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Performance analysis of a hybrid system HDD-SSD

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Abstract

The memory hierarchy in the latest computers is becoming subject of several significant changes. These changes try to improve significantly one of the most vulnerable points of computer systems inherited from one generation to another. The bottleneck of computers is the communication between main memory RAM and HDD. This study will focus on the benefit that provides the implementation of a hybrid system at the level of secondary memory. Through benchmarks which simulate applications that have significant dependence of the write and read processes will be analyzed through a machine where a hardware memory controller integrates SSD (Solid State Disk) and traditional disk HDD (Hard Disk Drive) together. Hybrid system performance will be compared with the standard system used to date.

Keywords: *intensive read-write, SSD (Solid State Disk), Hybrid HDD, NAND memory.*

1.0 INTRODUCTION

The widening gap between the advancement of CPU, memory system and hard disk makes the last the limiting factor in the overall system performance. The performance of a computer heavily depends on reducing disk access times and therefore the disk head positioning time that in turn relies on the data layout. We propose new hybrid architecture for the main storage. There are two kinds of storages - HDD and SSD. HDD is a widely used storage device in general. On the other hand, SSD is a new storage device and is expected to replace a HDD. These storages have very different features; thus the way to access data in those
storages is worked differently.
HDD is comprised of mechanical equipments. The architecture of a modern PC stores the OS and the application programs in the HDD. While the system boots up, the CPU must first load programs and data from the HDD into the system memory. Based on this relationship, even though the CPU operating speed is extremely fast, the efficiency of the whole system is being limited due to the mechanical access head movements of the HDD. To access data, it relocates a disk head at first and then rotates a platter. The time to relocate a disk head is called the "disk head positioning time".

An ordinary file system designed for HDD tries to manage the data blocks as sequentially as possible to reduce it. SSD does not need any mechanical action to access data because of its comprised semiconductors. Therefore, a SSD-based file system does not need to manage data sequentially as HDD to improve performance. However, SSD is very weak in some specific I/O environments where a large amount of re-write operations occur, due to not supporting data modifications.

So to make a comparison we can say that flash based storage devices show contrasting features than disk drives. One of those is that random-access writes to flash devices can take longer than magnetic disk drives while reads can finish earlier. The flash drives have faster random-access reads and sequential-access writes than the disk drives, and lower power consumption. By considering these features of HDD and SSD, we designed a hybrid storage where we best use the fast read access capability of SSD and the large capacity of HDDs.

To overcome the problem of HDD latency we can create RAID system using parallel I/O to increase data throughput, we improve the average read and write performance by 50% to 70% [1]. There is some improvement of the system performance by speeding up the disk, increasing the number of access heads, improving the access head's moving speed and adding more disks [2]. Some studies have used cache memory to improve the performance of the HDD [3], both by means of various mathematical calculations and by prefetching the data into the cache memory [4]. This technique reduces the access delay of the HDD and improves the performance by better mathematical calculations, raising the cache memory hit rate [5]. On the other hand, when the OS is loading data, a larger cache memory can prefetch more data for the OS to use. In other words, the OS stores data into the DRAM as a buffer until the HDD traffic is free, and then writes back to the HDD. Another approach proposes to add a NAND Flash memory as the level 2 cache to the HDD structure to decrease the mechanical access delay. The NAND Flash memory is used as storage medium to design an SSD and also to combine SSD and HDD as a hybrid storage device to improve the system performance and all this is done by a software acceleration method[6] (see fig 1).

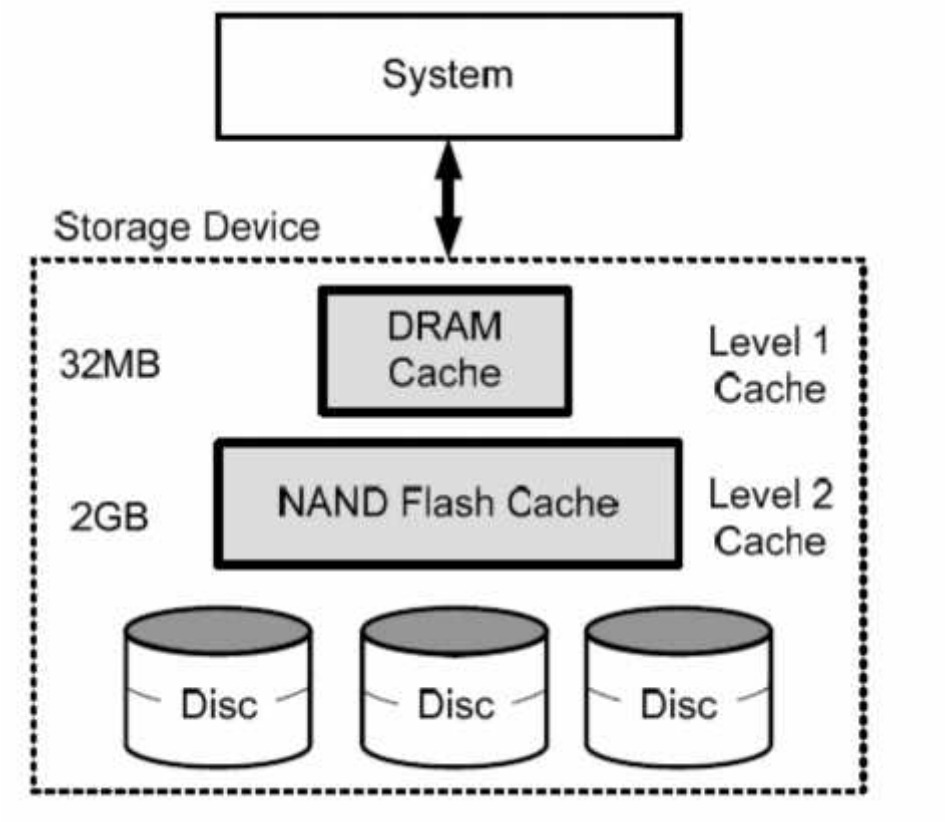

Figure 1. Block diagram for cache storage system

In Section II we illustrate the proposed architecture with the characteristic of the SATA SSD used, in Section III we measure the performance of the hybrid system, and in Section 4 we describe the test results. The final Section draws the conclusion and provides a look at future plans.

2.0 SYSTEM ARCHITECTURE

The proposed system architecture is illustrated in figure 2.

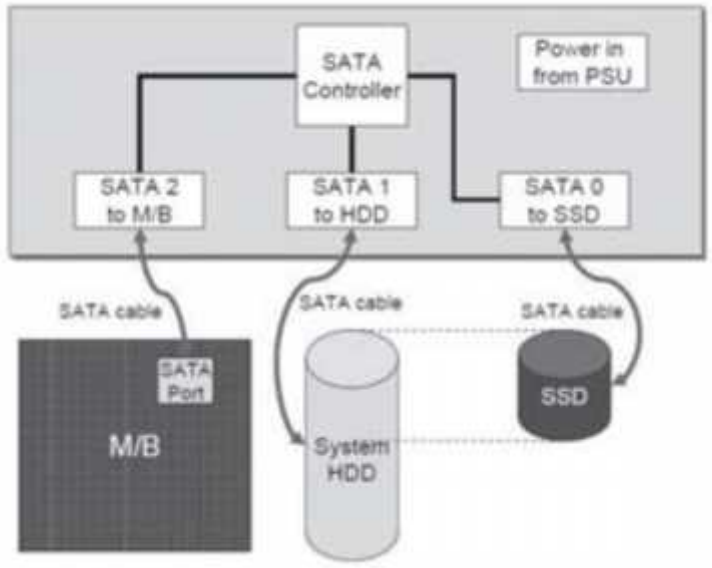

Figure 2 System Architecture

We used a hardware controller to connect SATA SSD with the system HDD. There are two types of the NAND Flash memory structures. One is Single Level Cell (SLC) and the other is
Multi Level Cell (MLC). For the SLC structure, each NAND Flash memory unit only can store one bit, but the MLC can store two or more bits. The MLC can store more
information than the SLC at a cost lower than the SLC, but the MLC's access speed is lower than the SLC's due to the MLC's need for a controller to deal with the several levels, the ECC function and decoding the information in a single cell. We used a 16GB Kingston SSDNow S100 with Sequential read throughput — 230 MB/s read, Sequential write throughput — 75 MB/s write. This kind of architecture can be applied in the system which is connecting the HDD to the SATA interface. There are two individual storage devices in our design, both managed by the OS: the SATA SSD and the SATA HDD. The OS spreads read accesses to the SSD flash because it is faster and when it comes to write it tends to go to the HDD.
We show the comparison of the performance of storage devices. The first device is a single HDD, the second is hybrid HDD device which consists of a normal HDD and the SATA SSD. We use fio [7] benchmark and disk utility benchmark to assess the performance of the devices.

3.0 EXPERIMENTAL RESULTS

In this section we will present the results of the experiment. Figure 3 represents the progress of the reading process in time in both cases, when is connected only the hard drive and in the other case of studying when SSD is connected via a disk controller. The process of reading is realized by some parameters previously defined as job - file. Size on disk available for reading is approximately 150 GB. Disk SSD has a capacity of 16 GB.
Figure 4 represents the progress of the writing process in time also in two cases. Is to be identified vertical scale used in two graphs which differ significantly.

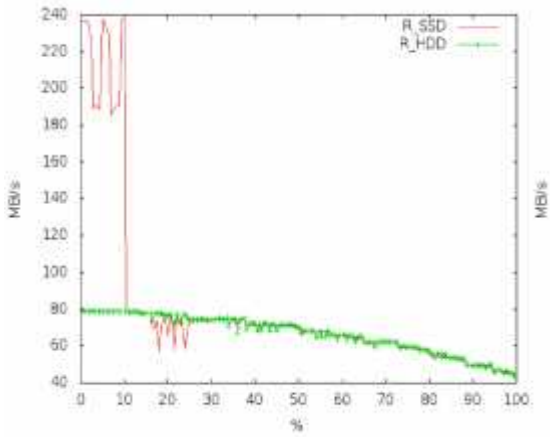

Figure 3, Reading Process

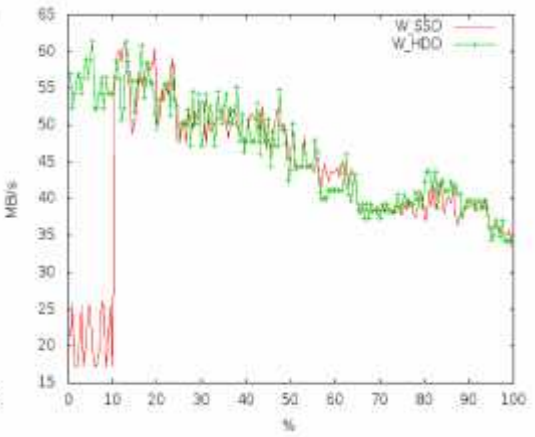

Figure 4, Writing Process

3.1 DISCUSSIONS

In terms of latency, bandwidth and performance in generally, our hybrid architecture with Solid State Disk and traditional Hard Disk is superior than the architecture used in well known systems to date. We can say without any doubt that any application which requires random access of reading and writing data, are good candidates to be used with hybrid technologies. In case of an application that doesn't require or support caching techniques this hybrid architecture proposed is better than traditional case but not as good as pure SSD architecture. However we remind that because of the high price per bit of Solid State Disk nobody, not yet, can choose pure SSD architecture as the only choice.
In every hybrid architecture which is native or with two disks separated (as in our architecture), the disk I/O performance benefits from the fast read access of the solid-state disk, precluding write operations from the degrading flash memory performance.

Referring to the data in graphs generated by the benchmark we can see clearly that the process of reading with hybrid architecture 'installed' has higher performance in terms of throughput. In the case of hybrid technology reading starts with a throughput 230 MB/s. While in case we use only Hard Disk Drive throughput does not exceed 80 MB/s. Since

SSD memory has a capacity of 16 GB after reading the entire information graph becomes stable and comparable to the case of using the hard disk.
To be evaluated is also the process of writing which does not have performance as we would like to be. We should in this case to consider the fact that SSD technology has to be more careful about writing process including optimization in the cells of DRAM memory (flash memory).

4.0 CONCLUSION

In this article we aimed to analyze a hybrid system through the controller which unites SSD-HDD, and using benchmarks we concluded the benefits from qualitative perspective. Being an area still under development the main conclusion is that the future will be a mix between old technology (HDD) and new technology (SSD) taking the positive effects of each. In this analysis we rely at the experimental conclusions by looking at cost-quality performance in terms of reading and writing data.

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