Jurnal Ilmiah KURSOR
Menuju Solusi Teknologi Informasi

Vol. 6, No. 4, Juli 2012 **ISSN 0216 – 0544**

REAL TIME ESTIMATION AND MONITORING OF POWER IN HOMOGENEOUS SERVER CLUSTER USING MULTIPLE LINEAR REGRESSION

[a]Supeno Djanali, [b]Hudan Studiawan
[a,b]Department of Informatics, Faculty of Information Technology,
ITS Surabaya, Indonesia, 60111
E-Mail: [a]supeno@its.ac.id

Abstrak

Estimasi daya merupakan salah satu bagian yang sangat penting dari optimasi daya di lingkungan klaster homogen. Sebelum daya dioptimalkan, terlebih dulu harus dihitung daya yang dikonsumsi oleh *server*. Beberapa studi telah dilakukan untuk memperkirakan daya yang dikonsumsi oleh seluruh anggota pada klaster. Namun, banyak dari studi tersebut yang masih menggunakan metode rumit dan perangkat keras yang mahal sehingga sulit untuk diterapkan di lingkungan klaster yang nyata. Dalam makalah ini, diusulkan metode estimasi daya yang lebih murah, sederhana, dan *real time* di klaster *web server*. Perhitungan yang lebih akurat dilakukan dengan menggunakan regresi linier berganda. Parameter yang digunakan adalah penggunaan prosesor, memori, dan antarmuka jaringan. Pemantauan secara terpadu dan *real time* dapat dicapai dengan menggunakan program *daemon* sederhana dan teknik pemrograman *socket*. Percobaan yang dilakukan pada klaster terdiri dari *empat web server* dan dua *load balancer* menunjukkan bahwa metode estimasi daya yang diusulkan mencapai akurasi 91,87% dan pemantauan daya berjalan dengan baik secara *real time*.

Kata kunci: EstimasiDaya, KlasterHomogen, Regresi Linier Berganda, *Web Server*.

Abstract

Power estimation is very important subtask of power optimization in homogeneous cluster environment. Before optimizing power, we must first calculate power consumed by a server. Several studies have been conducted to estimate power consumed by all members in the cluster. However, they still use a complicated method and expensive hardware such that difficult to implement in real cluster environment. In this paper, we propose cheaper, simpler, and real time power estimation methods on cluster of web server. More accurate calculation is conducted by using multiple linear regression. Parameters considered are utilization of processor, memory, and network interface. Real time and integrated monitoring can be achieved by employing simple daemon and socket programming technique. Experiments are performed in the cluster consisting of four web servers and two load balancers demonstrates that the proposed power estimation method achieves an accuracy of 91.87% and power monitoring run well in real time fashion.

Keywords: Power Estimation, Homogeneous Cluster, Multiple Linear Regression, Web Server.

INTRODUCTION

Power estimation means we can measure power consumption without using metering instrument. As a key subtask, estimation will make monitoring and power optimization become easier and more efficient. Power optimization will lead to energy saving. Various researches have been proposed to estimate power in single server. Estimated power at all system using the performance counters on microprocessors is discussed in [1]. Access to chipsets, microprocessors, memory, disk, and network input/output (I/O) is recorded by a microprocessor and these data are used to estimate power. In [2], power modeling in Itanium blade server environment that called Mantis is proposed. Mantis calculates the use of central processing unit (CPU), access to memory, as well as the level of I/O on hard disk and network. The data collected is then calculated by linear program to generate power estimation formula.

Using CPU utilization without counting the other server components proved to be accurate enough to estimate power consumed [3, 4]. Another approach by utilizing performance counters on microprocessors and only considering the processor frequency has also been proposed [5] and gives good results as well. There is software such as IBM Systems Director that able to perform real time power monitoring on chassis and its blade server in it. Unfortunately, this is expensive, commercially supported, and only available for blade server model.

Cluster is one type of distributed computer system, consisting of several stand-alone computers, and work together as integrated resource [6]. There are two types of cluster based on its member, homogenous and heterogonous. If member of cluster has the same specifications, then it is called homogenous and vice versa. Power estimation is not only performed in single server but also explored in cluster environment.

Cluster power model based on hardware utilization in order to obtain energy saving is designed in [7]. Utilization is simulated in various ways and then tested in small but real cluster. Considered hardware in this paper are CPU, memory, disk, and network. Inter-node variability in homogeneous clusters that leads to inaccurate models is observed in [8]. Solution to tackle this problem is proposed by considering variability parameter so it can give more accurate power models.

Online power estimation in virtualized environment based on Gaussian mixture model has also been researched [9]. However, this method is implemented in single node and not in cluster. To the best of our knowledge, there is no real time power monitoring in homogenous cluster. In this paper, we propose both estimation and monitoring in homogeneous cluster environment with real time performance.

In general, total power consumption of a server can be estimated from its hardware component utilization. Throughout this paper, component will refer to processor, memory, and network interface. These three parameters are enough to estimate power consumption in a server using multiple linear regression. We don’t include hard disk and swap utilization because our web server is not I/O disk intensive. Unlike previous study, we propose simple yet effective method to estimate consumed power by every computer in the cluster. Instead of using simple linear regression, we employ multiple linear regression with three component utilizations as parameter to improve estimation accuracy.

Proposed power monitoring can be implemented in cheap, real time, and install ready in blade or ordinary computer server using socket programming technique. Estimation software acts as daemon and sends information to monitoring server periodically.

This paper is organized as follows. First, we describe our homogeneous cluster architecture and the proposed method. The next section discusses experimental results. The last one presents conclusion and future works of our study.

PROPOSED METHOD

The cluster used in this study is the homogeneous one. It means each web server as cluster member has same specifications. We define three main steps to achieve the goal of this study: 1) gathering component utilization and power metering, 2) generating estimation formula, 3) real time power monitoring. Each step will be described briefly and first preceded by cluster architecture explanation and detail specifications of each computer as cluster member.

Cluster Architecture

There are four web servers and two load balancers in the cluster. Load balancer will distribute workload to all web servers using classic Round Robin approach. If one load balancer fails, the other one will handle request from client. Specification of computer is as follows: Intel Pentium Dual Core 3 GHz of processor, 1 GB of RAM, 250 GB of hard disk, and Linux Ubuntu Server 11.10 as operating system. Fig. 1 illustrates design of cluster architecture.

Gathering Component Utilization and Power Metering

We collect utilization information for processor, memory, and network I/O per second. These three components give the most significant contribution to power consumption. Thus, it makes sense why we choose them as estimation parameter. Power data is gathered by WattsUp Pro instrument. Instead of using manual measurement tool, we use WattsUp Pro that automatically measure power in Watt only from USB port and save the log file to its internal memory. The power usage log can be imported to laptop. The included software from its vendor can automatically graphs all the power data captured for maximum 32,000 records.

Utilization information is gathered in idle and benchmarked condition. We use web server benchmarking tool to give realistic request to cluster. Traffic given to web server is also incrementally changed. With this scenario, we will get various types of data from different cases.

Power data and component utilization log then synchronized per second. We have four parameters now: three components utilization and one power data. To verify the validity of proposed method, we divide power data into two parts: training data and testing data.

Generating Estimation Formula

We employ multiple linear regression to estimate power measurement. Data collection is conducted in only one server. Since all servers have the same specification, we can deploy estimation formula in other server in the cluster.

Parameter gathered from previous step is used as input of multiple linear regression. This method can better represent the number of independent variables in the predictor [10]. We use standard multiple linear regression equation as stated in [10] where n is the number of data, x_1 to x_3 show utilization of processor, memory, and network I/O, respectively. Utilization is drawn in percent. Variable y is power in Watts from WattsUp Pro instrument while b_0 through b_4 are constants to be generated by multiple linear regression. This step generates power estimation equation from the utilization of server components.

Real Time Power Monitoring

Generated formula from previous step is installed in every web server in the cluster. Every web server will send power usage to one server periodically. In this cluster, central server for receiving power data is one of load balancers. Sending and receiving data is implemented using socket programming technique in Python language programming.

This task will be configured as daemon (background process) that doing job silently and not interfere the main server service as web server.

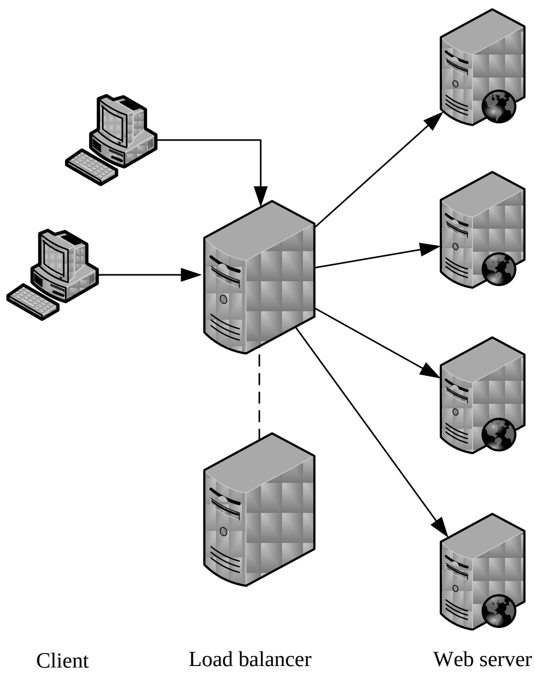

Figure 1.Cluster Architecture.

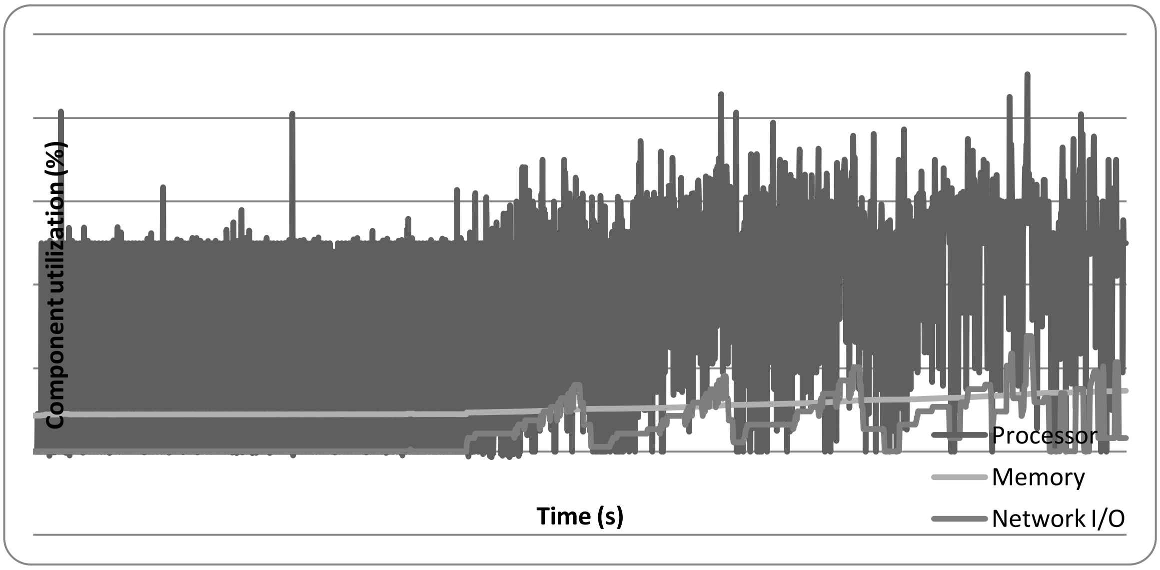

Figure 2. Component Utilization when Idle and Benchmarked.

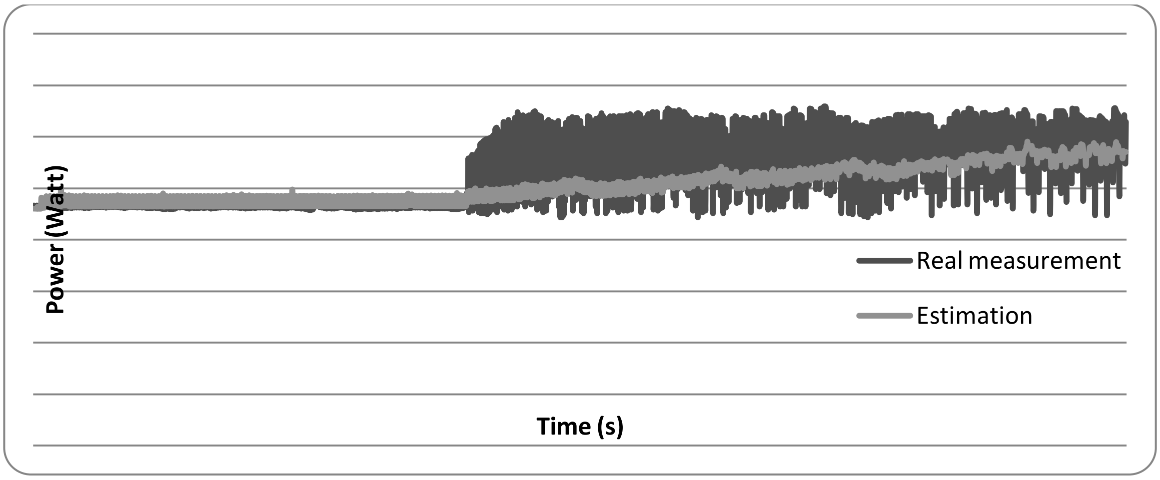

Figure 3. Comparison of real and Estimation Measurementfor Testing Data.

Administrator will monitor power usage from all members in cluster only by accessing one balancer. After intensive experiment, we find that one to two seconds period give the best real time performance when sending power data to balancer.

RESULT AND DISCUSSION

For web server benchmarking tool, we use Httperf and Autobench to automate the running of Httperf incrementally. Apache is still one of the best web servers worldwide and we install and configure it in the cluster. Haproxy as load balancer software is proven to give good result.

Communication between load balancer is served by Hearbeat. Pacemaker gives failover capability for two of them. We also employ and modify Psutils, a Python-based and open source tool for collecting information about component utilization.

Firstly, we setup Httperf in four servers and one computer as server to be benchmarked. We vary workload between 100 to 500 request per connection to give realistic workload to server. Component utilization versus time is shown in Fig. 2. There are two conditions when power measured: idle and benchmarked. We can see that the more load is given, the heavier the work of server component, and the greater the power consumed. Thus, the estimated power really can be done by considering the component utilization on the server. Component utilization is recorded and divided into training and testing data. They are 2000 records of component utilization, respectively.

Multiple linear regression is performed by GNU Scientific Library using training data. This method successfully generate estimation formula as shown in Equation (1)

$$Y = 3.154 + 0.0398x_1 + 1.495x_2 + 0.06668x_3 \quad (1)$$

where$y$ is estimated power and x_1 to x_3 are utilization of processor, memory, and network I/O, respectively.

We compare the estimated power from testing data and real measurements obtained from WattsUp Pro instrument. We also use testing data for counting accuracy. This comparison is shown in Figure 3. Accuracy, A, is calculated using the formula as shown in Equation (2)

$$A = mean\left(\frac{P_{real} - |P_{real} - P_{est}|}{P_{real}} x100\%\right) \quad (2)$$

where P_{real} is real measurement of power and P_{est} is estimated one.

Accuracy of power estimation is 91.87%. These results are quite good because the error rate is still less than 10% [2]. After that, the estimation formula is configured on each cluster member and run as a daemon. Then, the estimation result on each server is sent to the balancer. Figure 4 shows screenshot of real time monitoring. This screenshot is taken from balancer-side. Four servers (alpha-0, alpha-1, alpha-2, and alpha-3) send power data to balancer periodically.

CONCLUSION

In conclusion, we have successfully implemented real time power monitoring in homogeneous cluster of web server environment. Parameters considered in estimation are utilization of processor, memory, and network I/O. Hard disk and swap utilization are not included because our web server is not I/O disk intensive. Using multiple linear regression, the proposed method achieved accuracy of 91.87%. Combination of daemon and simple socket programming technique provide real time performance in application.

In the near future, we will develop power estimation in heterogeneous cluster. Thus, our method could be deployed in more flexible environment. One of idea is to use thermal design power (TDP) for each specific processor. It is a standard value from vendor which determines power dissipation. Using this value, we can make a general model for power estimation for various server specification. Since processor is the main component contributes to power consumption, TDP seems promising to give close power estimation value to reality.

REFERENCES

[1] Bircher WL and John LK. Complete System Power Estimation: A Trickle-Down Approach Based on Performance Events. *Proceedings of the IEEE International Symposium on Performance Analysis Systems and Software*. 158-168. 2007.

[2] Economou D, Rivoire S, Kozyrakis C, and Ranganathan P. Full-system power analysis and modeling for server environments. *Workshop on Modeling, Benchmarking and Simulation, University of Minnesota, Boston*. 2006.

[3] Fan X, WeberW, and Barroso LA. Power Provisioning for a Warehouse-sized Computer. *Proceedings of the ACM International Symposium on Computer Architecture*. 13-23. 2007.

[4] LiL, Bo Y, and GuoGZ. A Model of Web Server's Performance-Power Relationship. *Proceedings of the IEEE International Conference on Communication Software and Networks*. 260-264. 2009.

[5] [Rajamani K, Hanson H, RubioJC, GhiasiS, and Rawson FL. Online Power and Performance Estimation for Dynamic Power Management. *IBM Research Report*. 2006.

[6] Kopper K. The Linux Enterprise Cluster: Build a Highly Available Cluster with

Commodity Hardware and Free Software. San Francisco: No Starch Press. 2005.

[7] Minartz T, Kunkel JM, and Ludwig T. Simulation of Cluster Power Consumption and Energy-to-Solution. *Proceedings of 1st ACM International Conference on Energy Efficient Computing and Networking*. University of Passau, Germany. 2010.

[8] Davis JD, Rivoire S, Goldszmidt M, and Ardestani EK. Accounting for Variability in Large-Scale Cluster Power Models. *Proceedings of 2nd ACM Workshop on Exascale Evaluation and Research Techniques*. 2011.

[9] Dhiman G, Mihic K, and Rosing T. A System for Online Power Prediction in Virtualized Environments Using Gaussian Mixture Models. *Proceedings of 47th ACM/IEEE Design Automation Conference*. Anaheim, CA. 807 - 812. 2010.

[10] Walpole RE, Myers RH, Myers SL, and Ye K. *Probability and Statistics for Engineers & Scientists 8th Edition*. New Jersey: Prentice Hall. 2007.