Volume 3, Issue 12, December 2013 ISSN: 2277 128X
International Journal of Advanced Research in Computer Science and Software Engineering
Research Paper
Available online at: www.ijarcsse.com

A Survey on Various Power Measuring Techniques for a Virtual Machine

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***Abstract*— This paper states several power measuring models and its efficiency to measure the power accurately. The power models are classified as linear power models and empirical power models and power measuring technologies under those power models are addressed. A good power model characteristics and challenges when measuring power consumption are also stated.**

***Keywords*— Virtual Machine, Datacentres, Power models, Empirical power model, Linear power model**

I. INTRODUCTION

A cloud environment is a large number of computers that are connected together to form a communicating network and it is also defined as an individual or an organization that uses web application without installing it into the system. The virtualized datacenters plays an important role in cloud environment nowadays. The datacenter is a facility used to household a computer system. The virtualization technology consists of physical resources such as server and divides it into virtual resources called virtual machines. Virtual machine is a machine that executes program like a physical machine. The aim of cloud computing is to reduce the cost and to favor the users thus there is a need for measuring power consumption of a virtual machine. There are some challenges in power measuring they are stated as power measurement at fine time granularity and label resource use per VM (Kansal et al. 2010). The models should be aware of these issues.

II. POWER MEASURING MODELS

The total power consumption of a system can be measured using several models such as Joulemeter , Vmeter, WattAPP etc etc. It will be better to measure a power consumption of a individual virtual machine where VM power utilization can be accurately estimated or estimated with accuracy of bound error margins (Krishnan et al. 2010).The desirable characteristics for a power model is accuracy, usable parameters, predictable input, heterogeneity, support and speed. The power models are classified into two types linear power models and empirical power models. The linear power model is defined as linear where the relationship of an input and output are described by an equation of a straight line. But many linear power models are difficult to be applied on heterogeneous system (Peng Xio et al. 2012). Empirical power models are those that are based entirely on evaluation or any observation results. The approaches that are under linear models are WattApp, Vgreen, Joulemeter and trickle down effect. The approaches that are used based on empirical model are VMeter, PTopW, Decomposable PMC based model and DVFS using PMC based power models.

III. LINEAR POWER MODELS

A. *Processor Performance Events*

The total system power consumption can be measured using microprocessor performance events. Bircher et al (2010) proposes a 'trickle down effect' of microprocessor performance events. The trickle down power modeling gives an accurate representation of a full system power consumption. The whole system is divided into five subsystems such as CPU, chipset, memory, I/O , disk where the power can be measured separately. The CPU power model estimates the consumption of time spent on a halted state or an idle state. The memory is based on the number of cache included in the system. The strong predictors of memory power consumption are the findings of cache misses. The disk power modeling initiates two events that are DMA accesses and uncacheable accesses. The transfer of disks are maintained through DMA by disk controller and the number of uncacheable events by the processor are considered. So there is a possibility to detect accesses to I/O devices through the uncacheable accesses. The I/O power modelling used for observing DMA traffic. It includes three events DMA accesses on memory bus, uncacheable accesses and interrupts. The chipset power model is constant power model where it uses power from more than one domain hence the power cannot be measured directly the average difference in power is measured between multiple domains. The author also proposes some workloads to be exposed. The parameters of the workloads are percentage of halted processor and not halted processor, CPU clock frequency ,CPU voltage, data cache accesses, CPU temperature. Thus the system power consumption can be estimated using microprocessor performance events (W.L.Bircher et al 2005)

B. VGreen

Dhiman et al (2010) presents VGreen a multitiered software system applicable for a group of virtualized environment. It captures the performance characteristics for virtual machines and physical machines. This model estimates the power consumption and uses it for virtual machine power management. The parameters used are system level energy savings that is estimation of energy reduction and energy consumption using VGreen. The another parameter used is average weighted speedup that estimates the average speedup of virtual machine with VGreen. The advantage of using VGreen is a light weight with negligible runtime overhead.

C. WattApp

R.Koller et al (2010) presents WattApp an Power Aware Power Meter for shared data centers to deal with heterogeneous applications. The WattApp takes a set of N applications and M servers and estimates O(N*M) to built a power model. The parameters used are application parameter where the application throughput or the jobs executed per second are used as attributes to describe the application. The diverse applications are power benchmarks, web transaction workloads , HPC workloads and I/O intensive workloads. The SpecPower benchmark is considered as power benchmark that evaluates the performance characteristics (J.L.Henning et al 2006) . For web transaction workload the TPC-W is used as a representative benchmark for a transactional workload which also has a largest memory usage. The TPC-W uses web server to fetch the request and database server to process the web requests. The HPC workloads uses HPC applications that uses two vector based routines for the variants. Finally the I/O intensive workload uses Lotus Domino that is I/O bound application. Domino is an application which provides e-mail, messaging, web services and also application services. The advantage of this model is it provides accuracy, usability, speed and heterogeneity support for virtual machines.

D. Joulemeter

Kansal et al.(2010) proposes a mechanism for virtual machine metering called Joulemeter. The joulemeter solves power capping problems that enables reductions in cost of power provisioning. There are two challenges in power metering they are stated as power measurement at microsecond granularity that is the instantaneous power should be estimated every few seconds for each resource since the virtual machine using that resource changes every few microseconds. The other challenge is label resource use per virtual machine that is to determine which virtual machine is responsible for each resource. To compensate the first challenge the power model observes the resource state and then determine the power usage in that state. To compensate the second challenge it uses the hypervisors knowledge regarding the scheduling of resources for virtual machines. The parameters used are controlled workload, mix of realistic benchmark workloads, and similar workload as a model. First the training workload is executed and the models are trained on it. Another is a mix of realistic benchmark workload where multiple test runs are executed and the third parameter is similar workload as a model where one of the benchmark is trained and it is tested on other multiple benchmarks. Thus a Joulemeter is used as a virtual machine power metering approach and also implemented in virtualized platforms.

Table1- Comparative study on linear power models

Factors	**Bircher (2010)**	**Dhiman (2010)**	**Koller (2010)**	**Kansal (2010)**
Approaches Used	Trickle down effect	VGreen	WattApp	Joulemeter
Parameters Used	% halted processor, % not halted, CPU clock frequency, CPU voltage, Data Cache	Average weighted speedup	Power benchmark, Web transaction workloads, HPC workloads, I/O intensive workload	Controlled workload, Realistic workload
Merits	Addresses hardware costs	Light weight	Accuracy	Solves power capping problems
Demerits	Chipset error is high	Negligible performance impact of live migrating	Limited in terms of speed, usability	Cannot be directly applied to virtualized environment
Applications	Complete system power estimation	Multi-tire software system for estimating energy management VM's	Power aware meter	Estimate power consumption

IV. EMPIRICAL POWER MODELS

A. *VMETER*

Ala E.Husain et al (2010) proposes a new power modelling technique called Vmeter that is based on online monitoring of system resources and also the total power consumption. Vmeter estimates instantaneous power consumption of per VM that is measurement of individual virtual machine. It consists of two components such as

Vm_monitoring and Vm_power. Vm_monitoring is a thread running in each physical node in a cloud. Vm_power addresses a mechanism to compute an individual power consumption of a virtual machine.The parameters for finding it is

P(total)= C0 + C1 Pcpu+ C2 Pcache + C3 PDRAM + C4 Pdisk

where C1, C2, C3, C4 are the weights and Pcpu, Pcache, PDRAM, Pdisk are the hardware performance counter values for cpu, cache, DRAM and disk. P(total) is the total power consumption of a system. And C0 is the power consumed by the system when it is in a idle state. The author finally addresses that this model is efficient to estimate the power with average mean of 93% and the median accuracy of 94% or more than that . The work can be leverage on Xen (P.Barhan et al 2003).

B. *PTopW*

Hui Chen et al (2012) addresses some tools to achieve a fine grained power management using process level profiling. The process level profiling tool called 'PTopW is proposed. The role of PTopW is to monitor a real time power consumption where a process is running on windows. And a power aware system module called 'Energyguard'. The role of an energyguard is to eliminate the energy that are wasted by abnormal behaviours of applications. The working of energyguard is it gives a highlighted background colour to detect an abnormal situation. It has two components such as monitor component and white list analysis. The monitor component has two values threshold and current value. If the threshold value is lesser than a current value then the energyguard highlight the process and send an alarm to the users. The white list analysis have the rank of power consumed by processors if the process is not on a white list analysis then it consumes more power than compared to others. The parameters used are cpu, memory and disk. The cpu is described as when a program initially starts it collects the information of the system. After collecting the information of the power consumption of cpu it is divided into each process based on the processor time. The memory addresses three counters such as PagesOutputPerSec, PagesInputPerSec, CopyReadsPerSec.to calculate the time. The disk also addresses three counters such as PercentDiskReadTime,PercentDiskWriteTime,PercentIdleTime. The read time, write time, idle time of the disk are calculated. The disadvantage of the tool is PTopW is difficult to be applied widely.

C. *Decomposable Power Models*

R.Betran et al (2010) proposes a decomposable power model which is able to estimate a power consumption accurately. The author presented a methodology to produce a decomposable power model where the model inputs are defined first and then the training data is defined and third the collected data is trained and validated. The total power consumption is defined as $P_{total} = \left(\sum_{i-1} AR_i \times P_i\right) + P_{static}$.

The parameters are Ari is the activity ratio, Pi is the weight of the component, Pstatic is the overall static power consumption. The responsiveness of the models are validated. The validation of the models uses SPECcpu2006 benchmarks (J.L.Henning et al 2006).

D. DVFS using PMC based Power Models

R.Betran et al (2011) presents a power model based on PMC (Power Measuring Counters) to estimate energy accounting in virtualized systems. The author represents a threefold contributions where first it shows the Performance Monitoring Counters based power modelling are valid on virtualized environments. Then the DVFS (Dynamic Voltage Frequency Scaling) is used to avoid power and thermal emergencies. Atlast a methodology for accounting energy consumption is proposed. The DVFS mechanism allows to modify the processor's frequency and voltage. And also significantly reduce the operational costs. The power consumption is based on power monitoring counters . They are given by

Power=f+(PMC0+PMC1+……………+PMCn-1, PMCn).

The parameters are frequency 'f' and PMC0 is the initial performance monitoring counter, PMC1 is the next performance monitoring counter. The advantage of this methodology is it is applicable for a result less than 5% error.

Table2- Comparative study on empirical power model

Factors	**Ala E.Husain (2010)**	**Huichen (2012)**	**R.Betran (2010)**	**R.Betran (2011)**
Approaches Used	VMeter	PTopW	Decomposable Power Model	DVS using PMC based power model
Parameters Used	Weights of CPU, cache, disk, DRAM	CPU, Memory, Disk	Activity ratio, Weight of component, Static power consumption	Frequency, Performance monitor counter
Merits	Predicts power consumption of individual VM	Energy guard distinguish abnormal behaviors	Ensures accuracy & decomposability	Errors obtained are below 3%

Demerits	Execution time gives difference between mean and median values	PTopW is difficult to apply widely	Some micro architectural components does not have PMC's	Current model is restricted to processor and memory
Applications	Power modeling for virtualized clouds	Estimate power consumption	Power model for estimating energy consumption	Energy accounting for virtualized environments

V. CONCLUSION

The overall study of power measuring models such as power measuring models characteristics, challenges are mentioned in this paper. The linear power models and empirical power models are distinguished and the approaches which comes under linear power model are defined such as trickle down power modelling, VGreen, WattApp, Joulemeter and similarly for empirical power model the approaches are described such as Vmeter, PTopW, Decomposable power models and DVFS using PMC based power models.

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