Green Computing Techniques to Power Management and Energy Efficiency

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---**ABSTRACT**---

Green computing is one of the emergent computing technology in the field of computer science engineering and technology to provide Green Information technology (Green TI/GC). It is mainly used to protect environment, optimize energy consumption and keeps Green environment. Increasing energy efficiency and reducing the use of hazardous materials are the main goals of green computing. Green computing ultimately focuses on ways in reducing overall environmental impacts. It require the integration of Green computing Practices such as recycling, electronic waste removal power consumption, virtualization, improving cooling technology, and optimization of the requirements. The major power consumption components are processors and the main memory in the servers. Green computing is the concept which is trying to confine this procedure by inventing new methods that would work efficiently while consuming less energy and making less population. This paper focuses on green computing techniques, in order to achieve low power consumptions. This paper includes green computing techniques and power saving.

Keywords - **energy efficiency, electronic waste, green computing, power consumption, and recycling.**

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1. INTRODUCTION

Green computing is the environmentally responsible use of computers and related resources such practices include the implementation of energy-efficient central processing units, servers and peripherals as well as reduced resource consumption and proper disposal of electronic waste (e-waste). It also defined as the designing manufacturing/engineering, using and disposing of computing devices in a way that reduces their environmental impact. Main goals of green computing are to reduce the use of toxic and hazards materials and improve the energy efficiency, recycling factory waste. Green computing is the requirement to save the energy with the expenses.

1.1. Advantages of Green computing

a. Reduce the energy usage from green computing techniques translated into lower carbon dioxide emissions, stemming from a reduction in the fossil fuel used in power plants and transportation.

b. Conserving resources means less energy is required to produce, use and dispose of products.

c. Saving energy and resources save money.

d. Green computing even includes changing government policy to encourage recycling and lowering energy use by individuals and businesses.

e. Reduce the risk existing in the laptops such as chemical known to cause cancer, nerve damage and immune reactions in humans

2. ENERGY CONSUMPTION AT DIFFERENT LEVELS IN COMPUTING

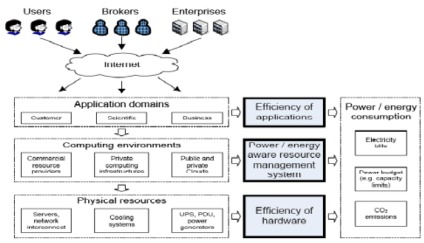

Fig 1: energy consumption at different levels in computer systems

The energy consumption is not only determined by the efficiency of the physical resources, but it is also dependent on the resource management system deployed in the infrastructure and efficiency of applications running in the system. Energy efficiency impacts end users in terms of resource usage costs, which are typically determined by the Total Cost of Ownership (TCO) incurred by a resource provider.

Higher power consumption results not only in electricity bills, but also in additional requirements to cooling system and power delivery infrastructure, i.e Uninterruptible Power Supplies (UPS), Power Distribution Units (PDU),etc. With the grow computer components density, the cooling problem becomes crucial, as more heat has to dissipated for a square meter. The problem is especially important for 1U and blade servers. These form factors are the most difficult to cool because of high density of the components, and thus lack of space for the air flow. Blade servers give the advantage of more computational power in less rack space.

Apart from the overwhelming operating costs and the Total Cost of Acquisition (TCA), another rising concern is the environmental impact in terms of carbon dioxide (CO_2) emissions caused by high energy consumption. Therefore, the reduction of power and energy consumption has become a first-order objective in the design of modern computing systems. The roots of energy-efficient computing, or Green IT, energy-efficient products in order to reduce the greenhouse gas emissions. The term “green computing” was introduced to refer to energy-efficient personal computers. End user and environmental requirements for IT equipment including video adapters, monitors, keyboards, computers, peripherals, IT systems and even mobile phones.

Energy-efficient resource management has been first introduce in the context of battery feed mobile devices, where energy consumption has to be reduced in order to improve the battery lifetime.

3. POWER AND ENGREY MODELS

Power and energy management mechanism it is essential to clearly distinguish the background terms. Power and energy can be defined in terms of work that a system performs. Power is the rate at which the system performs the work, while energy is the total amount of work performed over a period of time. Power and energy are measured in watts (W) and watt-hour (Wh) respectively. Electric current is the flow of electric charge measured in Amperes (Amps). Amperes define the amount of electric charge transferred by a circuit per second. Work is done at the rate of one watt when on Ampere is transferred through a potential.difference of one volt. A kilowatt-hour(kWh) is the amount of energy equivalent to a power of 1 kilowatt(1000 watts) running for 1 hour.

Formally, power and energy can be defined as in (1) and (2).

$$P=W/T \qquad (1)$$

$$E=P.T \qquad (2)$$

Where P is power, T is a period of time, W is the total work performed in that period of time, and E is energy. The difference between power and energy is very important, because reduction of the power consumption does not always reduce the consumed energy. For example, the power consumption can be decreased by lowering the CPU performance. However , in this case a program may require longer time to complete its execution consuming the same amount of energy. On one hand, reduction of the peak power consumption will result in decreased costs of the infrastructure provisioning, such as costs associated with capacities of UPS, PDU, power generators, cooling system and power distribution equipment. On the other hand, decreased energy consumption will lead to reduction of the electricity bills.

3.1. Static and Dynamic Power Consumption

The main power consumption in Complementary Metal-Oxide-Semiconductor (CMOS) circuits comprises static and dynamic power.

The static power is mainly determined by the type of transistors and process technology. Reduction of the static power requires improvements of the low-level system design.

Dynamic power consumption is created by circuit activity (transistor switches, changes of values in registers, etc) The sources of the dynamic power consumption are short-circuit current and switched capacitance. Short –circuit causes only 10-15% of the total power consumption and so far no way has been found to reduce this value without compromising the performance. Switched capacitance is the primary source of the dynamic power consumption therefore the dynamic power consumption can be defined as in (3).

Where a is the switching activity, C is the physical capacitance, V is the supply voltage are determined, and f is the clock frequency. Whereas combined reduction of the supply voltage and clock frequency lies in the roots of the widely adopted

$$P_{dynamic} = a.C.V^2 .f, \qquad (3)$$

DPM technique called Dynamic Voltage and Frequency Scaling (DVFS). The main idea this technique is to intentionally down-scale CPU performance, when it is not fully utilized by decreasing the voltage and frequency of CPU that in ideal case should result in cubic reduction of the dynamic power consumption. DVFS is supported by most modern CPU including mobile desktop and server system.

3.2. Sources of power consumption

According to data provides provided by Intel Labs. The main part of power consumed by a server is drawn by the CPU ,followed by the memory and losses due to power supply inefficiency. The data show that the CPU no longer dominates power consumption by a server. This resulted from continuous improvement of the CPU power efficiency and application of power saving techniques. (e.g DVFS) that enable active low- power modes.

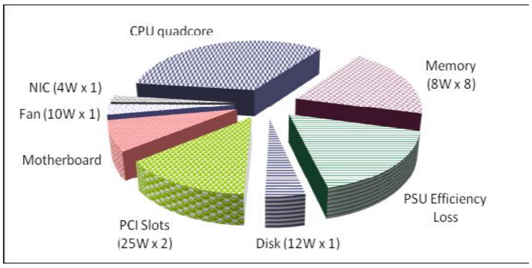

Fig 2: Power consumption by servers components

In these modes a CPU consumes a fraction of the total power, while preserving the ability to execute programs. As a result current desktop and server CPUs can consume less than 30% of their peak power at low activity modes.

Leading to dynamic power range of more than 70% of the peak power. In contrast, dynamic power ranges of all other server's components are much narrower. Less than 50% for DRAM ,25% for disk drives, 15% for network switches, and negligible for other components can only be completely or partially switched off. Reason for reduction of the fraction of power consumed by the CPU relatively to the whole system is adoption of multi-core architectures.

Multi-core processors are much more efficient than conventional. Adoption of multi core CPU along with the increasing use of virtualization technologies and data-intensive applicant resulted in growing amount memory in servers.

3.3. Modeling power consumption

To develop new policies for DPM and understand their model of dynamic power consumption. Such a Model has to able to predict the actual value of the power consumption based on some run-time system characteristics. One of the way to accomplish this is to utilize power monitoring capabilities that are built in modern computing Servers. Strong relationship between the CPU. Utilization and total power consumption by a server. The idea behind the proposed model is that the power consumption in the idle stat up the power consumed when the server is fully utilized.

4. PROBLEMS OF HIGH POWER AND ENERGY CONSUMPTION

The energy consumption by computing facilities rises monetary, environmental and system performance concerns. Including low-power processors, solid state drives and energy-efficient monitors have alleviated the energy consumption issue to a certain degree a series of software approaches have significantly contributed to the improvement and energy efficiency.

4.1 High Power Consumption

The main reason of them power inefficiency in data centers in low average utilization of the resources. The main run-time reasons of underutilization in data centers are variability of the work load and statistical effects. Modern service applications cannot be kept on fully utilized servers as even non-significant workload fluctuation will lead to performance degradation and failing to provide the expected QoS. On the other hand servers in a non-virtualized data center are unlikely to be completely idle because of background tasks or distributed data bases or file systems.

4.2. High Energy Consumption

Considering the power consumption the main problem is the minimization of the peak power required to feed a completely utilized system. In contrast, the energy consumption is defined by the average power consumption over a period of time. Therefore the actual energy consumption by a data center does not affect the cost of the infrastructure. On the other hand it is reflected in the electricity cost consumed by the system during the period of operation which is the main component of a data center's operating costs.

5. POWER/ENERGY MANAGEMENT IN COMPUTING SYSTEMS

Large volume of research work has been done in the area of power and energy-efficient resource management in computing systems. As power and energy management techniques are closely connected from this point we will refer to them as power management.

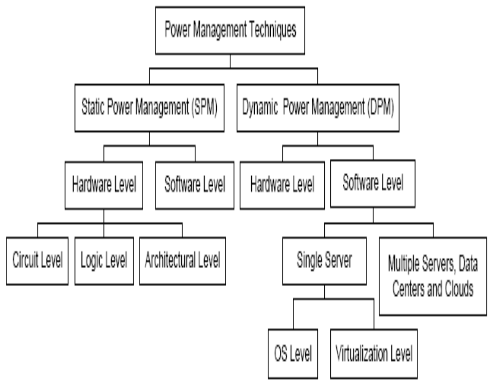

Fig3: Power and energy management

The high level power management techniques can be divided into static and dynamic. As power and energy management techniques are the hardware point of view, Static Power Management (SPM) contains all the optimization methods that are applied at the design time at the circuit, logic, architectural and system levels. Circuit level optimizations are focused on the reduction of switching activity power of individual logic gates and transistor level combinational circuits by the application of complete gate design and system design it is extremely important carefully consider implementation of programs that are supposed to run in the system. DPM techniques that include methods and strategies for run-time adaptation of a system's state. DPM techniques can be distinguished by the level at which they are applied hardware or software.

Hardware DPM varies for different hardware components, but usually can be classified as Dynamic Performance Scaling (DPS),such as DVFS, and partial or complete Dynamic Components Dynamic Component Deactivation (DCD) during periods of inactivity. In contrast software DPM techniques utilize interface to the system's power management and according to their policies apply hardware DPM. The Advanced Power Management (APM) and its successor, the Advanced configuration and Power Interface (ACPI) have drastically simplified the software power management and resulted in board research studies in this area. DVFS creates a board dynamic power range for the CPU enabling extremely low-power active modes. Another technology that can improve the utilization of resources and thus reduce the power consumption is virtualization of computer resources. Cloud computing naturally leads to power-efficiency by providing the following characteristics:

- Economy of scale due to elimination of redundancies.
- Improved utilization of the resources.
- Location independence –VMs can be moved to a place where energy is cheaper.
- Scaling up and down resource usage can be adjusted to current requirements.
- Efficient resource management by the cloud provide.

Therefore cloud providers have to deal with the power-performance trade off minimization of the power consumption while meeting the QoS requirements.

6. GREEN COMPUTING TECHNIQUES MANAGE POWER IN COMPUTER SYSTEM

These techniques can be classified at different levels:

1. Hardware and Firmware Level
2. Operating System Level
3. Virtualization Level
4. Data Center Level

Fig.4.Power Management Techniques in Green Computing

6.1. Hardware and Firmware Level

The DPM techniques applied at the hardware and firmware level can be divided in to two categories:

1. Dynamic Components Deactivation (DCD).
2. Dynamic Performance Scaling (DPS).

The DCD techniques are built upon the idea of the clock gating of parts of an electronic components or complete disabling during periods of inactivity. The problem could be easily solved if transitions between power states would cause negligible power and performance overhead. However transitions to low-power states usually lead to additional power consumption and delays caused by the re-initialization of the components. A transition to low-power state is worthwhile only if the period of inactivity is longer than the aggregated delay of transitions form and into the active state and saved power is higher than required to reinitialize the components.

6.1.1. Dynamic Component Deactivation (DCD)

Computer components that do not support performance scaling and can only be deactivated idle. The problem is trivial in the case of a negligible transition has to be done only if the idle period is transitions lead not only to delays which can degrade performance of the systems, but to additional power. Therefore to achieve efficiency a transition has to be done only if the idle period is long enough to cover the transition overhead. DCD techniques can be divided into predictive and stochastic.

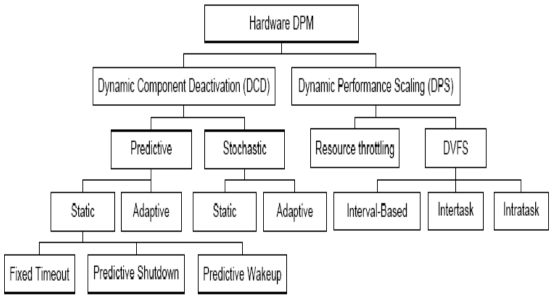

Fig 5. Hardware and Firmware Level

Predictive techniques are based on the correlation between the past history of the system behavior and its near future. A non-ideal prediction can result in an over-prediction or under-prediction. An over-prediction means that the actual idle period is shorter than the predicted leading to a performance penalty. On the other hand, an under-prediction means that the actual idle period is longer the predicted . Predictive techniques can be further split into static and adaptive, which are discussed below Static techniques utilize some threshold for a real-time execution parameter to make predictions of idle periods. The simplest policy is called fixed timeout. The idea is to define the length of time after which a period of inactivity can be treated as long enough to do a transition to a low-power state. Activation of the component is initiated once the first request to a component is received. Another way to provide the adaptation is to maintain a list of possible values of the parameter of interest and assign weights to the values according to their efficiency at previous intervals. The actual value is obtained as a weighted average over all the values in the list. In general, adaptive techniques are more efficient than static when the type of the workload is unknown a priori.

Another way to deal with non-deterministic system behavior is to formulate the problem as a stochastic optimization, which requires building of an appropriate probabilistic model of the system. It is important to note, that the results, obtained using the stochastic approach, are expected values, and there is no guarantee that the solution will be optimal for a particular case. Moreover, constructing a stochastic model of the system in practice may not be straightforward. If the model is not accurate, the policies using this model may not provide an efficient system control.

6.1.2. Dynamic Performance Scaling (DPS)

DPS includes different techniques that can be applied to computer components supporting dynamic adjustment of their performance proportionally to the power consumption. This idea lies in the roots of the widely adopted Dynamic Voltage and Frequency Scaling (DVFS) technique.

6.1.2.1. Dynamic Voltage and Frequency Scaling (DVFS)

DVFS reduces the number of instructions a processor can issue in a given amount of time, thus reducing the performance. This, in turn, increases run time for program segments which are sufficiently CPU-bound. Although the application of DVFS may seem to be straightforward, real-world systems raise many complexities that have to be considered. First of all, due to complex architectures of modern CPUs (i.e. pipelining, multi-level cache, etc.), the prediction of the required CPU clock frequency that will meet application's performance requirements is not trivial. In summary, DVFS can provide substantial energy savings; however, it has to be applied carefully, as the result may significantly vary for different hardware and software system architectures.

6.2. Operating System Level

The characteristics used to classify the operating system level.

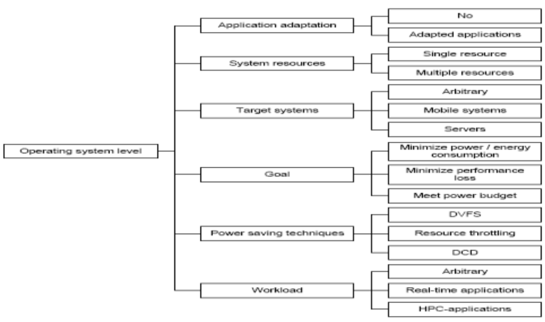

Fig.6. Operating System Level

Table 1.Characteristics of operating system level

Project name	System resources	Target systems	Goal	Power-saving techniques
Ondem and Government	**CPU**	**Arbitrary**	**Minimise power consumption**	**DVFS**
Eco System	**CPU, Memory, Disk Storage, Network, Interface**	**Mobile System**	**Achieve target battery lifetime**	**Resource throttling**
Nemesis OS, Neugeba and McAuley	**CPU, Memory, Disk storage, Network Interface**	**Mobile Systems**	**Achieve Target battery lifetime**	**Resource throttling**

6.3. Virtualization Level

The virtualization level enables the abstraction of an OS and applications running on it from the hardware. The virtualization layer lies between the hardware and OS and; therefore, a Virtual Machine Monitor (VMM) takes control over resource multiplexing and has to be involved in the system's power management in order to provide efficient operation. There are two ways of how a VMM can participate in the power management:

1. A VMM can act as a power-aware OS without distinction between VMs: monitor the overall system's performance and appropriately apply DVFS or any DCD techniques to the system components.
2. Another way is to leverage OS's specific power management policies and application-level knowledge, and map power management calls from different VMs on actual changes in the hardware's power state or enforce system-wide power limits in a coordinated manner.

6.4. Data Center Level

The main goal of data center level is:

- Minimize energy consumption, satisfy performance requirements.
- Minimize power consumption, minimize performance loss .

7. CONCLUSIONS AND FUTURE DIRECTIONS

In recent years, energy efficiency has emerged as one of the most important design requirements for modern computing systems, such as data centers and Clouds, as they continue to consume enormous amounts of electrical power. Apart from high operating costs incurred by computing resources, this leads to significant emissions of carbon dioxide into the environment. For example, currently IT infrastructures contribute about 2% of total CO_2 footprints. Unless energy-efficient techniques and algorithms to manage computing resources are developed, IT's contribution in the world's energy consumption and CO_2 emissions is expected to rapidly grow. This is obviously unacceptable in the age of climate change and global warming. In this chapter, we have studied and classified different ways to achieve power and energy efficiency in computing systems. The recent developments have been discussed and categorized over the hardware, operating system, virtualization and data center levels.

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