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An Empirical Study on Energy Estimation Tools

Anithakrishna G[1] , M Mohankumar[2]

[1] *Department of Computer Application, Mahatma Gandhi University, India*

[2] *Department of CS, IT and CA, Karpagam Academy of Higher Education, India*

ABSTRACT

Technically improvedproducts including hardware and software offer manifold opportunities to reduce energy consumption for a movement towards sustainability. Green computing refers to an effective advancement towards the design and manufacture of software products, using computers and its resources with minimal or no impact on environment. The objective of Green computing as of now is to effectively manage power and energy efficiency, by choosing eco-friendly hardware and software, and recycling them to increase the product's life. Cloud centres reduce the resource usage but consume a huge amount of energy,have high management cost and residue and leave bad spoor on the environment. The energy efficiency of a software product can be calculated by hardware or software implementations. While using hardware to calculate the energy efficiency, we won't be able to track correctly the energy dissipation spots in the product. For overcoming this, we have designed a model in which we can correctly identify the energy consuming spots and develop a tool which conforms to the green standard of computing.

[Keywords: Energy efficiency, green computing, sustainability, green model, distributed energy meter, green cloud, energy estimation]

INTRODUCTION

At present we are facing a lot of environmental issues like destruction of natural assets, change in climate, depletion of resources etc. Our whole society should be aware of it and strive to find a solution quickly[18].Our educational institutions can play a great role to encourage environmental sustainability measures[8]. Here we are focusing on sustainable software model.'Green in IT' focuses on reduction of power consumption inIT, whereas 'Green by IT' enables technology to save energy in other areas.

Energy Efficiency through IT surely saves energy but also has some rebound effect [21]. For that Hilty conducted some case study on vending machines and noticedthat in the early stage power consumed by the vending machinesused to be high but within a few years energy consumption was brought down withlow-power-mode machines with intelligent energy handlingtechnologies[24]. This technically improved and efficient machine got higher demand than the old dull[2] machines.By the way, total consumption of resource may increase instead.

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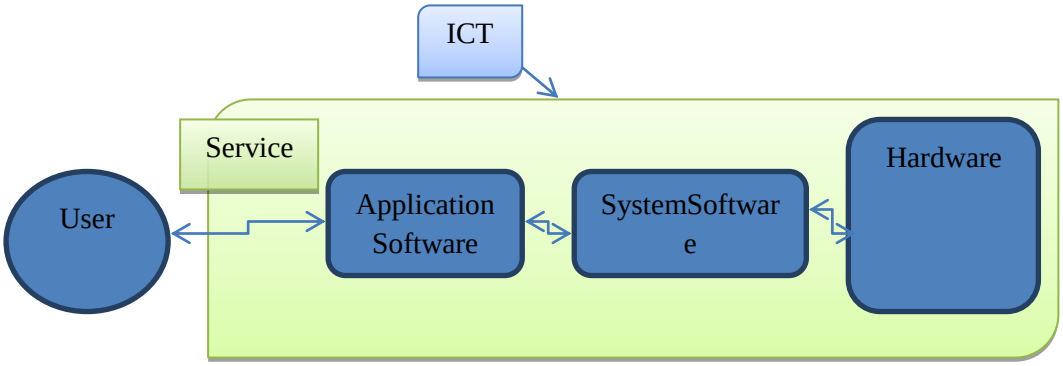
LITERATURE REVIEW

L.M. Hitlypresented a paper after conducting a case study on vending machines to find the effect of smart technologies on energy efficiency and energy consumption rate. Bernard Aebischer presented a paper highlighting the history, and measuring and modelling, of ICT devices and Life cycle Assessment of software to find the relationship between the hardware and software.S.A Chowdhury focused on a system call-based model to estimate energy consumption without any hardware implementation. Noah Sabry introduced a migration model which was an optimized model to identify green energy sourceswith data centres to have a green data centre.Abram Hindle proposed a model in Bigdata approach which would consider CPU and system call of application and distribute unseen applications or simulation.

Energy requirement in ICT Devices and the effect of Software

LCA in 90s was a Life Cycle Assessment analysing the impact of a product on the environment throughout the life cycle. SIS in 2001 stood for Sustainability in Information Society focusing on the effect of informatization on sustainability[4]. TA which is the acronym of Technology Assessment is conducted in SIS to study the effect of ICT in society.



The figure above shows the production system which includes application software and system software and hardware which provide the desired result[5]. Software products have a significant effect on energy flow. The characteristics of software define which hardware features are utilized and how much energy is consumed by the end system[1]. Now energy-consuming processes are moving to cloud so that the end user can manage withlow storage and processing capacity. But we should be concerned about energy consumption [20] in network and data centres.

Energy and Power

Power is measured in watts and is the rate of completed work. We can define power as rate of energy consumption. That means energy is the total work done in the course of a particular duration of time.

P=E/T

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Various methods are there to measure energy consumption and the traditional way is to measure directly from board which is easy to perform; but we cannot analyze or pointout the place where the actual power consumption occurs. Another method is measuring through models without implementing any hardware components.

Green cloud

Green approach always refers to the resource utilization by improving and minimizing the number of system resources [22].But it results in unintended energy consumption for data traffic through cloud. Noah Sabry tried to migrate to virtual machine by Dijkstra and minimum flow technique. It focuses on minimum delay and green network connection which ensure low consumption of energy[3]. A general conclusion about energy consumption on network components is almost constant and routers consume high electric power irrespective of data traffic. Various virtual machine types are setup based on hardware measures like memory, CPU etc. of each cloud provider[6]. Distribution of cloud service through virtual machine migration optimizes the consumption of energy.

Energy consumption on cloud can be measuredby various[15] methods which are hardware-based, virtualization-based, energy-model-based and simulation-based. W. Lin proposed an energy consumption monitoring tool known as Distributed Energy Meter meant for heterogeneous cloud environment. DEM follows a master-slave-architecture, where slave measures the consumption by the cloud server, whereas master measures CPU and thememory of each slave. In DEM there are two categories of data packets, namely static and dynamic.

STATIC INFORMATION DATA PACKET

- Slave request pkt
- Master request reply pkt
- Master RRD request pkg
- Slave RRD response pkg
- Slave Alarm pkg

DYNAMIC INFORMATION DATA PACKET

- Real Time data pkt

Energy efficient application development models

It is only when we have the ability to measure the energy consumption of a particular application that we can develop energy efficient software products.S.A. Chowdhury has introduced an energy model that monitors the system calls to measure the energy consumption directly[7]. Here energy estimation is done by calculating the count of system call. Energy is considered as the whole power over time, and the interface between application and operating system is termed as system call. Some components of the system use the

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power for a few more times even after the execution of the application. Such energy leak is known as Tail energy. Some earlier energy models like utilization model and instruction-based models have their own disadvantages. Utilization-based models focus on CPU,screen and Wi-Fi but cannot model tail energy[11], whereas instruction-based modelsthat are usedformonitoringareplatform-dependent and more complex. System-call-based modelling provides access to various input/output modules.

In system-call-based modelling to capture energy details of various applications, they use Green Miner, and it uses common machine learning approach such as linear and support-vector regressions. Energy consumption models test multiple applications and we cannot capture idle time of application through system call. It monitors the interval,when the user is not interacting with the system, and deducts the time from total energy consumption to get the average energy consumption of the application.

Many surveys point to the importance of software development in an energy efficient manner. For that we need a user-friendly tool to evaluate the current energy consumption. [9]. Green Oracle is a model that we can download to estimate the energy after identifying the resource usage. To develop such a tool, first we have to find the version of committed application with test script, collect the resource usage of the application and corresponding energy consumption by green miner for a specific test case of an application.

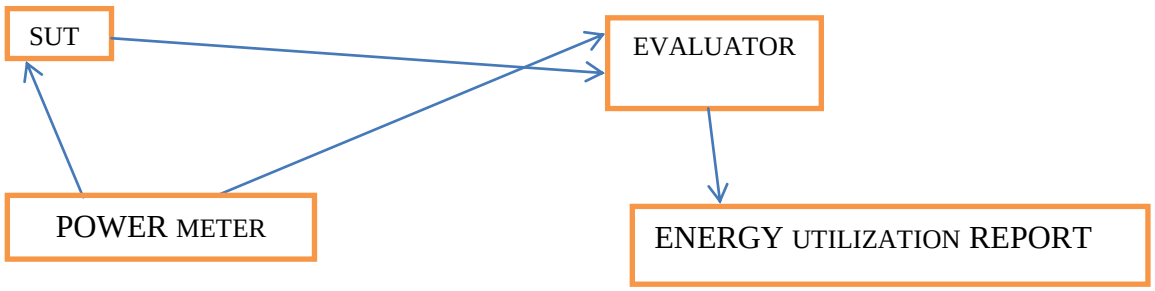
They used the strace command in Linux to list the system call, and –c returns the count of various system calls. The pseudo file /proc in Linux contains the captured CPU jiffies and other information regarding the process.

Description of various applicationscontains the information as listed below:

Application	**Type**	**No. of versions**	**No. of unique system calls**	**Time period of commits of versions**	**Source**
Firefox	Browser	156	84	JUL 2011-JUL 2011	APKrepos 4
ChromeShell	Browser	50	76	MAR 2015-MAR 2015	APK repos1

Then we manually group the system calls based on their characteristics and select the best machine learning algorithm out ofSVR, Ridge, Bagging and Lasso to predict the energy consumption.

Eva Kern has proposed a study on sustainable product and set a configuration to compare electricity consumption of software products[13]. First setup the application which we want to test on System under Test (SUT).



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There is a power meter to monitor the power supply [19]and the collected data are analyzed to generate a comparable result.

Neural modelling to incorporate Time series

There is a need to develop certain tools that can locate the time, reason and module of a software product consuming the most energy toenable the development of energy-efficient software.We can categorize energy measuring approaches as hardware model,software model and hybrid model. Hardware models measure certain components, whereas software models[12] consider certain things like component utilization, API and system calls. Hybrid models mix both approaches [16].

In deep neural network Recurrent Neural Network is more efficient [23] compared to Forward Neural Network due to its back-edge feature (looping), but RNN has saturation problem on long time step. To overcome these issues, we have to add more memory cells.

First, we have to select the test case to calculate resource usage and energy consumed by application. It is the subset of Green Oracle data set to collect the time series of system call. In this we are calculating power sample, measurement and energy usage periodically.

Eva Gracia Martin presents an approach to measure or model the power consumption,which, in his model, can be direct or simulative[17]. In a simulative approach activity factor depends on any hardware simulation in the environment, whereas in direct approach it depends on accessing PMC which is less portable compared to simulative. Here it includes a comparative study on Very Fast Decision Tree and Hoeffding Adaptive tree to analyzean infinite stream of data.

Green Model for Energy Estimation

Now developers are concernedwith the energy efficiency of the software product along with its functionalities. ShaifulChowdhuryhas proposed a model for energy consumption with automatic test generation. Green Scalar is the model which performs estimation without any hardware implementations in an Android system[14]. Here they have introduced Green Monkey which is a test generation method with less energy consumption. They have a heuristic selection procedure for the best test case.

Discussion

From the previous section it is clear that energy efficient software production is the right way to build sustainable products and more energy efficient models by analysing more data which focus on energy efficiency. Minimum test case can test all functionalities by complete code coverage focusing on CPU utilization and energy estimationof theartefact.

Conclusionand Outlook

We can scale up to construct a model for designing the testing tool that can calculate the energy efficiency of any given software. Green computing is becoming popular in today's technological field and more and more people are becoming aware of the need of software and technologies that adheres to the principles of green computing. Plenty of research has been carried out in the field of green computing to come up with

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products that are sustainable to the environment, ensure developing low power consuming software and promote recycling of electronic wastes.

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