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# Green Computing-A Technology for High Performance Computing Systems

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**Abstract:** Green computing is a currentresearch area which addresses energy challenges. The present research foresees the duality of green computing with recent trends in the areas of computing such as high performance computing. Power consumption is in megawatts of range reaching to an intolerable scale. This results in both high operating and maintenance costs and high failure rates, which is now a major concern. It hasset new challenges to the advancement of high performance systems. We need huge amount of energy to power these large data centres. Thus green computing has become a challenge for cloud data centres and high performance computing systems to conserve energy. The goal of this research paper is to provide an overview about the power management techniques for high performance systems.

**Key words:** Green Cloud Computing · Static Scheduling · Dynamic Scheduling · Power Aware Computing

## INTRODUCTION

High performance computing (HPC), comprises of clusters, special-purpose multiprocessors, huge data stores and high speed networks [1], is rapidly becoming a fundamental researchmechanism in the field of science and engineering. Green computing can be broadly defined as the technique of reducing the overall energyconsumption of HPC systems by using energy-efficient design techniques. The research area has reaped increasing attention in recent years in ICT. The cloud data centres consume mega watts of power. Hence, there is a need to balance the growth of HPC systems such as clusters and data centres with green design in order to reduce the environmental impact. The high-performance green computing is an umbrella which can span the spectrum from green infrastructure such as energy-efficient buildings to green energy-efficient server design to green software and applications and CPU switch-off). The main aim of this research paper is to cater an overview about the power management techniques to improve efficiency of the HPC resources management in terms of power consumption.

**Green Computing:** Green computing is a broad phrase depicting a character of computing that is interested in improving energy efficiency and reducing carbon foot prints. Computing units can range from desktop personal computers, laptops, servers, networking equipment, cabling and more. Green computing is an essential domain of the computing sciences because of the significant demand computing requires of our resources. The computing life cycle includes pollution in the form of carbon dioxide, lead and other toxic materials. The carbon dioxide pollution happens at power plants where power is produced to computing nodes. These same power plants also emit mercury emissions and pollute our land and our water [2]. As the computers in the power plants run inefficiently, the power consumption will be more and leading to pollution. It is essential that we have to design the algorithms for reducing the environmental burden of computing to prevent or reduce the pollution caused by computers. Green computing is the utilization of PCs and related resources in an efficient manner. This involves the implementation of energy-efficient computing products such as central processing units (CPUs), servers and peripherals as well as proper disposal of electronic waste.

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Fig. 1: Green Computing

According to some estimates [3] the server runs on 100 watts and requires 50 watts to cool them. Small scale servers require 100 watts power supply. Medium scale servers consume around 200 watts power. When power consumption of servers goesdown then server turns out to green server. The power consumption of systems in India was 778 kWh in January 2012. It will be doubly by 2020. IT sectors contribute 10% of overall power consumption. A typical desktop computer uses about 65 to 250 watts. Laptop uses about 15-60 watts. Laptop is greener than desktop computer. Tablet PC consumes less power than Laptop. Power consumption is major problem of coming days. Reduce them and save the Earth and life. Green HPC deals with making HPC systems more energy efficient.

A current report from the Natural Resources Defence Council (NRDC) reveals that the U.S. data centres consumed a massive 91 bnkWh of electricity in 2013 and continues to rise to about 140 bn kWh by 2020, which is equivalent to 500 megawatt that can be equated to 50 large power plants. The Uptime Institute annual data centre survey in 2014 reveals that the power usage in data centres which is measured in power usage efficiency (PUE) metrics have levelled at around 1.7following quite a long while of consistent change [4].

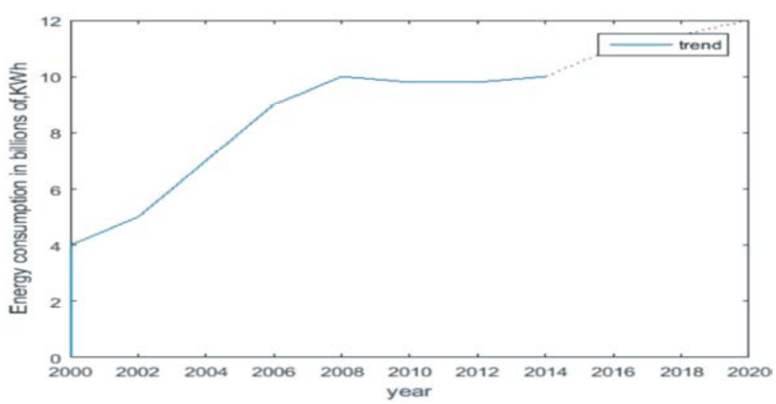


Fig. 2: Energy consumption of servers and data centres in Germany from 2000 to 2020 (Source: Border step)

In 2014, the energy consumption rate of the German data centres increase by 3 % to 10 billion kilowatt-hours. In 2020,it has been predicted that the energy consumption of data centres in Germany would reach almost 12 billion kWh as shown in the figure above.

Theelectricity usage of data centres worldwide increased by about 56% from 2005 to 2010 instead of doubling, while in the US it increased by about 36% instead of doubling [5].

- Electricity usage in global data centres in 2010 is between 1.1% and 1.5% of total electricity usage, respectively. For the US that number was between 1.7 and 2.2%.
- Electricity used in US data centres in 2010 was significantly lower than predicted by the EPA's 2007 report to Congress on data centres. That result reflected this study's reduced electricity growth rates compared to earlier estimates, which were driven

mainly by a lower server installed base than was earlier predicted rather than the efficiency improvements anticipated in the report to Congress.
- While Google is a high profile user of computer servers, less than 1% of electricity used by data centres worldwide was attributable to that company's data centre operations.

The rapid rates of growth in data centre electricity use that prevailed from 2000 to 2005 slowed significantly from 2005 to 2010, yielding total electricity use by data centres in 2010 of about 1.3% of all electricity use for the world and 2% of all electricity use for the US [6].

**Power Management Techniques:** Machine independent data access is the most recent trend and distributed computing is quenching this thirst. In cloud computing, resources are conveyed as a service over a system to the clients on a "Pay as you utilize" strategy. Millions of users have started to use this technology and the number is expected to increase in the years to come. Subsequently enhancing energy utilization on the cloud is unavoidable. The enhancement of energy utilization on the cloud is called green cloud computing.

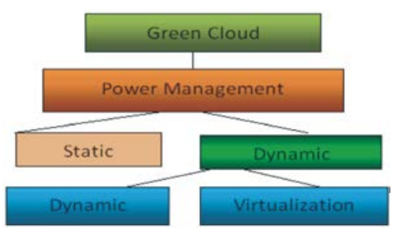


Fig. 3: Energy management in Cloud Computing

Innovations and trends have helped provide tremendous performance improvement over the years. At the same time they have created new problems that demand immediate consideration, i.e. problems like power consumption. There are two power management techniques used to reduce power consumption in computer systems. The authors [7] describe different power management techniques that aim to reduce power consumption.Static Power Management (SPM) and Dynamic Power Management (DPM)

SPM technique can be subdivided into two areas. First one technique targets CPU. It investigates power consumption involved at both cycle and instruction levels. The second technique targets all the system components.DPM uses runtime behaviour to reduce power when the system is serving light workloads or when it is idle. DPM can be achieved using Dynamic Voltage Scaling (DVS) which can be implemented at the CPU-level or system-level to save energy of all system components like memory, hard drive, I/O devices, display etc. Deploying these power performance models and power optimization at all system levels will lead to generation of energy efficient systems.

Slating of tasks plays an important task in green cloud computing. We know that scheduling is the method by which tasks are given access to system resources (e.g. processor). There are two types of scheduling: Static scheduling: schedule tasks before runtime and Dynamic scheduling: schedule tasks at runtime

We apply power management techniques on the static and dynamic schedules. Power aware computing is one of the primary goals in building a new system. By power aware computing, we mean to optimize energy and power consumption as much as possible without compromising much on performance.

There are two basic types in this approach,

- Static Power aware: Apply static scheduling algorithms at compile time to optimize power consumption. It also puts the system components to idle state when not in use.
- Dynamic Power aware technique applies dynamic scheduling algorithms at run time to optimize power consumption and DVS (Dynamic Voltage Scaling) scales down the CPU supply Voltage and frequency

In the paper [8] authors have addressed energy management for distributed real time systems where communication times are significant and tasks may have precedence constraints.

**Static Slack:** application executes for its worst case but finishes before deadline. Global static slack: difference between length of static schedule and deadline.

In Global scheduling with Greedy Slack Reclamation[9] has been discussed. If a process on that particular processor finishes its execution prior to the expected canonical time, then the slack is carried over to the next process in that processor and the processor speed is down sized to reduce power consumption by that processor.

**Global Scheduling with Shared Slack Reclamation:** The slack is distributes amongst the various processors in the system. Thus, the slack is "Shared" amongst the various processors.

**List Scheduling with Shared Slack Reclamation:** In order for any task to be ready for execution, its predecessors should have finished their execution. It has a tendency of changing the execution order, thus may take longer than Canonical execution time.

**Fixed Scheduling with Shared Slack Reclamation:** In this scheduling scheme, the order of execution of tasks is same as that in the precedence graph. This guarantees that execution does not take longer than canonical execution.

It can be concluded that the various slack sharing concepts for multi processor environment to reduce power consumption works effectively. Dynamic scheduling with varied levels of frequency/energy has been proven to be more efficient than Static Power Management by up to 44%.

**Greedy SPM[10]:** Shift the static schedule and allocate the entire global static slack to first task on each processor, if the task is independent. By shifting all tasks, the precedence and synchronization constraints are maintained. Energy consumed, Ec=(29/72)E where, E is energy consumed when No Power Management (NPM) is applied.

**Simple SPM (S-SPM):** The global static slack is distributed over the length of schedule. Not optimal in terms of energy consumption because of the different degrees of parallelism in a schedule. S-SPM wastes an additional 1 unit of slack by uniformly stretching the whole schedule. Energy consumed, Ec = (4/9) E where, E is energy consumed when No Power Management (NPM) is applied.

SPM with Parallelism (P-SPM) Allocates more slack to sections with higher parallelism, thereby reducing the idle periods in the system. Energy consumed, $E_c = 0.3464E$, where, E is energy consumed when No Power Management (NPM) is applied.22% more energy is saved compared to S-SPM.

The paper [11] presents a technique for power and energy reduction in general purposeMicroprocessors, which is known as dynamic voltage frequency scaling (DVFS) which is an effective mechanism for reducing processor power and energy consumption. It focuses on multiple levels of voltages and frequencies, to be adjusted during the run time, for reducing power consumption for each process. Every process is expected to finish in an estimated worst time known as Canonical time. Slack refers to the difference in time between the expected canonical time and the actual time of execution for each process. Thus, dynamic power saving techniques makes use of various levels of voltages and processor clock cycles for varied execution time and energy consumption.

The scheduling of real-time tasks in wireless systems can be done using Gain based Static Scheduling (GSS)]. In each iteration, the highest energy gain yielding entity is chosen. It is allocated just enough slack to reduce its performance mode by one level. The remaining slack is allocated in a similar fashion to the remaining entities. At the end of each iteration, the individual energy gain values are updated. In order to keep track of the messages which can utilize more slack without affecting any constraints, the GSS algorithm maintains a set Q and updates it after each iteration. The algorithm terminates once the set Q becomes empty. In Distributed Slack Propagation Algorithm (DSP)-Dynamic Slack, for each task, the option of using the slack for itself is called option zero and the option of propagating the slack further is called option one. To decide whether a Task should choose option zero or one, we need to evaluate the absolute energy reductions that would be obtained by each of the two options. In order to capture these different options and estimate their energy gains, a data structure called the Slack Propagation Tree (SPT) is used. In an SPT each message and task is represented as a separate node in the tree. DSP Algorithmuses the SPT data structure to reduce the performance levels of the tasks and messages using the Dynamic slack. It proceeds in iterations updating the tuple values of the SPT nodes in each iteration. The run-time of the DSP algorithm can be estimated as, O(v2(kt + km) where, v = the number of tasks and messages allocated to the processor of interest.

The RAPM (Reliability aware power mgmt) techniques for real-time applicationsrun both the primary and its corresponding backup task on the same processor. This technique eliminates the transient faults (temporary faults-bit errors). It has two major drawbacks,

- Cannot offer performance greater than 50%
- Does not provide redundancy to tolerate permanent failures

The pre-emptive scheduling has been used in this work. A standby processor is added to withstand the permanent failure of single CPU. The scheduling algorithms used are EDF (Earliest Deadline First-is computed on-line) and EDL (Earliest Deadline Late-is computed offline).On the primary processor, the task is run using DVS techniques, thus reducing power consumption. The scheduling algorithm used is EDF. On the secondary processor, the backup task is run at maximum frequency. This helps in retaining system original reliability. EDL is used to scheduling backup task. Using this algorithm we delay the backup task as much as possible. Many backup tasks are cancelled even before they start executing. If the primary task runs to completion successfully, the backup task is cancelled. Otherwise, the backup task runs to completion. The joint use of EDF and EDL on primary and secondary processors respectively, minimizes the overlap between the two copies at run time. It also helps us reduce energy cost due to backup task executions.

Once the task on the primary processor runs to completion, a test is performed to check if the task is executed successfully. If yes, the backup task is cancelled. Else, the backup task runs to completion.

There are two variants of SSPT (Standby Sparing for periodic tasks) used:

**Aggressive SSPT:** A job can utilize the entire slack and slow down as much as possible. If the job completes before the deadline, the slack can be used for upcoming tasks.

**Conservative SSPT:** A task is not allowed to run below its average case utilization, this approach has abalanced slack distribution among all jobs.

When RAPM, aggressive SSPT, conservative SSPT were compared, conservative SSPT showed superior performance and had energy gains up-to 15%.

## CONCLUSIONS

In this paper, the two power management techniques have been discussed, static power management and dynamic power management techniques by exploring a hardware redundancy technique for periodic real-time tasks based on standby-sparing technique. The concept of slack has been discussed in detail using various algorithms. The framework uses the EDF algorithm on the primary CPU and the EDL algorithm on the spare CPU. An advantage of this framework is that repeatedly the execution of the backups can be cancelled upon the early and successful completion of the primary copies. The stand-by sparing technique conserve more energy compared to RAPM for most scenarios still preserving the original reliability in terms of tolerance to transient faults. TheP-SPM can save 10-20% more energy compared with simple static power management (S-SPM) for parallel systems, which distributes global static slack proportionally to the length of the schedule and save 10% more than the static scheme discussed. While the gap-filling technique can save 5% more energy when applied after greedy.

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