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Energy Efficient Allocation for Cloud System Using Evolutionary Algorithm

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Abstract— In recent years, high-performance computing service for research and application is improvement quickly. The computer systems serving for high-performance computing is growing up. The advent of cloud computing has changed the way that manages and uses computer system resources. Therefore, scheduling techniques become important tools in cloud computing. In this article, we will introduce a scheduling technique to reduce energy consumption for cloud systems using evolutionary algorithm. The effectiveness of the algorithm is shown by experimental results. Thereby, demonstrating the energy-aware ability of evolutionary algorithm in comparison with related researchs.

Keywords— energy-aware scheduling, virtual machine allocation, cloud computing, resource management, evolutionary algorithm

I. INTRODUCTION

In recent years, high-performance computing service for research and application is improvement quickly. Typically, it apply in calculation of research weather forecast, or analysis statistical of stock market. Therefore, the parallel system serve the high-performance computing is growing as an inevitable trend.

Cloud computing has changed the way to manage and use system resources. It has many advantages such as flexibility, scalability and easy system, responding user demands with a reasonable cost. In cloud computing technology, virtualization is a mainstream characteristic. Cloud systems can provide many types of services that fit the different user demands, such as: Infrastructure as a Service (IaaS), Platform as a Service (PaaS), Software as a Service (SaaS). Customers wish to use the computing infrastructure at a low cost and simplicity of deployment issues. Through hiring cloud computing infrastructure, they can reduce the cost of construction and maintenance of their system. They are also easier to upgrade the computing infrastructure by hiring new infrastructure from suppliers without having to change the old computer system. Technology companies such as Microsoft, IBM, Google, ... spend millions of dollar for researching about cloud systems each year.

A computing system uses cloud computing technology can provide thousands of virtual resources to users. Thus, the management of these virtual resources manually will not bring high efficiency. Scheduling techniques become important tools in cloud computing. Using the optimal schedule helps the system administrator to use resources efficiently and still meet the requirements of users. Scheduling technique also enables providers allocating resources to users according to their purposes in the best way. However, most research on scheduling

for cloud computing system based concerns about the performance of the system, or for the purpose of quality of service to fit the user demands. The researchs are interested in power consumption of the system is still quite limited in number.

In this article, we will introduce a scheduling technique to reduce energy consumption for cloud systems using evolutionary algorithm. Chapter 2 will talk about the relevant research on aware-energy. Chapter 3 provides energy problem model. Chapter 4 proposed evolutionary algorithm to solve the energy problem. Chapter 5 describes and evaluates the experimental results. Chapter 6 summarizes the paper.

II. RELATED WORK

Cloud system includes one or more data centers that use large power. For that reason, demand for energy efficiency of system is reducing power consumption in order to lower operating costs. High energy usage will increase the temperature of the electronic devices, leading to instability in the system. Research [10] also show that activities in the information and communications technology caused 2% of CO_2. So they want to reduce harmful emissions from using resource, with the aim to build Green information technology infrastructure.

Minh Quan Dang et al. [2] proposed T-Alloc algorithm to minimize system power. Researchers consider problem of assigning jobs into servers to increase the energy efficiency of centralized data system, including cost of manpower to perform the configuration system. T-Alloc algorithm is designed based on heuristic that transfer heavy load jobs for servers with multiple CPU cores and lightweight load jobs for server with fewer CPU cores. Based on the experimental results, algorithm T-Alloc offer solution with better for energy saving and faster performance which compare to solving problem by linear model.

Yan Ma et al. [4] consider reducing energy problem for cloud system with applications that are a set of the independent task and can execute in parallel. A new feature of the problem is the application which must perform continuously and have deadline for each task. Cloud system consist of heterogeneous computers which have difference hardware configuration. Execution time of a task when executed on computer with different hardware configuration is different. The author proposed EES algorithm to solve problem. EES based on heuristic, try assigning more and more tasks on computers which have best energy efficiency.

Nguyen Quang Hung et al. [9] proposed EPOBF algorithm to solve energy problem for heterogeneous system, use different types of virtual machine. The jobs are fixed. Algorithm based on the Performance-per-watt value to decide assigning the job to the machine.

III. MATHEMATICAL MODEL FOR ENERGY PROBLEM

A. Cloud computing infrastructure model

Heterogeneous computer systems consist of multiple computers with different hardware configurations. System have n computers, $C = \{c_1, ..., c_n\}$. Each computer can offer some different types of virtual machine (VM). System specification of virtual machine based on demands of each job. Assuming that, the system supports h virtual machines, $A = \{a_1, ..., a_h\}$. Each computer can maximum supply a number of VMs for each type VM at a time, so as not to exceed the resources of the computer allows this. The average CPU usage of a VM on a computer can identify by surveillance resources technical. For example, we run a VM on a computer and use software to monitor resources such as BMC Patrol or Tivoli to measure the average CPU usage of that one. Besides, a VM execute only one job at a time. In this problem, we focused on the energy consumption of the physical machine without regard to energy of other components such as air conditioning systems, network devices, ... Power consumption of the machine is calculated using the formula [2]:

$$P = P_{idle} + (P_{\max} - P_{idle}) * \alpha * \frac{s * f^3 * U}{P_{CPU\max} - P_{CPUidle}}$$

We use Dynamic Power Management technique [4] to save energy consumption. At a time, the computer has two state: - Active status, which means that the computer is providing VMs to serve certain jobs. - Idle status, meaning that the computer does not provide any VM. Then, computer will be switched off to reduce power consumption.

B. Job model

We consider static job model, meaning the jobs were known in advance, and no job is required unusual. The user's request is a set of m jobs, $J = \{j_1, j_2, ..., j_m\}$. Each job requires system to provide the number of VMs which have different type depending on demands of job. The number of z type VMs that the j job required is the v_{jz}. Each job has informations about the release time, the deadline, the execute time. The execute time is fixed and known in advance. The start time of job is not fixed and can be changed flexibly. However, the job is not allowed to start before the release time and end after the deadline. This ensure the user demands is guaranteed. This is also a new point of our paper than previous researchs. Each job must be executed

sequentially from the beginning until the end on the VM has been allocated that one. Our research did not consider splitting job during execution time.

C. Energy optimization problem

Input: Cloud system have *n* computers with different hardwares. There are *m* jobs sent to the system with informations that is introduced in job model.

Output: A best schedule distribute VMs that are required by jobs into computers with the criteria to minimize power consumption of cloud system.

Problem constraints:

- Constraint 1. Number of VMs provided for each job must equal to the job demands.
- Constraint 2. Resources each computer used to allocate VM is not beyond their capacity at a time.
- Constraint 3. A job is not allowed to start before the release time.
- Constraint 4. A job is not finished after the deadline.
- Constraint 5. A job must be executed continuously.
- Constraint 6. A VM execute only one job at a time.

IV. EVOLUTIONARY ALGORITHM FOR ENERGY OPTIMIZATION PROBLEM

To solve the energy optimization problem for cloud system, we used evolutionary algorithm to find an appropriate schedule.

A. Performing a gene

A gene is a solution of the problem. It is represented by 3-dimensional array:

- The first dimension represents the computers of system.
- The second dimension represents the time.
- The third dimension represents the VMs of jobs that are assigned to the computer at a time.

B. Initializing the first population

The genes in first population will be randomly generated. Generating a gene as follows:

- Selecting randomly each job in the job set.
- For each job, selecting each VM that job needs. Then, randomly assigned this VM to a random computer if that computer can contain it.
- Repeat this until the end. Finally, we have a gene.

C. Determination fitness function

Fitness function is energy consumption function for a gene.

$$f = \sum_{i=1}^{n} P_i$$

D. Genetic operators

In our evolutionary algorithm, we only use mutation operators to improve the genes in population. To ensure the constraints of the problem, we used the following mutation operators:

- First operator move a VM of random selected job to a random suitable machine.
- Second operator permute two random jobs. We must check constraints for two jobs.
- Third operator slip a random job on gene. Checking constraints for that job.

E. Selection process

The selection process will be based on roullet wheel of classic GA algorithm. The probability of selection was calculated using the formula:

$$p_i = \frac{f_i}{\sum_{k=1}^{n} f_k}$$

F. Evolutionary algorithm

TABLE I
PROCEDURE EVOLUTIONARY ALGORITHM

```
Procedure Evolutionary Algorithm
Begin
    Initializing the first population P
    Evaluating P
    For i = 1 to n
        If not end_condition then
            p = Random()
            If p < pmut1 then
                Do first mutation operator
            If p < pmut2 then
                Do second mutation operator
            If p < pmut3 then
                Do third mutation operator
            Selection P
            Evaluating P
        Else
            Exit
End
```

V. EXPERIMENTAL RESULTS

Simulation system consists of heterogeneous computers are randomly generated. The computer has the hardware configuration of three types. Hardware configurations and informations on the three types are taken from [3].

TABLE II
HARDWARE CONFIGURATION OF COMPUTER

Type	Cores	f	RAM	P_{idle}	$P_{\max}$	$P_{CPUidle}$	$P_{CPU\max}$	α
1	2	1.9	2	76.44	103.39	9.88	33.18	1.7
2	4	2.2	4	95.75	171.70	20.14	91.88	1.68
3	6	2.4	8	128	229	22	99.6	0.93

Three VM type have resource configuration as follows: {1; 2; 4} core, {1.5; 2; 2} GHz, {512; 1024; 2048} MB.

Set of jobs is randomly generated by the following methods:

- The release time is randomly generated in the range [0,9].
- The excute time are randomly generated in the range [2,4].
- Generating a random number in a range [0,3]. Deadline is calculated by sumimg release time, excute time and random number.
- The number of VMs of job demand is randomly generated in the range [1,3].

Generating five sets of experimental data. The experimental results will be compared with EPOBF algorithm to show the effectiveness in reducing energy. Energy efficiency of EA is better than EPOBF algorithm in every case. The experimental results are shown by the figure below.

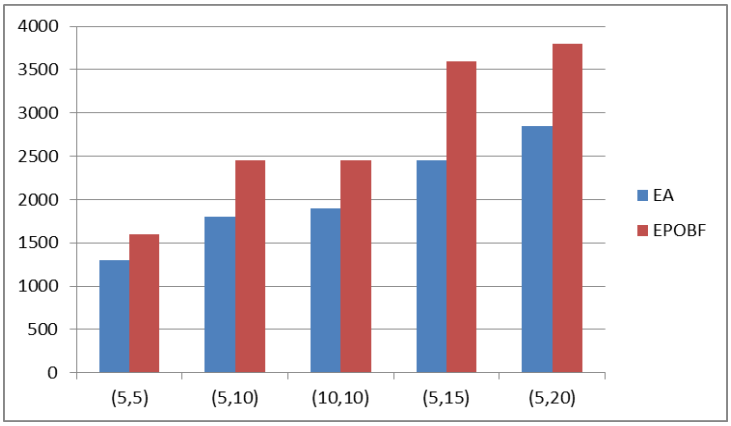

Fig. 1 A chart compares the energy consumption of the experimental system between EA and EPOBF

VI. CONCLUSIONS

Our paper focused on scheduling problem to minimize energy consumption for cloud systems. This research has some new features compared to the related research such as support many different types of VM, the jobs is not fixed and can start execute flexibility in a period of appropriate time, the jobs may require different types of VM. This paper also proposes evolutionary algorithm to solve the energy problem. The effectiveness of the algorithm is indicated in the experimental results section.

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