Reduced Energy Consumption in Operating System Regarding Personal Computer

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Abstract

Recently, the demand of "Green Computing", which represents an environmentally responsible way of reducing power consumption, and involves various environmental issues such as waste management and greenhouse gases is increasing explosively. We have laid great emphasis on the need to minimize power consumption and heat dissipation by computer systems, as well as the requirement for changing the current power scheme options in their operating systems (OS). In this paper, we have provided a comprehensive technical review of the existing, though challenging, work on minimizing power consumption by computer systems, by utilizing various approaches, and emphasized on the software approach by making use of dynamic power management as it is used by most of the OSs in their power scheme configurations, seeking a better understanding of the power management schemes and current issues, and future directions in this field. Herein, we review the various approaches and techniques, including hardware, software, the central processing unit (CPU) usage and algorithmic approaches for power economy. On the basis of analysis and observations, we found that this area still requires a lot of work, and needs to be focused towards some new intelligent approaches so that human inactivity periods for computer systems could be reduced intelligently.

Keywords: CPU Usage; Dynamic Power, Management; Operating Systems; Personal Computers;

Introduction

We cannot escape the fact that the world is becoming more and more dependent upon the use of information and communication technology (ICT), and that personal computers (PC) are one of the means. All over the world, PCs are being increasingly used right from kids to professionals in the course of their everyday lives, and this shows why we see such a phenomenal growth in sales of PCs over the last few years. There are basically two major reasons behind this: 1) technology is becoming cheaper with each passing day, and 2) people are getting more and more addicted to these ICT products. But the offshoot in getting used to these technologies are the innumerable other adverse effects caused to our environment, health and economy. It can be clearly seen that PCs occupy the largest share among the several available ICT products in the market, thus, making them also responsible for the high quantum of power consumption [1]. Consequently, this surge in power consumption leads to a greater demand for power production by most of the developing countries, as their existing power production is insufficient to meet their citizens' demands, and they have to face a number of power cuts and load-shedding situations in order to maintain a fair balance between demand and supply.

The motive behind this research on minimizing power consumption by PCs derives from a human tendency to leave the computer system running in between jobs, and as to when work is likely to be resumed is not at all predictable. The running computer system consumes electricity, and it is estimated that a typical desktop PC with a 17-inch flat-panel LCD monitor requires about 65–100 watts for the computer, and 35 watts for the monitor. If left on 24×7 for one year, this system will consume 874 kilowatt hours of electricity – enough to release 341 kg of carbon dioxide into the atmosphere, and can also be equated to driving 1312 km in an average car [2]. On the other hand, by turning off this computer system *when not in use* (i.e., lunch times, weekends, during meetings) *for one year*, one can save as much energy as it takes to wash 464 loads of washing, or to run your microwave 24 hours a day for one week [3]. Even the various options used by the power scheme in the OS are not sufficient to save power, for example, screen savers are actually power wasters because when the screen saver kicks in, more power is consumed by the hard disk drive (HDD), CPU and monitor [4]. According to a study performed by IST at the University of Waterloo, for a Pentium 4, 1.7 GHz machine without the monitor, it was found that during the system boot-up, power requirement is close to 110 watts; in idle mode, it uses close to 60 watts; and in full power-saving mode, with no hard disk spin and the machine in sleep mode, power consumption is close 35 watts [5].

Measuring Power Consumption

To reach at any solutions as stated in the above section, first, let us see the various methods available for measuring the power consumption of a PC and its various peripheral devices. Over a period of time, various techniques for measuring power consumption by PCs have been proposed. These techniques can be categorized into various categories, like hardware based approaches; software based approaches; minimizing the CPU usage; and by using algorithm based approaches. The work done by various groups of researchers on these different approaches are given in the following sections.

Hardware-based approaches

A lot of work for minimizing the power consumption of a computer system is done by using external hardware for monitoring the various activities of the system and the various devices attached to it. The work of software power consumption can be classified into three categories:

i. Using simulations
ii. Measurement-based estimation
iii. Direct measurement

The author has proposed a simulation-based power model using FAST simulator, and stated that traditional power models that were used with software simulators can directly benefit from this simulator high-level view of FAST simulator is shown. The functional model (FM) implemented is software running on a general purpose processor, which could also be put in hardware for performance improvement. This simulator is able to tolerate the overhead communication between FM and Timing Model (TM). Another approach used by the authors in presents the second category approach, that is, a measurement-based estimation, architecture of power measurement tool.

Software-based approaches

These kinds of approaches are also known as Dynamic Power Management (DPM) where a software program is used for measuring the power consumption of a computer system. The author has presented a survey and various techniques for minimizing power consumption using DPM. DPM at the OS level refers to supply voltage and clock frequency adjustment schemes implemented while tasks are running. Basically, DPM deploys three types of techniques:

i. Predictive approach
ii. Stochastic approach
iii. Time-out approach

Minimizing CPU Usage

The author has presented a systematic method of CPU usage metering and stated that the OS manages all resources, including CPU time. It keeps track of each process's resource consumption. It also updates the CPU time utilization of a process at every timer interrupt, which is generated at a fixed time interval. There are some models of machines that learn prediction [6], and that finds the CPU's idle and activity patterns. This prediction model utilizes the concept of a variety of C-states defined by ACPI [7]. These C-states are C0, C1, C2 and C3. Where C0 refers to active state, and rest states are the idle state where power consumption of the CPU decreases as we move from C1 to C2 to C3. Some other models, like cluster model [8, 9] and scheduling model are also presented by the authors for minimizing the CPU usage for reducing power consumption. Some research studies focus on CPU power management, or monitoring activities of devices, or CPU sharing for minimizing energy consumption. In the authors have stated that the CPU and all its devices, like memory, chipset and bus controller are not controlled by the device driver, and this could be done by observing the OS kernel itself. If the OS kernel is busy it shows that the CPU and various other devices are busy in processing, and by minimizing the CPU processing, energy used could be minimized.

Using Algorithmic Approaches

Some communities of researchers are working on various algorithms to minimize power consumption by a computer system and its peripheral devices like CPU, HDD. These algorithms are given below:

***Back-off algorithm*:**

By using this proposed algorithm for switching on or off the user equipment which supports the multiple radio access technology to save the power.

***PowerNap algorithm*:**

By using this proposed algorithm, it enables the entire system to transition rapidly into and out of a low power state, and all activities are suspended until new work arrives. This approach works on two modes, the active mode and the nap mode.

***Power-scheduling algorithms*:**

By using these power-scheduling algorithms, one can reduce the power consumption of portable embedded devices. In their approaches, either one has tried to minimize the data transfer in between CPU and memory, so that power consumption could be minimized, or proposed an algorithm that basically uses the system scheduling and sets the deadline of the task to the value indicated by the user to dynamically scale voltage and frequency, or presented an algorithm under different workload configurations with/without time constraint, respectively.

***Soft Watt*:**

By using this simulator-based algorithmic approach that basically checks the different states of the computer's hardware, like CPU, memory, HDD, one can identify the power-hungry OS services and characterize the variance in the kernel power scheme with respect to workload. This kind of approach is used by various researchers in their work over the period of time for measuring the power consumption of a PC using different methods.

***Power–aware algorithms*:**

By using these algorithms, one can change the supply voltage and frequency at appropriate times to optimize a combined consideration of performance and energy consumption.

Challenges and Directions

Before concluding this paper, in this section we discuss the potential challenges and future directions in the area of minimizing power consumption of a computer system. We classify the power-minimizing challenges into four broad categories: 1) The challenges come with the use of hardware. If we look at the scenario from the end user's point of view, then the user has to pay an additional amount for buying the power-saving device. Will it be worthwhile? An answer to this question in most of the cases would be in the negative, because the user will consider such kinds of devices as optional, and will always try to avoid the additional amount of expenditure for this. This scenario is also best suited for users in developing countries like China, India, and Indonesia, where users always try to think about the many ways of how to minimize the cost of a computer system while purchasing a new computer system. Whereas, if we introduce some kind of chip, sensor or device at the motherboard level, capable enough to detect human inactivity, then this could be a good option, and the user will have to go in for it because, in that case, no other choice will be available. But, unfortunately, such a kind of motherboard that could detect human inactivity and take its own decision to switch off the computer system is yet to hit the market. 2) The challenges come from designing of the system software, application software or tools for measuring and minimizing the power consumption of a computer system. If it is application software, then this is to be installed over the current OS, however, again the question will remain the same as it was in the previous section: how many users will be ready to pay for such a kind of software? Again the response will be in the negative. However, if we incorporate some changes at the OS level in the existing power schemes by providing some intelligent methods to detect human inactivity and unnecessary power consumption, this could be a better option at no extra cost from the end user's side.

Finally, in directions for the future, we can say that the future of the software and hardware industries is still very bright, and in the coming days, many new developments will take place. For solving of the problem we have focused on the software part, and suggested that in place of using the existing time-out options of the power schemes, we can design some intelligent methods, as discussed, for sensing human inactivity and minimizing power consumption. Similarly, some more methods could be designed for the existing power schemes of OSs, which will be suitable for both end users as well as the environment.

Conclusion

In this paper, we have presented a technical review of techniques for minimizing power consumption by computer systems. We have discussed and evaluated the various techniques used for reckoning power consumption by using hardware, software, CPU usage and various algorithmic approaches. On the basis of the aforementioned studies, we conclude that there is a great requirement for changing the OS's power schemes by proposing some intelligent schemes to sense human inactivity. The available options in the power scheme are based on the time-out approach, and are not sufficient enough to minimize power consumption. We also discussed the challenges, as well as future research directions, in developing effective solutions for minimizing power consumption by a computer system.

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