Understanding of Rewrite Penalty for Flash Memory SSD based High Performance Computing Real Time Systems

Sanam Shahla Rizvi and Tae-Sun Chung

Abstract— **Flash memory is continuously been dominating on hard disk drives for high computing applications by last more than two decades. Currently the high capacity MLC flash SSDs are becoming center of attraction for modern real time systems to support their increasing storage and throughput demands. However, special hardware erase-before-write characteristics impose considerable performance penalty on flash storage systems. This paper evaluates the performance of modern MLC flash SSDs in their factory-fresh and used form from well known manufacturers and compares the response time and throughput results. Experimental results based on modern benchmark are provided and discussed to give the better idea to users for suitable storage devices for their real time systems.**

Index Terms—**Flash memory; high performance computing; MLC; real time systems; simulation; SSD.**

I. Introduction

Flash memory is a non-volatile solid state memory which has many attractive features such as small size, fast access speed, shock resistance, high reliability and light weight. Because of decreasing price and increasing capacity, it is becoming ideal storage media for consumer electronics, embedded systems and multimedia applications like wireless sensor nodes, MP3 players, audio equipments, mobile phones, PDAs, DVDs, camcorders, note books, laptop and personal computers [1]-[5].

Currently, the Multi-level cell (MLC) flash memory is becoming popular for large size applications due to its continuously increasing capacity, decreasing price and high throughput. MLC flash is capable to store more than one bit of data in single memory cell that increases the amount of data storage.

Flash memory array is partitioned into equal sized erase units called blocks, and each block is composed of fixed number of read/write units called pages. Every page has two sections, data area and spare area. The spare section is used to store the metadata about data in data area. Flash memory has three kinds of operations: page-read, page-write and block-erase. The sizes of pages and blocks differ by product.

Even though flash memory has many attractive features, it does not support in-place-update operation due to its erase-before-write characteristics [6]. For updating data on any memory page, system moves large amount of stored data from block containing modifying page to main memory and erases the complete block to rewrite the revised data. Thus, on every update, costly data migration and lengthy erase operation highly degrade the overall system performance. Further more, erase-before-write hurdle increases with time when memory is exhausted and there is not enough space remaining to store future data. In that case, system triggers frequent erase operations on memory blocks to clean obsolete data for providing free space to new data. This process again degrades considerable system performance in terms of response time and throughput.

Previous researchers have provided many remarkable flash based system architectures and layer designs as [1]-[5],[7]-[15]. However, very few schemes particularly addressed the MLC features and challenges as [16]-[18]. In our knowledge, there is not any research presented before that did not append their in-house developed software modules and demonstrated the evaluations only on market particulars expect the recently presented simulation based paper [19]. However, the research in [19] does not consider the rewrite penalty over storage systems and only compares the throughput performance between flash SSD drives and hard disk drives.

This paper evaluates the performance penalty on rewrite operation for the flash drives in their factory-fresh and used form from two well known manufacturers on their market specifications. Further more the simulation results for response time, data throughput and CPU utilization are discussed for fair evaluation of storage mediums to give the choice to users to select the right product that better suits their storage needs.

II. Performance Evaluation

A. Simulation Methodology

An experimental test-bed is build with four modern MLC flash SSDs from Samsung and Intel manufacturers. Table I compares the specifications of all four, Samsung A [20], Samsung B [21], Intel A [22], and Intel B [23] drives.

First test is applied to compare the obtained response time from Samsung factory-fresh devices with empty pages and used devices after applying 4K random writes.

Second test is applied on all four drives to evaluate the throughput performance. HD Tach v3.01 [24] benchmark is used to determine the sequential read speed, random access speed, interface burst speed and CPU utilization of the drive where burst throughput is the speed that data can be accessed from the drive's read-ahead memory register. This measures the speed of the drive and controller interface. To demonstrate the performance effectiveness, benchmark is executed three times and averaged the obtained results.

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TABLE I: THE ARRANGEMENT OF CHANNELS

	Samsung A	Samsung B	Intel A	Intel B
Density	256GB	256GB	32GB	80GB
Max. Reads	220MB/s	220MB/s	250MB/s	250MB/s
Max. Writes	200MB/s	200MB/s	170MB/s	70MB/s
Endurance Cycles (typ.)	10,000	10,000	100,000	10,000
MTBF(Hours)	1,000,000	1,000,000	1,200,000	1,200,000

B. *Experimental Results*

Fig. 1. shows the results in unit of milliseconds obtained by first test where response time of Samsung A and B factory-fresh drives with empty pages and used drives after applying 4k random writes is compared. As figure shows, both drives reduce their response time and degrade their performance overall 93% after being used due to block rewrite penalty.

Fig. 2 demonstrates the results in unit of MB/s achieved by second test using HD Tach benchmark where Intel products deliver by far the more volume 23% for average sequential read and 2.5% for read burst throughput. At the same time, Intel A and B products reduce system performance by consuming 24.5% and 14.8% more CPU utilization respectively than Samsung drives. However, all four derives optimize random access data throughput with 0.1ms.

III. CONCLUSION

To support the ever increasing data volume of modern real time applications, users are always being in search of peak capacity storage devices with reasonable price. This trade-off is started been decreasing by new MLC flash drives. Therefore, MLC flash becoming ideal storage media for real time systems due to its attractive features like large capacity and high throughput in low cost. However, flash memory suffers by erase-before-write characteristic. This drawback imposes performance penalty on high throughput demanding systems. However, manufacturers are continuously trying to reduce this hurdle and provide good features to improve overall system performance.

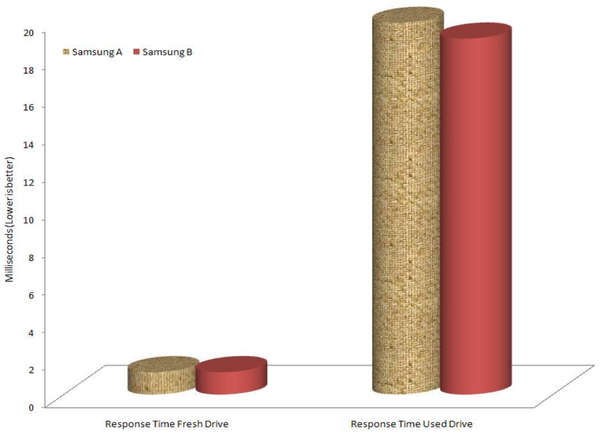

Fig. 1. Response time of fresh and used drives in unit of Milliseconds (Lower is better).

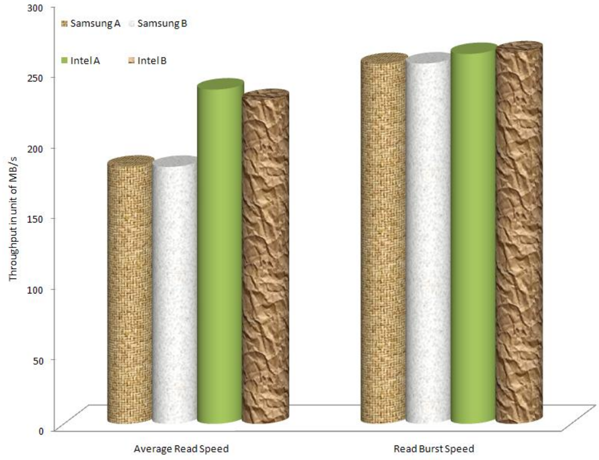

Fig. 2. HD Tach: Average read and read burst throughput in unit of MB/s.

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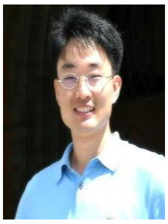

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