Survey on Power Optimization for Disk Based Systems

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Abstract

Energy optimization has become a growing concern in the present world. Energy optimization can influence the overall system design and reliability. Power can greatly influence the performance of the disk, as power dissipation generates heat that affects stability and reliability of the component, particularly for large server systems. Hence, developers concentrate on the configuration of disk arrays which can deliver extremely high performance. Though, there are several significant techniques for tackling disk power for laptops and workstations, using them in a server environment are a considerable challenge, especially under stringent performance needs. Excessive power consumption is a major barrier to the market acceptance of hard disks in mobile electronic devices. Studying and reducing power consumption, however, often comprises running time intensive disk traces on real hardware with specialized power-monitoring equipment. Most of the conventional energy optimization techniques are based on architectural level techniques and is found to be effective only in certain scenarios. This paper proposes a survey on the disk energy optimization techniques. This paper analyses the functionalities, advantages and the disadvantages of the various techniques for the disk power consumption.

Keywords: *Power Dissipation, Traditional Power Management (TPM), Finite-Element (FE) Model, Flash Memory, Data Prefetching*

1. Introduction

The performance has been the main aim when designing hardware and software. Disk drive [23] [25] designers try to construct faster hard disks with denser storage capacity, while software designers adjust their functions for peak performance on a given hardware platform.

Recently, power dissipation has become a rising anxiety. Though, conventionally regarded as a problem for mobile, battery-operated systems, power also creates disputes in terms of electricity charges and overall system design and reliability.

Studies and investigations on disk power management can be an annoying procedure, as important disk traces take long time to run, and researchers need access to expensive power-monitoring equipment.

In majority of the single-disk applications, Traditional Power Management (TPM) consists of two steps. TPM initially identifies appropriate idle periods, then spins down [27] the disk to a low-power standby mode when the power management approach forecasts that doing so will save energy. But, spinning the disk back up from this standby mode when the system receives an I/O request incurs additional latency and power costs.

Organizing power in single-disk systems such as laptops and desktops has been an extensive area of research [19, 20]. There are various conventional techniques proposed in the literature for disk power consumption. Most of the traditional techniques are based on architectural mechanism like spinning down idle disks [21] [22] or rotating disk with reduced speed. Even though, these implementing them still presents challenges that need additional research. Excessive power consumption is a main blockade to the market acceptance of hard disks in mobile electronic devices.

Thus, due to the importance of the power consumption and its influence in the current market, there are several approaches developed by various researchers for the energy optimization [26] of the disks. This paper deals with the analysis of the various existing approaches for disk energy optimization.

2. Literature Survey

Power utilization of disk systems is a significant issue in systematic computing where data-intensive applications exercise disk storage comprehensively. At the same time one can turn inoperative disks [24] when idleness is identified, turning up them takes many cycles and utilizes additional power. Consequently, it can be extremely helpful when put into practice to enhance the re-usage of disk, specifically using the same set of disks as much as feasible. When it is possible to put into practice, the unexploited disks can be detained in the so called spin-down mode for maximum length of time, and this assists in enhance power savings.

Kandemir et al., [1] suggested a method for minimizing the disk power utilization by enhancing re-usage of disk. The proposed technique reorganized a particular application code by taking only the disk boundaries of the datasets it manipulate into consideration. The disk layout-conscious technique executed inside an openly-accessible compilation structure and evaluated it against a traditional data reuse optimization technique that is also executed by utilizing the same compiler using six scientific applications that carry out disk I/O. The consequences gathered until now specifies that this layout-conscious technique and the traditional data reuse optimization technique decreases the disk energy utilization by 25.3% and 10.3%, correspondingly, typically, over the case where no disk power optimization is functional. The equivalent savings in overall energy consumption together with CPU, memory and network energies are approximately 6.5% for the traditional technique and 16.5% for this disk layout-conscious technique. The experimental estimation also proves that the savings achieved are reliable with varying number of disks and any other disk layouts.

Disk subsystem is recognized to be a most important contributor to the entire power consumption of high-end parallel systems. Earlier researches recommended numerous architectural-level approaches to diminish disk power by captivating benefit of idle time period experienced by disks. Even though such approaches have been identified to be very successful in some cases, they all have a general disadvantage: they function in a reactive way, i.e., they manage disk power by examining previous disk movement (for instance, idle and active periods) and approximating future ones. As a result, they can fail to notice the chances for consuming power and gain noteworthy performance consequences because of inaccuracies in forecasting idle and active time periods. Inspired by this examination, Seung Woo Son et al., [2] proposes and estimates a compiler-driven technique to reducing disk power utilization of array-based scientific applications accomplishing on parallel systems. The proposed technique exposes disk layout data to the compiler, permitting it to obtain the disk access pattern, specifically the arrangement in which parallel disks are accessed. This technique also reveals two uses of this data. The first use is that is easy to put proactive disk power management into practice, to be precise, choose the most suitable power-saving approach and disk-preactivation approach according to the compiler-predicted future idle and active periods of parallel disks. The second use is that it is simple to reorganize the application code to enhance the time-span of idle disk periods, which shows the way to improved utilization of available power-saving capabilities. Both these approaches are employed in this technique inside an optimizing compiler and tested their efficiency with the help of a set of benchmark codes from the Spec 2000 suite and a disk power simulator. Experimental consequences show that the compiler-driven disk power management is a very potential method. The experimental outcome also exposes that, even though proactive disk power management is very efficient, code restructuring for disk power accomplishes further energy savings across all the benchmarks examined, and these savings are extremely near to best possible savings that can be achieved through an integer linear programming (ILP)-based method.

Enhancing security and reducing power utilization are essential for large-scale data storage organizations. Even though numerous studies have been concentrated on data protection and energy efficiency, the majority of the available techniques have concentrated on just one of these two metrics. Shu Yin et al., [3] presented a novel technique to incorporate power optimization with security services to boost the security of energy-efficient large-scale storage organizations. In this approach, the dynamic speed control for power management procedure is used, or DRPM, to preserve energy in protected storage systems. The author had given two manners of incorporating privacy services with the dynamic disk speed control method. The first method - security aggressive in nature - is mostly concentrated on the enhancement of storage system security with fewer importances on energy preservation. The second method provides advanced precedence to energy preservation as different to the security optimization. The experimental outcome shows that the energy-aggressive method offers better energy savings than the security-aggressive method. On the other hand, the superiority of security realized by the security-aggressive method is advanced than that of the energy-aggressive method. Furthermore, the observed result shows that energy savings yielded by the two methods turn out to be more distinct when the data size is larger. The result demonstrates that the response time of the security-aggressive method is more responsive to data size than that of the energy-aggressive method.

Storage finds an essential role in the performance of a lot of applications. Numerous applications, particularly those that run on servers, are I/O concentrated and so need better performance storage systems. These high-end storage systems use a large quantity of power, the most quantity of which is because of the disk drives. Optimizing disk structural designs is a design time with run time concern and necessitates balancing between performance and power. There are dissimilar figures of advantage, for instance performance and energy, and a huge space of design and runtime "knobs" that can be utilized to optimize disk drive performance. Specified such a huge space, it is desirable to have an organized method to optimally set these knobs to assure the figures of advantage as resourcefully as achievable. Sankar et al., [4] present the sensitivity-based optimization technique for disk architectures (SODA), which influences results before obtained in digital circuit design optimization circumstances. By means of comprehensive models of the electro-mechanical manners of disk drives and a suite of practical workloads, SODA can assist in design and runtime optimization of disk drive structural designs.

The dynamic voltage and frequency scaling method in CPUs is an illustration of regulating a device's control variable to exchange power consumption and performance. This inspiration of energy optimization by means of speed control has been then applied to additional components of electronic systems such as disk drives and wireless transceivers. The energy-optimal speed profile (a function of time) of a common device that has to carry out a specified task in a certain time is obtained systematically. Ravishankar Rao et al., [5] proposed technique is technique to devices with either distinct or continuous-speed sets. The most significant improvement of the technique is that for discrete-speed sets, the environment of the fundamental continuous power-speed association does not require to be known. The discrete power-speed data points just require convincing a W-convex relation: a discrete analog of a convex function. According to the observation that the majority of devices have W-convex power-speed associations, it is exposed that the optimal speed profile utilizes at most one speed for permanent speeds or two speeds. Additionally, each device has a built-in speed (self-sufficient of the task) uc at which it uses the smallest amount of energy per unit work completed. It is revealed that this speed can be computed directly from measured values of power-speed data points (for distinct-speed sets) or by an investigational line search process where each step engrosses determining a power-speed data point for continuous-speed sets. In whichever case, no curve fit or information of analytical power models is essential. The most favorable speed profile was revealed to be either uc or the smallest feasible speed(s) for the particular task, with the option depending on the energy overheads and task constraints.

Significant performance, high reliability and energy-proficient storage systems are very vital for mobile data-intensive applications such as remote surgery and mobile data center. Mobile disk-array-based storage systems are more liable to disk malfunctions than with traditional stationary storage systems. This is mainly because of their complicated application environments. Moreover, Mobile disk-array-based storage has very inadequate power supply. Hence, data reconstruction techniques, which are carried out in the existence of disk malfunctions, for mobile storage systems must be performance-driven, reliability-aware, and energy-efficient. Existing reconstruction approaches cannot accomplish the three objectives concurrently as they mostly overlooked the information that mobile disks have much superior failure rates than stationary disks. In addition, they generally disregard energy-saving. In this paper, Tao Xie et al., [6] proposed a novel reconstruction approach, called Multi-level Caching-based Reconstruction Optimization (MICRO), which can be used to RAID-structured mobile storage systems to obviously cut down reconstruction times and user response times while saving energy. MICRO collaboratively uses storage cache and disk array controller cache to lessen the number of physical disk accesses produced by reconstruction. The simulation results reveal that MICRO technique lessens reconstruction times on average 20.22% and 9.34% when compared with the approaches like DOR and PRO. Moreover, it saves energy no less than 30.4% and 13%, respectively.

Kyungtae Kim et al., [7] investigate the vibrant features of slim optical disk drives and the modification of their structural dynamics to decrease vibration using a simplified Finite-Element (FE) model. The FE model was generated by means of a basic geometry and valid element types that efficiently reflect the dynamic characteristic features. Experimental Modal Analysis (EMA) is used to verify FE system. Design parameters were taken out and chosen to adapt the structural dynamics using design of experiments, topology optimization, and modal strain energy distribution. A prototype of the modified model was formed and its anti-vibration significance was evaluated using EMA.

Energy consumption has turned out to be a vital concern in the design of battery-operated mobile devices and complicated data centers. The storage hierarchy, which comprises memory and disks, is a key energy consumer in such systems; particularly for high-end servers at data centers. Majority of the research has focused on energy control techniques for storage systems that transition a device into a low power mode when a certain usage function goes beyond a particular threshold. These techniques are complicated to apply in real systems, since designers must carefully and manually tune threshold values; its performance is still very low. In order to tackle these drawbacks, Xiaodong Li et al., [8] developed three algorithms: 1) a performance guarantee approach that designers can use with any fundamental energy-control algorithm 2) a performance-directed control technique that occasionally allocates a static configuration to various devices by solving an optimization problem 3) Additional performance-directed control technique that dynamically self-tunes based on an optimal set of thresholds.

A video player may prefetch video frames into buffer to allow disk to go into standby mode, which comprises entire spindown of the spindle motor. Frequent spindowns, but, influence disk long life, so it is very vital to reduce the number of times that disk enters standby mode. Minseok Song et al., [9] proposed the design and implementation of a data prefetching approach that lessens disk power consumption for a limited number of disk spindowns. A data prefetching system is presented that entirely exploits the available buffer space and examine how power consumption is influenced by the bit-rates of the frames in the buffer. Then the issue is devised that decides when the disk should enter standby mode and offer an optimal solution using dynamic programming. The proposed approach is implemented in MPlayer running on the Linux 2.6. The simulation results reveal that it minimizes disk energy consumption by up to 59%.

Minimizing energy consumption is a vital issue for data centers. Storage is one of the main consumers of energy among various components of a data center. Earlier researches have revealed that the average idle period for a server disk in a data center is very little compared to the time taken to spin down and spin up. This greatly limits the effectiveness of disk power management schemes. Qingbo Zhu et al., [10] in this paper proposes several power-aware storage cache management techniques that offer more chances for the fundamental disk power management approaches to save energy. More particularly, an off-line power-aware greedy algorithm is proposed that is better energy-efficient than Belady's off-line algorithm (which minimizes cache misses only). An online power-aware cache replacement algorithm is also proposed in this paper. The trace-driven simulations reveal that, the proposed algorithm saves 16% more disk energy when compared with LRU and offers 50% better average response time for OLTP I/O workloads. The effects of four storage cache write policies on disk energy consumption are also examined.

Portable media players are vastly using Hard Disk Drives (HDD) to meet their storage needs, but HDDs consume a

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considerable amount of energy. Hence video frames are prefetched into Dynamic Random Access Memory (DRAM) to facilitate the disk to go into low-power mode; but majority of the mobile systems have limited DRAM, so only very few energy is actually saved in this way. Jaewoo Kim et al., [11] propose two new energy saving approaches: one enhances the use of DRAM in storing prefetched frames, and the other widens this technique by using auxiliary flash memory. The experimental results reveal that deploying a realistic amount of auxiliary flash minimizes disk energy consumption by up to 86% when compared with traditional prefetching techniques.

In recent times, the requirement for micro hard disk drive that offers high-capacity detachable storage for handheld electronic devices is mounting quickly. The most important issue in the design of seek servo controller in micro disk drives is to diminish power utilization. The input power sent to the seek servo system is used by the transistors of power amplifier and motor coil resistance. Chang-Ik Kang et al., [12] proposed a novel seek servo controller for diminishing the power utilization. In this technique, Fourier decomposition and constrained nonlinear programming are used to find out the optimum seek profile that diminishes the power utilization.

To maintain the huge storage necessities, consumer electronics for video playback are progressively more being outfitted with hard disk drives (HDD) that use a considerable amount of energy. A video player possibly will prefetch several frames to provide a chance to disk to go to standby mode, however this might cause playback to be unclear or blocked if appropriate power mode transitions are not built-in. Jaedoo Go et al., [13] provided the design, implementation and estimation of a data prefetching method for energy-aware video data retrieval for portable media players (PMP). A difficulty is formulated when the prefetching is used for variable-bit-rate (VBR) streams to diminish disk energy utilization and then developed a novel energy-aware data retrieval scheme that prefetches video data in a quick way in order to raise the period in which disk reside in standby mode while promising the real-time service. This method is implemented in the legacy video player known as Mplayer that is characteristically used for Linux-based consumer machines. Experimental observation shows that it saves energy to the extent that 51% compared with traditional methods.

A hybrid hard disk drive that makes use of a non-volatile memory as a cache is increasing attractiveness because of its enhanced consistency and performance. Wanhyung Ryu et al., [14] proposed the design and implementation of a data prefetching method that makes use of flash memory to lessen disk energy utilization in media players. According to the estimated time used to prefetch data into flash memory, selectively decide when to spin up or down the disk in an appropriate way with the intention of reducing disk energy utilization while offering real-time video playback. This method is implemented in MPlayer operating under the platform of the Linux 2.6. Experimental observation shows that the disk energy utilization can be reduced between 35% and 63%, when a sensible amount of flash memory to a small DRAM can be added.

More power utilization of high-performance systems show the way to consistency, survivability, and cooling related difficulties. Inspired by this examination, numerous modern efforts concentrated on minimizing disk power utilization with the help of hardware, OS and compiler based approaches. Seung Woo Son et al., [15] developed a new technique to minimize disk power utilization of large-scale, array-concentrated scientific applications. It recommends and estimates a compiler-based technique that utilizes two complementary approaches: data reorganization and disk mapping. The data reorganization approach finds out an appropriate layout for data in the array space, while the second approach disk mapping, chooses the related layout in the disk space. The objective of data reorganization and disk mapping is to guarantee that data (from the various disk-resident arrays) that are accessed within the equivalent loop iteration are co-located in the similar set of disks. In this approach, the disk inter-access times (idle periods of disks) can be increased and this consecutively permits enhanced utilization of the basic hardware mechanisms used for minimizing power. The experimental results also confirms that both the components of this method are extremely significant since applying any of these components alone does not produce large savings for the majority of the applications.

Disk subsystem is recognized to be a most important contributor to the entire power budget of large-scale parallel systems. The majority of scientific applications at the moment rely greatly on disk I/O for out-of-core computations, check-pointing, and revelation of data. To diminish surplus energy utilization on disk system, previous studies proposed numerous hardware or OS-based disk power management methods. At the same time as such methods have been identified to be efficient in some cases, they possibly will miss opportunities for enhanced energy savings because of their reactive nature. Whereas compiler based methods can create more precise decisions on a specified application by extracting disk access patterns statically, the shortage of runtime details on the condition of shared disks possibly will lead to incorrect decisions when multiple applications makes use of the similar set of disks concurrently. Seung Woo Son et al., [16] recommended a runtime system based approach that offers more efficient disk power management. In this method, the compiler presents vital information on the future disk access patterns and favorite disk speeds from the perception of individual applications, and a runtime system uses this information together with current state of the shared disks to formulate decisions that satisfy to all applications. To test the performance of proposed technique runtime system support within PVFS2, a parallel file system is examined. The experimental outcome with four I/O-intensive scientific applications specify large energy savings: 19.4% and 39.9% over the formerly-proposed pure software and pure hardware based methods, correspondingly.

Bircher et al., [17] proposes the use of microprocessor performance contradictions for online calculation of entire system power utilization. This technique takes the benefit of the “trickle-down” result of performance measures in microprocessors. Though it has been well-known that CPU power utilization is correlated to processor performance, the utilization of recognized performance-related events within a microprocessor for instance cache misses and DMA transactions to approximate power utilization in memory and disk and other subsystems external of the microprocessor is new. By means of amount of definite systems running scientific, business and productivity workloads, power models for six subsystems (CPU, memory, chipset, I/O, disk and GPU) on two platforms (server and desktop) are implemented and validated. These models are revealed to possess an normal error of under 9% per subsystem across the considered workloads. With the utilization of these models and existing on-chip performance event counters, it is feasible to approximate system power utilization without the requirement for power sensing hardware.

Flash memory has several smart characteristics like little size, low-power utilization, shock resistance, and elevated performance. Because of these high-quality characteristics, flash memory has been extensively used in the mobile consumer devices for example portable media players (PMPs) and smart phones. On the other hand, the expenditure of flash memory is more to accommodate constantly-growing mobile applications and multimedia contents. With the help of flash memory and mobile disk collectively as secondary storage is a different solution to offer large storage capacity with reasonable cost. Since heterogeneous storage devices are collectively used, the system requires a buffer management strategy that is responsive to different I/O characteristics of buffered blocks based on which devices they belong to. Particularly, power consumption price of all storage devices must be taken into consideration in the design of an effective buffer management strategy because battery restriction of mobile systems is essential. Hyojung Kang et al., [18] developed an innovative buffer management strategy for mobile systems that has heterogeneous storage devices like flash memory and mobile disk. With the consideration of different power-consumption rates all storage media in addition to I/O operation type and reference potential of buffered blocks, this strategy minimizes storage power utilization considerably and also enhances I/O performances.

APPROACHES	FUNCTIONALITIES
[1]	Disk layout-conscious approach restructures a given application code considering the disk layouts of the datasets it manipulates
[2]	Exposes disk layout information to the compiler, allowing it to derive the disk access pattern. Disk power management Application code to increase the length of idle disk periods
[3]	Dynamic speed control for power management tech or DRPM.
[4]	Sensitivity-based optimization methodology for disk architectures (SODA.
[5]	Energy-optimal speed profile (a function of time) of a generic device that has to execute a given task in a given time is obtained analytically
[6]	A novel reconstruction strategy, called multi-level caching-based reconstruction optimization (MICRO). MICRO collaboratively utilizes storage cache and disk array controller cache to diminish the number of physical disk accesses caused by reconstruction.
[7]	A simplified finite-element (FE) model. Constructed using simplified geometry and valid element types
[9]	Data prefetching scheme that minimizes disk power consumption for a limited number of disk spindowns
[10]	An off-line power-aware greedy algorithm is proposed that is better energy-efficient
[11]	Two new energy saving schemes: one improves the utilization of DRAM in storing prefetched frames, and the other extends this approach by making use of auxiliary flash memory.
[12]	Fourier decomposition and constrained nonlinear programming are used to find out the optimum seek profile that diminishes the power utilization.
[13]	Design, implementation and estimation of a data prefetching method for energy-aware video data retrieval.
[14]	Use of flash memory to lessen disk energy utilization in media players.
[15]	A compiler-based technique that utilizes two complementary approaches: data reorganization and disk mapping.
[16]	Compiler provides vital information on the future disk access patterns and favorite disk speeds from the perception of individual applications.
[17]	Cache misses and DMA transactions to approximate power utilization in memory and disk and other subsystems external of the microprocessor.
[18]	Buffer management strategy for mobile systems that contains flash memory which has several smart characteristics like little size, low-power utilization, shock resistance, and elevated performance.

3. Problems and Directions

Various disk power consumption techniques have been available in the literature. Previous researches on power consumption mostly focused on the architectural level techniques. These approaches takes advantages of idle periods experimented by disks. Existing disk power consumption techniques suffer from various drawbacks. The most common limitation of most of the existing energy optimization techniques is that, the techniques operate in a reactive manner. Moreover, the system can miss the power saving opportunities. Moreover, there are various performance degradations because of the inaccuracies in predicting the idle and active time. With subject to different kinds of disturbances that yield unresolved issues and uncertain consequences in different disk energy optimization problems. With such limitations, it is difficult to save power in the disk systems effectively by these kinds existing techniques. Therefore, other types of modern techniques are necessary for effective energy optimization.

- Better disk scheduling techniques are needed for better performance.
- Need to identify better and significant disk idle and active time.
- Moreover, better optimized compilers are necessary for better power consumption of the disks.

4. Conclusion

This review is undertaken to explore and analyze the existing disk power consumption techniques present in the literature which are very much required to maintain significant power saving capability. This paper attempts to present major studies of disk energy optimization techniques, such as adopting architectural mechanisms such as spinning down idle disks, Traditional Power Management (TPM) etc which is available in the literature. These conventional energy optimization techniques form the basis for the new innovation of the effective power consumption approaches. Most of the stabilization techniques available in the literature operate in reactive manner, and moreover there is significant performance penalities. By contrast, the advantages of PSO techniques convinced and encouraged many researchers to apply these techniques to solve the problems of power system control.

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