Research on the Establishment of MSR Model in Cloud Computing based on Standard Performance Evaluation

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Abstract: The paper proposed a new method to establishment the MSR model in cloud computing based on standard performance evaluation. In general, the change case of server energy consumption is complex, a variety of factors are mixed together. However, with the changes in computer architecture, the relationship between energy and resource utilizations may not be linear. In fact, this paper explored a variety of regression analysis methods to estimate the energy consumption accurately while using low computational overhead. Experimental results show that in adoption of energy model presented in this paper, the prediction accuracy can reach more than 95%.

Keywords: Cloud Computing, Data Centre, Energy Modeling, Resource Scheduling Algorithm.

1. INTRODUCTION

Energy model is an important part of the cloud data centre. In the cloud data centres which are intermittently running, users and managers need to understand how their behaviour effects on computer energy consumption, so as to take corresponding control measures, to achieve the goal of energy efficiency optimization. With the support of hardware vendors on energy consumption, many components have supported the real-time measurement of energy consumption, but one side the pure physical measurement can predict the needs of future energy consumption; In the other side, they can provide effective contact between resource utilization and energy consumption, and that is the enter point none other than a lot of energy efficiency optimization algorithm. Now, as a result of the constant expansion of the cloud data centre scale, the characteristics of data centre energy consumption are also becoming complicated, many researchers have proposed practical models. However, the efficiency optimization works have huge differences direct at SaaS, PaaS and IaaS (software/platform/infrastructure as a service), and the portability is lack among different levels of energy consumption models.

Therefore, this article attempts to build reasonable and reliable energy model for the cloud data centre servers from the cloud infrastructure layers, and then compare the impact of energy model by different sampling and mathematical methods. In the first place, it focuses on the characteristics of the nonlinear energy model built by us; then, it use the research achievement of energy model suggested by this article on algorithm and experiment, in order to demonstrate the effectiveness of the energy model stated by this article, and the energy model is also applied in other energy consumption research work.

2. ENERGY MODEL OF CLOUD DATA CENTER

2.1. The Established Principle of Energy Model

Generally, an accurate and efficiency energy model is very important for the optimization works of cloud data center, although the hardware integration lots of energy modules and components associated with energy consumption, but it can only measure the real-time energy consumption of this module or this node. They can't predict the future energy consumption; neither can they connect energy consumption with system utilization rate efficiently and essentially. Therefore, we need a cute and efficient energy module to provide efficient support on subsequent resource scheduling algorithm.

1. Whole system. The model should be connected with whole system energy consumption by system with information, not only modeling aiming at a separate component;

2. Accurate. The accuracy of the optimization algorithm direct at the energy efficiency of system should be high enough, for example, the average relative deviation of the model should be little than 10%. In addition, the more precise the model is at first, the more advantages to later optimize work;

3. Express. Energy model should forecast energy consumption as quick as possible even real-time;

4. Universality. Model framework should be generally used for different systems, such as for different processors, and memory control technology;

5. Elastic. Model should be able to expand or contract easily according to the size of the cloud computing environment;

6. Simple. Model should be as simple as possible, when the prediction accuracy and support of energy saving optimization method are not affected at the same time,
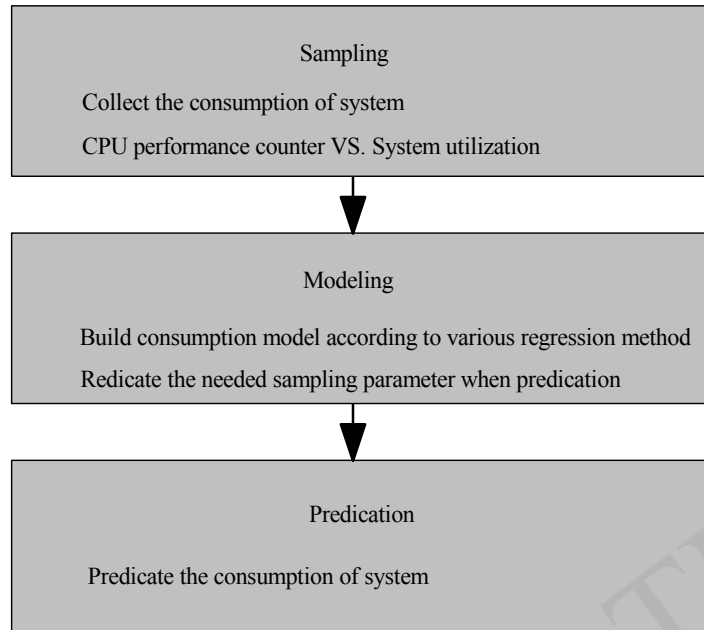
Fig. (1). Basic process of energy molding.

the number of input parameters and the complexity of the model should be reduced as possible.

2.2. The Basic Process of Energy Model

As shown in Fig. (**1**), it includes the following three basic steps: gathering energy consumption and its related resources information; establish energy model according to the regression analysis method; monitoring energy consumption of system with energy model. The specific processes are as follows:

1.　Sampling

First of all, collect system energy consumption and the influence factors on energy consumption of service when the applications are running. According to the informed research [1, 2], this article finally determine the two basic directions of sampling: processor performance counters system utilization.

2.　Build energy model

In general, the change case of server energy consumption is complex, a variety of factors are mixed together. Therefore, we must get the complex research objects into simple and idealized research objects, and live up to the energy consumption principle put forward before. However, the contributions to energy consumption of resource information divisors obtained by sampling are uneven, this paper us3the method of regression analysis, with means of mathematics, medium filtering through energy consumption factor, thus reducing the number of factors were introduced, on the basis of the small influence precision to achieve the purpose of reducing model complexity.

3.　The accuracy of the test energy model, and use the model of monitoring system energy consumption

According to the energy model, we can selectively collect factors or components which have great influence on energy consumption, using for real-time monitoring of system energy consumption.

This article does not discuss to take the heat of node server as the parameters of energy model individual, while the heat energy consumption is huge [3, 4], but the collection of heat parameters needs additional sensors and hardware, and the modeling methods has big difference with the methods of this article. Therefore, this article can't take the server heat as a parameter to establish energy model temporarily, but set up the energy model of the system layer according to the system resource utilization.

4.　Standard inspection procedure Benchmark

To learn the performance of node server, researchers can run a set of procedure or operation on the server, the program is called the standard inspection procedures (benchmark). Benchmark is usually associated with the performance of a certain part of computer hardware, such as the floating point of processor, the read and write access speed of hard disk, etc. Benchmark is typically used in comparison between different subsystems in computers with different system structures. Common Benchmark include: computing model, such as SPEC2006; Disk I/O type, such as I/Ozone; Network type, such as Netperf (see in Table **1**).

We use SPEC2006 (Standard Performance Evaluation Currency) as Benchmark in the process of energy modeling, the SPEC is a loose open source institution, it is as a NCGA (National Computer Graphics Association) of a group, founded in the 1980 s, the founders of the team come from HP, DEC, MIPS, SUN, they have a set of standard test procedure for evaluating the performance of the new machine.

Table 1. Common benchmark and its type.

Benchmark Type	Name	Calculation Type
SPEC2006	CINT(gobmk); CFP	CPU、Memory intensive
NPB	cg, mg , ep, lu	CPU、Network-intensive
Disk	Postmark, iozone, bonnie	CPU、I/O intensive
Netperf	Netperf client	Network-intensive

One group of standard inspection procedure was called SPEC89, contains 10 procedures; SPEC92 is then expanded to 20 programs, including six integer program and 14 floating-point, respectively called SPECint92 SPECfp92. Subsequently, the SPEC and released some new standard inspection procedures (such as SPEC95 SPEChpc96 SPECweb96, SPEC2000, etc.). The SPEC2006 is an effective tools to assess computing performance of the application of computer really, and these real scenes including machines go, weather forecast, linear programming algorithm, video coding, genetic sequence search, compilers, discrete event simulation, quantum computing, molecular dynamics simulation and physical simulation of ray tracing, fluid mechanics calculation, finite element method of structural mechanics, speech recognition.

According to the related research [4, 5] and our experiment summarize, the cloud computing infrastructure, the node state of CPU and memory has the most energy consumption and adjustable parts. So we choose the utilization rate of the two parts as the basic parameter of the energy model, and take it into multiple regression models.

3. ENERGY MODEL PROCESS BASED ON THE COMPUTER NODES OF CLOUD DATA CENTRE

3.1. Monitor Events of Performance Counter

Intel processor has introduced in performance monitoring systems from the Pentium (Pentium) series through a set of specific model of performance monitoring counter (MSR). These counters allow selecting the performance parameters of processor for monitoring and measurement, and the performance information can be used to adjust the system and the performance of the compiler. In the Intel P6 series processors, performance monitoring mechanism has been enhanced, allowed to monitor events which have more widely rights. Subsequently, Pentium4 and Xeon processor have introduced a new monitoring mechanism and a new set of performance events. Performance monitoring mechanism is unstructured in the Pentium, P6 series, Pentium4 and Xeon, they all depend on the particular model (processor series incompatible). Starting from the Intel Core Solo and Intel Core Duo, processors support a set of structured performance events and a set of unstructured performance events. Generally speaking, the events that can be monitored include instructions, cache and page table cache, etc.

1. Instruction

By comparing the energy consumption and performance monitoring events it can be clearly seen that the instruction cycle always has a prominent contribution to energy consumption. Usually, when executing a command, the more the cells participate in the work, the higher power consumption will be.

2. Cache

Take Xeon E5620 as an example, this is a processor based on microstructure. Its level 1 cache (L1 cache) is divided into two parts: one part focuses on the instruction cache (precompiled instruction), the other part is the data cache. Level 2 cache (L2 cache) is a unified cache of data and instruction. Each processor core has its own L1 cache and L2 cache. The level 3 cache (L3 cache) is shared by all the processor cores, is a unified compatible data and instruction cache. The cache is used to reduce the latency of memory access and improve the data processing speed of the processor. In general, the lack of instruction and data cache means cell needs to stop, until the available resource appears. The low lack and high hit of L1 / LLC cache have advantages on the fast instruction execution, which affects the energy consumption.

3. Page table buffer (TLB)

TLB stores the page directory and page table entries which are recently often visited, to improve the translation speed from virtual addresses to physical addresses. These will help to speed up memory access, when its need to access the page table in the system memory, the TLB can effectively reduce the number of accessing memory. TLB is divided into data TLB and instruction TLB. If TLB misses, the processor stops until the main memory complete the work, and indirectly affects the system energy consumption. As a result, these performance events could be impact factors of energy consumption. But they are different in different processors; important factor can be effectively filtered out through mathematical way, and to establish models. The performance of linear energy model based on performance counter is shown below:

$$P = C_0 + \sum_{i=1}^{n} C_i * P_i \tag{1}$$

Among it, C_0 is constant P_I expresses the collected performance counter events, C_i expresses the impact factors on

energy consumption of event i. C_0 and C_i can be achieved through a simple linear regression.

3.2. Energy Model Based on System Usage

As mentioned above, the performance counter is introduced by Intel Pentium series processor, and not all existing processor support this kind of monitoring system structure, and there are certain differences between different types of processors. On the other hand, because of a particular application or virtual machine is hard to get the data of performance events such as cache miss before running, so it is difficult to know the increasing scope of energy consumption through the performance counters to predict the scope of energy consumption led by applications or virtual machine. However, the preliminary application estimates of energy consumption is extremely important to the source scheduling algorithm that has optimize energy consumption, as a result, the energy consumption model based on system usage study is very necessary.

3.3. The Energy Model Based on CPU Usage

CPU is the main energy consumption part in computer system, and it has convenient adjustment method. Therefore, by adjusting the CPU state to regulate the whole data centre energy consumption state of the system is the main method of saving energy. In the energy model, mostly involves the adjustment of the state of the CPU. We first select one representative that only uses CPU usage to predict energy consumption model of [6-8]. Model as shown in Formula (2), the energy consumption predicted by the energy model is a linear function of the CPU usage, C0 is constant, C1 express CPU utilization of the impact factor of energy consumption, C0 and C1 is obtained by simple linear regression:

$$P=C_0+C_1U_{CPU} \tag{2}$$

4. THE EXPERIMENT AND RESULT ANALYSIS OF ENERGY

4.1. Experiment Platform

In this experiment, the experimental environment nodes use Intel Xeon E5620 CPU, the main memory is 48G, and Linux kernel is the version of 2.6.32-220.el6. X86_64. The tool monitoring performance counters is perf-2.6.32. Compiler environment is GCC - 4.4.6.

4.2. Training and Testing Set

In order to effectively sampling, we put the SPEC2006 as our standard inspection procedures. SPEC2006 is divided into floating-point and integer calculation these two types, to make full use of the information of the processor, we separate these two kinds of calculation into two parts: one part is used for collecting information of performance counter, and build model; Another part is used during model checking, to

analysis the influence of different mathematical method on model based on the performance counter. The specific classification is shown in Table **2**.

Table 2. Training set and testing set of energy modeling based on performance counter.

	Training Set	Test Set
integer type Benchmark	bzip2,gcc, sjeng, h264ref, astar, xalancbmk, gobmk	hmmer, libquantum, mcf, omnetpp
floating-point type Benchmark	bwaves, gamess, zeusmp, gromac, cactusADM, calculix, GemsFDTD, tonto, wrf, sphinx3, dealII, soplex, povray	lbm, leslie3d, milc, namd

4.3. Acquisition and Modeling

We run each Benchmark for 10 times in the training set of servers, gathering performance monitoring events of 3 Xeon processors mentioned in Table **3**.

We obtained multiple sets of data through the above procedures, and use three kinds of mathematical models to carry on regression analysis, respectively are: the least squares regression under the linear regression, lasso regression and the nonlinear SVR. We use SPSS software to have multiple linear least squares regression, and use the glmnet package to implement the Lasso regression, the package can have efficiently Lasso regression and ridge regression on linear regression and a mixture of both regressions; In view of the SVR, we obtain the energy consumption model adopting libsvm tools, through data normalization, the training sample etc. steps.

CONCLUSION

This article proceeds with the angle of processor performance counters and system utilization, combining with multiple linear regression stepwise regression and Lasso regression, polynomial under nonlinear regression, polynomial + index form and support vector machine (SVM) regression, to analysis and summarize the influence of different parameters and methods on the server energy model. Generally speaking, model based on performance counters adopt general multivariate linear regression, and the energy model based on system usage is suggested to adopt polynomial nonlinear model. On the other hand, the model effect of performance counter is better than using the model of system usage, but use the system usage model can effectively estimate the effect on single application, this is critical for many resource scheduling methods based on energy consumption awareness. And under the condition of sampling only a few system usage of components related to energy consumption, after the system

Table 3. Performance monitoring events of Intel Xeon E5620.

CPU-cycles	L1-dcache-loads	LLC-loads
stalled-cycles-frontend	L1-dcache-load-misses	LLC-load-misses
stalled-cycles-backend	L1-dcache-stores	LLC-stores
instructions	L1-dcache-store-misses	LLC-store-misses
stalled cycles per insn	L1-dcache-prefetches	LLC-prefetches
cache-references	L1-dcache-prefetch-misses	LLC-prefetch-misses
cache-misses	L1-icache-loads	context-switche
branch-instructions	L1-icache-load-misses	CPU-migrations
branch-misses	dTLB-loads	alignment-faults
bus-cycles	dTLB-load-misses	emulation-faults
task-clock	dTLB-stores	branch-loads
page-faults	dTLB-store-misses	branch-load-misses
minor-faults	iTLB-loads	
major-faults	iTLB-load-misses	

is stable, can control the deviation of energy consumption model within 5%, so we use the method in follow-up study.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflicts of interest.

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