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# SURVEY ON RELIABILITY OF SOLID-STATE-DRIVE BASED STORAGE SYSTEMS

Jayashri H, Dr.Sheela S V

[1]*PG student Department of Information Science and Engineering, BMSCE*
[2]*Associate professor, Department of Information science and engineering BMSCE*

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**Abstract—***Solid-state-drives based RAID is a group of solid-state-drives, which are protected by using the parity disks. If the program and erasecycles raises, the stoppage probability in solid-state-drive alsoraises. Depending up on how the parity allotmentis happening among the solid-state-drive, the reliability of the solid-state-drive gets changes. Evenly or unevenly we can allot theparities among solid-state-drive based RAIDs. In even parity allotment, all the solid-state-drives tire out with the same rate which escort to simultaneous failure of solid-state-drives. In odd parity allotment, either one of thesolid-state-drive in RAID might get fail prior to any other drive. The problems such as Simultaneous failure of solid-state-drives andfailure of one of the solid-state drive prior to any other drive will become the drawbacksof solid-state-drive with RAID as they reduce the reliability of solid-state-drives based RAIDs. These drawbacks can be overcome by using Hybrid RAID. This Hybrid RAID alters the allotment of parity when the number of P/E cycle reaches to some predefined limit.*

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***Index Terms****- Solid-state-drive, RAID, Reliability, P/Ecycle (program/erase)*

## I. INTRODUCTION

Solid-state-drivemakes use of NAND based flash memory, which is a type of non-volatile memory that has the capability to store the data even after the power goes off. The benefit of solid-state-drive over hard disk drives is higher Input and output performance, further reliability, less power consumption [6].
The solid-state-drives are used for multi scale computing of big data driven applications. The development of multi-core processor has the performance gap between CPU and storage devices due to slow mechanical positioning nature of HDD's. The performance optimization and the reliability of storage system can be achieved by using RAID architecture and flash based solid-state-drive which [3].

Single solid-state-drive cannot fulfill the performance and reliability of storage systems. Furthermore failure of Solid-state-drives exists in the controller silicon which renders the Solid-state-drive unusable. Error correction code is used by solid-state-drives to protect the data. The protection is restricted since the bit error rate raises as solid-state-drives issues more erase operations. Thussolid-state-drive with RAID algorithm is required to build high performance and reliability of solid-state-drives based storage systems. Using parity bases RAID that is RAID 4 and RAID 5 the original data is encoded in to parities then data and parities are stripped across multiple Solid-state-drives to provide storage redundancy against failure. The goals provided by the RAID are, first performance is raised by using stripping and second fault tolerance is increased by using redundancy.
Make use of solid-state-drives in RAID can escort to these main reliability challenges: 1)The number of P/E cycles is restricted for each solid-state-drive which is called as the survival limit, 2) the dependence between the number of P/E cycles and bit error rates in Solid-state-drives leading to variation in the reliability of Solid-state-drives in RAID, 3)based on the workloads each Solid-state-drives has different number of P/E cycle in different instant of time resulting in time varying bit- error-rates, which shows that: 1.In Solid-state-drives based RAID system, limited survival is the main concern , and 2) different bit error rates of solid-state-drives in RAID systems and also time-varying bit error rates in each solid-state-drives are 2 main difficulties in modeling the reliability of the solid-state-drives -based RAID systems.
Applying RAID algorithms to solid-state-drives is crucial due to the special characteristics of flash-based solid-state-drives, such as the erase-before-write and wear-out problems
The feature of solid-state-drive: In these years, solid-state-driveshave been broadly used in many applications becauseof their advantage,low power consumption, low access latencies and high performance and further reliability. solid-state-drivesrely on NAND flash memory to store user data. NAND based solid-state-driveshas the drawbacks such as out-of-place update and asymmetric readwrite operations. The characteristic of flash memory does not allow rewriting a data block unless the corresponding memory block is erased. Erasing before each write operation imposes significant erase cycles to solid-state-

 

drives. In other way, NAND flash memory suffers frominherent restricted number of erase cycles. After specific number of erase cycles for every block, the block would wear out, and stored data may not be reliable anymore which is referred as survival limit. Some advanced algorithms such as wear-leveling address in which the survival limit of solid-state-drives by evenly distributing erase cycles in all blocks. Some other managing methods such as garbage collection may intense the wear-out of blocks. By raising the write-intensive applications, survival limit becomes more pronounced, and requires more consideration

Parity disk is ahard disk drive, the flash wear-out and erase-before-write problems caused by the parityupdate operations are avoided. Moreover, the mirroring buffer improves the small random write performance. Our reliability analysis shows that the reliability of hybrid raid with Solid-state-drives is better than that of either a HDD-based or a solid-state-drives -based disk array of the same capacity.

Dispute of applying RAID algorithms to solid-state-drives: 1)solid-state-drives-based disk arrays from the point of reliability, performance and cost, however, has the three main challenges: 1). RAID0, which does not have data redundancy, is not reliable for solid-state-drives -based disk arrays. 2). RAID1 and that duplicates the data redundancy are too expensive for solid-state-drives-based disk arrays to be cost-effective because of the high cost/GB

Motivation: Failures of solid-state-drives typically occur in the controller silicon rather than the flash device as indicated by recent studies. Thus it is necessary to apply RAID algorithms to solid-state-drives for applications that require less power consumption, high performance and high reliability. However, simply applying RAID algorithms to solid-state-drives can be nontrivial, as discussed in the earlier section. The limitations of solid-state-drives must be addressed when designing solid-state-drives-based disk arrays. Solid-state-drives with RAID increases the performance and reliability based on distribution of parities among the Solid-state-drives, which can be done by allotting parities evenly or unevenly. Solid-state-drives with even parity allotment would wear out with the same rate, which causesconcurrentfailures of solid-state-drives. Solid-state-drives with uneven parity allotmentleads to failure of one of the solid-state-drivesin RAID .Both these two disadvantages, i.e., the concurrent failures of Solid-state-drives and the quick failure of one of the solid-state-drives, reduces the reliability of solid-state-drivesbased RAIDs. Hybrid RAID is one of the solutions to enhance performance and reliability by using both even parity and uneven parity allotment[2][7].

The main idea of Hybrid RAID is to merge the even and uneven parity allotment. Hybrid RAID initially allots the parity units among disks evenly. When the number of P/E cycles reaches to a predefined number, Hybrid RAID changes the parity allotmentfrom even allotmentto uneven allotment. The point where Hybrid RAID changes from even allotmentto uneven allotmentis called switching point.

## II. APPROACHES

The first approach is use of solid-state-drive instead of hard disk drive. A functionality of solid-state-drivesissame as that of hard drive, but data is stored on interconnected flash memory chips that retain the data even when there's no power Present. These flash memory chips are typically faster and more reliable.

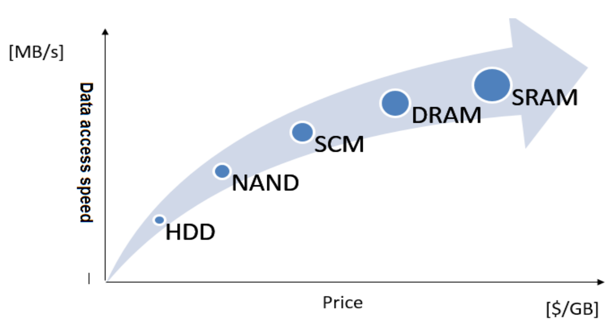


Fig.1. Memory Hierarchy

Solid-state-drives are consequently more expensive than HDD.Singlesolid-state-drives cannot satisfy the performance and reliability of storage systems. Moreover failure of Solid-state-drives occurs in the controller silicon which renders the solid-state-drives unusable. Solid-state-drives use error correction codes to protect the data; the protection is limited since the bit error rate increases as Solid-state-drives issue more erase operations. Thus applying RAID algorithms to solid-state-drives is necessary to build high performance and reliability of Solid-state-drives based storage systems. The second approach is Raid algorithms to solid-state-drives .First, RAID0, there is no data redundancy so not reliable for solid-state-drives-based disk arrays Second, RAID1 which stores the duplicate data but these are too expensive for solid-state-drive-based disk arrays.

 

Third approach is RAID4 in which parity block is stored in one disk i.e. parity disk, which leads to increase in the number of P/E cycles of that disk. Using paritybased RAID, the original data is encoded into parities, and the data and parities are striped across multiple solid-state-drivesto provide storage redundancy against failures. Moreover, small writes to solid-state-drivesmakes the poor performance which in turn makes the write performance worse for the parity-based disk arrays.

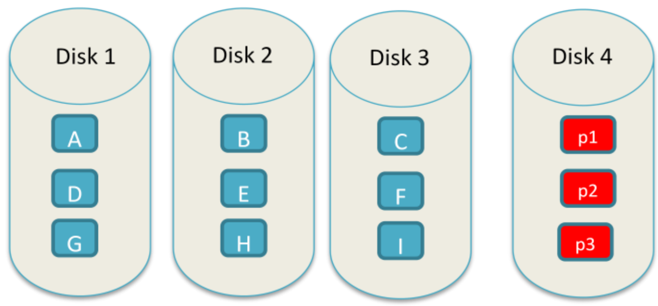


Fig.2. RAID4 (blocked stripped and dedicated parity disk)

Fourth approach is RAID5, in which parity block is distributed among all the disks. In RAID5 by distributing parity block among datadisks evenly, the P/E cycles are distributed among the disks with the same ratio. In solid-state-drivesbased RAID5, reconstruct lost symbols for one device failure. A

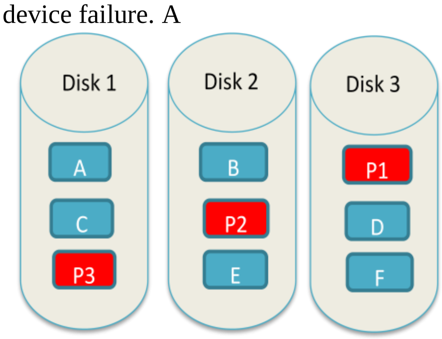


Fig.3.RAID5 (Block stripped and distributed parity)

RAID5 array is divided into many stripes, each of which consists of one parity symbol that is encoded from the data symbols in the same stripe. Solid-state-driveswith even parity distribution would wear out with the same rate, which causes simultaneous failures of solid-state-drives which degrades the performance and reliability.

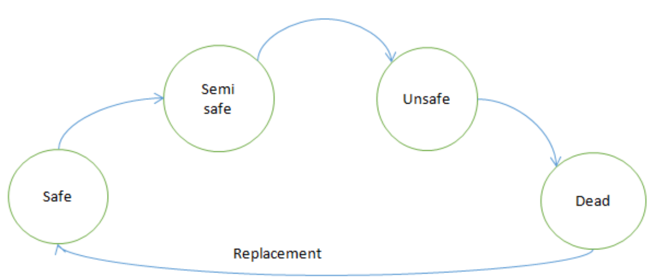


Fig.4.The state diagram of solid-state-drive in different zones.

The following are the four zones used to define the duration of
Solid-state-drives operation

- Safe zone: The bit error rate of solid-state-drive is near zero so we can assume the reliability of solid-state-drive is close to one in the safe zone.
- Semi safe zone: The bit error rate of solid-state-drive is not equal to zero but still it is low so the read and write operations are high enough for solid-state-drive. The reliability of the RAID system decreases if the number of solid-state-drivego away from safe zone to semi safe zone

 

- Unsafe zone: The bit error rate of solid-state-drive is high so the reliability drastically decreases as compared to the unsafe zone.
- Dead zone: solid-state-drive is not reliable in this zone so it gets replaced with newsolid-state-drive.

In Hybrid RAID two metrics are used to evaluate the
reliability of solid-state-drive base RAID by considering the above zones.

1. Depending on the duration of safe time: Here solid-state-drives of RAID systems are kept in the safe zone. The duration of safe time is the time when the 1st solid-state-drivego away from the safe zone. The reliability is high as long as the solid-state-drives are in the safe zone.
2. depending on the variance of the dead time: Variance of the dead time is calculated by taking the difference of the dead times of solid-state-drives.

The approach Hybrid RAID is used to overcome reliability issues occur during the above approaches in which even and uneven parity distribution are merged. Hybrid RAID initially distributes the parity units among disks evenly. When the number of P/E cycles reaches to a predefined number, Hybrid RAID changes the parity distribution from even distribution to uneven distribution. The point where Hybrid RAID changes from even distribution to uneven distribution is called switching point.

## III. ADVANTAGESOFHYBRIDRAIDOVEROTHERRAIDS

Hybrid RAID provides higher reliability in comparison to the traditional RAIDs by mitigating the weaknesses of traditional RAIDs in two ways: 1) it postpones the 1st failure in the RAID by holding the disks in the safe zone for longer time than uneven distributed parity RAIDs i.e. RAID4 2) it prevents from simultaneous failures by increasing the variance of dead time among disks as compared with even distributedparity RAIDs, i.e. RAID5 [3].

Hybrid Raid uses the following steps to reduce the simultaneous failure and postpones the first failure of the disk:

1. Parity units are allotted evenly among all the disks as long as no disk goes away from the safe zone. Disks in the safe zone are high enough to provide the high reliability in raid system.
2. The parity allotment policy is changed if the disk go away from the safe zone, they are now stored in a victim disk, leads to a faster wear out of victim disk compare to other disks. The disks that enter the unsafe zone can be selected as victim disk during the operation .When the victim disk reaches to endurance limit, it can be substituted with fresh disk.
3. The system will switch back to first step i.e. even parity allotment, when all the disks of the array are substituted with fresh disks [1].

The challenge for Hybrid RAID is switching point, this switching point is the time when it leaves the safe zone.

## IV. CONCLUSIONS

Hybrid RAID is the approach used to enhance the reliability of solid-state-drive based storage systems.HybridRAID uses the even parity distribution and uneven parity distribution. Depending on the P/E cycles of solid-state-drive, the parity distribution changes in Hybrid RAID. Initially even parity distribution is applied to the hybrid RAID among the disks to raise the safe time duration and also used for postponing the first failure. When the number of P/E cycles reaches to its defined value then hybrid RAID switches to the uneven parity distribution. Due to this change the simultaneous disk failure in the system gets avoided. Hy-RAID with other RAID approaches is compared by using the metrics 1. depending on the safe time duration 2. depending on the variance of dead time.

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