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A Power Monitoring System Based on a Multi-Component Power Model

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ABSTRACT

As the increasing IT energy consumption emerged as a prominent issue, computer system energy consumption monitoring and optimization has gradually become a significant research forefront. However, most existing energy monitoring methods are limited to hardware-based measurement or coarse-grained energy consumption estimation. They cannot provide fine-grained energy consumption data (i.e., component energy consumption) and high-scalability for distributed cloud environments. In this article, the authors first study widely-used power models of CPUs, memory and hard disks. Then, following an investigation into disk power behaviors in sequential I/O and random I/O, they propose an improved I/O-mode aware disk power model with multiple variables and thresholds. They developed EnergyMeter, a monitoring software utility that can provide accurate power estimate by exploiting a multi-component power model. Experiments based on PCMark prove that the average error of EnergyMeter is merely 5% under a variety of workloads

KEYWORDS

Cloud Computing, Power Measurement, Power Model, Power Monitoring

1. INTRODUCTION

Statistically, worldwide data center power consumption has increased from 700 billion degrees to 3300 billion degrees from 2000 to 2007. By 2020 the figure will increase another 1 trillion degrees (Green, 2010). Only 8.5 percent of data center executives expect data center capacity to remain adequate by 2015. So by 2020, the construction of the data center is at least twice the 2010 scale, reaching 78 billion US dollars (Data Center Users Group, 2014). In 2012, total data center power consumption in China reached 66.45 billion kwh, accounting for 1.8% of the national industrial electricity consumption. This value is equal to the total annual electricity consumption in Tianjin, while the Three Gorges power generation but 78.3 billion kwh (ICTresearch company, 2012-2013). The domestic data center capacity may also increase by 5~8 times in the next 5 years. High energy consumption in data centers not only leads to over consumption of electricity and system instability, but also causes negative environmental impact.

High energy consumption comes from two aspects: one is the corresponding hardware devices to store and process data including processor, memory, hard disk and other service components; the other aspect is the energy consumption of large-scale network transfer overhead. At present, the main research direction is optimizing the energy consumption of hardware devices. The increasing scale of data centers makes the rapid growth of the number of physical equipment. But the average

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utilization of each server is less than 50% (Barroso & Hölzle, 2007). In addition, for every watt of electricity consumed by the calculation unit, an extra consumption of 0.5 to 1 watt is produced by the cooling facilities (Ranganathan, Leech, Irwin, & Chase, 2006). Therefore, improving the utilization of service clusters and energy efficiency is an urgent issue. As the foundation for power-efficient systems, we need to develop an energy monitoring and management framework which includes three key features: 1) fine-grained energy measurement and monitoring methods; 2) accurate energy modeling and analysis to predict power consumption; 3) energy-saving optimization strategies and algorithms to reduce power consumption.

The main contribution of this work is summarized as follows. 1) The authors first study widely-used power models of CPU, memory and hard disk. 2) With an investigation into the disk power behaviors in sequential I/O and random I/O, we propose an improved I/O-mode aware disk power model with multiple variables and thresholds. 3) The authors developed *EnergyMeter* (EM), a monitoring software utility that can provide accurate power estimate by exploiting a multi-component power model. Experiments based on *PCMark* proves that the average error of EM is merely 5% under a variety of workloads. Therefore, this tool can well support power-aware schedulers (e.g., Lin, Xu, He & Li, 2017; Hsu, Slagter, Chen & Chung, 2014; Karthikeyan, Jayachandran & Venkataraman, 2015) to build green data centers.

The outline of this paper is as follows. Section 2 analyzes the research status of current energy consumption measurement system. Section 3 gives the architecture of EM and the design of energy model. In section 4, we illustrate the concrete implementation method. The last section points out that the current EM can be used as the slave node in the distributed node, the manager can use the later developed EM master program to collect the data for statistics, so that the whole measurement system can be distributed to the distributed system Cluster for energy consumption monitoring.

2. RELATED WORK

At present, most energy consumption monitoring software are still not popular. This section first analyzes the current mainstream energy consumption measurement methods. And then we introduce two energy consumption estimation software: Joulemeter and PowerTOP.

2.1. Energy Consumption Calculation Method

In the previous study, the existing methods of energy consumption can be summarized as follows (W. Lin & W. Wu, 2016): Hardware-based direct measurement methods (Shenyang, 2013; Ofoegbu & Udoh, 2016), Energy model-based methods, Virtualization Technology -based methods (Stoess, Lang & Bellosa, 2007) and simulation-based energy consumption estimation methods (Luo, Wu, Tsai, Di & Zhang, 2013). The Hardware-based direct measurement method is mainly applied to traditional data centers. The external power supply and the host (or work nodes) are connected to physical instrument to obtain coarse-grained energy consumption data. The method based on the energy consumption model mainly obtains the resource utilization ratio and uses energy consumption model to calculate energy consumption. The measurement based on virtualization technology is mainly applied to energy measurement and monitoring in virtual environment, using indirect measurement mechanisms to monitor the energy consumption of VM. Simulation-based energy consumption estimation method is designed for simulating cloud resource scheduling and cloud task scheduling process. Energy model-based method is a mainstream method to calculate the energy consumption of cloud computing because of its high flexibility and fine granular energy consumption.

2.2. Joulemeter

Joulemeter (Michel & Jie, 2010) is a tool with multiple power models for measuring the power consumption of virtual machines, servers, desktops, laptops and individual processes. It provides