state saved to memory)	0.0095
4	Server sleep (state saved to hard drive)	0.0096
5	Server shutdown	0.0095

In order to reduce energy consumption, further considerations of transfer target of each mode virtual machines are necessary, that is, operating mode and hot mode virtual machines are converged in a cluster of physical machines of minimum amount to reduce energy consumption by shutting down idle physical machines; the cold mode virtual machines are converged in another cluster of physical machines of as few physical machines as possible to reduce energy consumption through collective sleep. The pseudo-code of the algorithm is shown in 1

Algorithm 1 Virtual machine mode transfer algorithm supporting energy protection

Input: the number of hot mode to be adjusted m , the total number of cold mode on the non-sleeping servers a , the number of sleeping physical machines c

Output: mode sets after adjustment

BEGIN

1. Initialization parameter b
2. **IF** $m > 0$
3. **IF** $m > a$
4. Select m cold modes to switch to hot mode
5. **ELSE**
6. Switch a cold mode on non-sleeping servers to hot mode
7. Wake up a physical machine to switch $m-a$ colds to hot mode
8. **END IF**
9. **ELSE IF** $m < 0$
10. **IF** $a-m > b$
11. Migrate virtual machines on servers, sleep a server, update mode sets
12. **ELSE**
13. Switch m hot mode to cold mode based on hot mode sleep selection algorithm, update mode sets

END

B. Hot mode sleep selection strategy based on energy protection

When reducing the number of hot mode virtual machines, hot mode virtual machines are switched to cold mode. In this paper, it will choose a solution with greater decrement in energy consumption. Table 2 shows the measured power consumption of loaded servers in the experiment. The data analysis result shows that servers with more cold mode switch from hot mode to cold mode will reduce less energy consumption. In contrast, physical machines with fewer cold mode switch from hot mode to cold mode will reduce greater energy consumption. Therefore, when reducing the number of hot mode virtual machines, to ensure as few energy consumption as possible, physical machines are set to sleep as the number of cold mode exceeds the number on a physical machine. Therefore, the optimal solution is to reduce hot mode on physical machines with more cold mode, so that it will reduce the number of migrated virtual machines while the physical machines are sleep.

TABLE 2. LOAD POWER CONSUMPTION OF SERVERS

Number of VMs CPU Utilization	1	2	3	4
0%	0.1093	0.1089	0.1098	0.1103
20%	0.1316	0.1355	0.1399	0.1424
60%	0.1317	0.1404	0.1472	0.1543
80%	0.1380	0.1441	0.1573	0.1652
100%	0.1385	0.1509	0.1618	0.1691

Number of VMs CPU Utilization	5	6	7	8
0%	0.1099	0.1093	0.1086	0.1095
20%	0.1481	0.1527	0.1548	0.1565
60%	0.1569	0.1659	0.1694	0.1765
80%	0.1656	0.1689	0.1747	0.1822
100%	0.1732	0.1734	0.1769	0.1824

From the above analyses, this paper designs a hot mode sleep selection algorithm supporting energy protection, the pseudo-code of which is shown in 2.

Algorithm. 2 Hot mode sleep selection strategy supporting energy protection

Input: current system virtual machine deployment solution, number of hot mode to sleep m , residual resources of server i

$R_{cpu}[i]$

Output: mode sets after adjustment

BEGIN

1. Initialization parameter f
2. **FOR** $i=1$ to f
3. For resource residual of each server R_{cpu} sort to

get R'_{cpu}

4. **END FOR**
 5. **FOR** $i=1$ to f
 6. Calculate the number of hot mode num in the set of virtual machines corresponding to $R'_{cpu}[i]$ servers
 7. **IF** $sum \geq m$
 8. Transfer m hot mode to cold mode set
 9. **Break**
 10. **ELSE**
 11. Transfer sum hot mode to cold mode set
 12. $m=m-sum$
 13. Update mode sets
 14. **END IF**
 15. **END FOR**
- END**
-

C. Cold mode wake-up selection strategy based on energy protection

When increasing the number of hot mode virtual machines, cold mode virtual machines are switched to hot mode. In this paper, it will choose a solution with less increment in energy consumption. According to the energy consumption model of physical machines, the physical machines with more cold mode switch from cold mode to hot mode will generate greater energy consumption. On the contrary, physical machines with less cold mode switch from cold mode to hot mode will generate less energy consumption. Therefore, in order to consume as few energy as possible when increasing the number of hot mode virtual machines, this paper designs a cold mode wake-up selection algorithm supporting energy protection, the pseudo-code of which is shown in 3.

Algorithm. 3 Cold mode wake-up selection algorithm supporting energy guarantee

Input: current system virtual machine deployment solution, the number of cold mode to wake up m

Output: mode sets after adjustment

BEGIN

1. Initialization parameter f
 2. **FOR** $i=1$ to f
 3. For resource residual of each server R_{cpu} sort to
- get R'_{cpu}
4. **END FOR**
 5. **FOR** $i=1$ to f
 6. Calculate the number of cold mode num in the set of virtual machines corresponding to $R'_{cpu}[i]$ servers
 7. **IF** $sum \geq m$
 8. Transfer m cold mode to hot mode set
 9. **Break**
 10. **ELSE**
 11. Transfer sum cold modes to hot mode set
 12. $m=m-sum$
 13. Update each mode sets
 14. **END IF**
 15. **END FOR**
- END**
-

IV. EXPERIMENTAL RESULTS AND ANALYSIS

Table 3 shows a default set of experimental parameters. To better characterize each method, the loadrunner is used to load the backup system in three time periods: during 0-4 hours, simulate 0-5,000 requests per second; during 5-8 hours, simulate 5,000-10,000 requests per second; during 8-12 hours, simulate 1,000-10,000 requests per second. In each time period, three experiments are conducted to test the adjustment methods: the first experiment uses control method 1, and the second experiment uses control method 2. The number of operating modes is adjusted according to the predicted concurrency against control method 2 for fairness. The third experiment uses the method designed in this paper. Finally, this experiment uses the system energy consumption as an index to analyze the performance of adjustment methods to verify the effectiveness of the virtual machine mode transfer method based on energy consumption optimization designed in this paper.

TABLE 3. EXPERIMENTAL PARAMETERS

symbol	Description	value
T	Total time of an experiment	12h
n	Number of virtual machines allocated for an experiment	20sets
C	Maximum number of virtual machines loaded on a server	8sets
S_F	Average failure time of each virtual machine in an experiment	4h
MSB	Number of backup servers	variable

In this paper, three sets of controlled experiments are conducted, comparing method 1 (all operating modes), method 2 (traditional backup method), and the method

designed in this paper (virtual machine mode transfer method based on energy consumption optimization), and the results are shown in Figure 1:

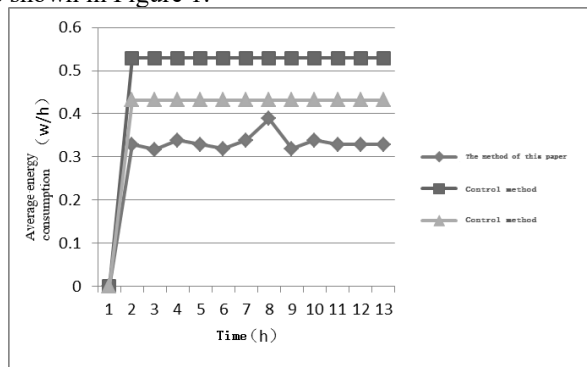


Figure 1. Energy consumption under different VM adjusting methods

Figure 1 shows that within 12 hours, the average energy consumption of the working virtual machines under the adjustment method proposed in this paper is much lower than that of the control method 1. Because the dynamic optimization method in this paper includes a mode transfer strategy based on energy protection, which transfers cold mode to a physical machine as much as possible, while the control method 1 that has all virtual machines in working state without considering energy savings consumes the most energy. The control method 2 is a traditional backup method that only considers a backup mode (cold mode) which is in sleep state, so that consumes less energy. It is calculated that the proposed strategy in this paper generates an average energy savings of 12.16% compared to the control method 1 and 10.15% compared to the control method 2.

V. CONCLUSION AND EXPECTATION

In this paper, a virtual machine mode transfer method supporting energy consumption optimization is proposed, and three sets of controlled experiments are designed to verify the effectiveness of the proposed method, which can make flexible adjustment according to the request status, and reduces energy consumption while ensuring cloud service performance and responding to user requirements.

In this paper, with respect to the mode transfer method that supports energy protection, when the operating mode virtual machines fail, the complete switch of hot mode is taken into account without expecting failure during switch, which may affect the effectiveness of dynamic optimization strategy. It is recommended that switch failure types of hot mode switch may be included in further studies.

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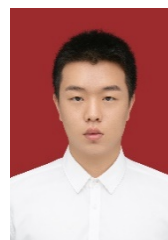
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