Reliable Energy-Aware SSD based RAID-6 System

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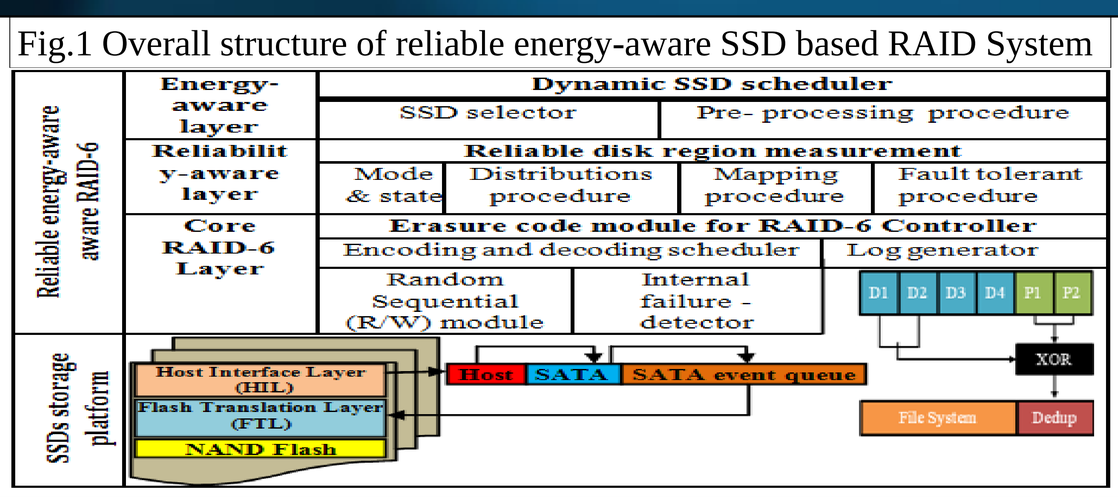
Motivation and goals

- **Challenges of SSD markets deal with**
- Breakthroughs in terms of energy consumption, reliability, performance of SSDs
- Achieve optimal energy consumption for HDD, SSD and large storage systems
  - ✓ Dynamic voltage measurement
  - ✓ Auto power management
  - ✓ Compiler directed energy optimization
- Performance and energy use of RAID systems with various type SSDs
- Reliability system and some criteria
  - ✓ Cost for replication based schemes are expensive
  - ✓ Erasure codes considering power management
  - ✓Need to measure repair transition rate
  - ✓ Average data loss during *N* iterations of IO operations on critically exposed sectors
  - ✓ Lower utilization level produces lower failure rates

- **Goals**
- Proposes an energy aware algorithm
- Model which enable SSDs to increase the performance and decrease the level of power consumption

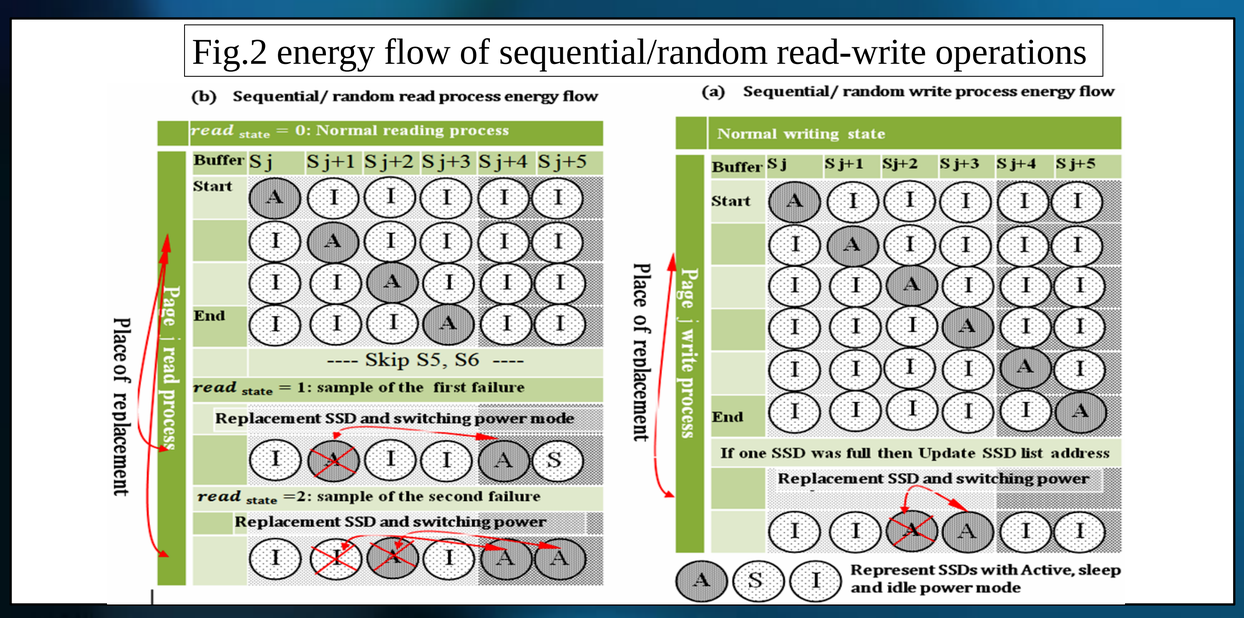
Proposed RAID System

Fig.1 Overall structure of reliable energy-aware SSD based RAID System



- Core layer in the RAID-6 controller
  - ✓ Encoding and decoding scheduler
  - ✓ Random and sequential read and write modules with an internal failure detector using erasure codes
  - ✓ Traces are updated using the log generator
- Reliability-aware layer
  - ✓ Procedures for prediction of SSD reliability
    - ➢ Use erasure codes generated from the core layer
- Energy-aware layer
  - ✓ Pre-processing procedure
    - ➢ Initialize the reliability measurement and utilization level
  - ✓ SSD selector and pre-processing procedure.
    - ➢ Set the status of selected SSD power mode to idle-sleep-active via imported traces
  - ✓ Dynamic SSD scheduler
    - ➢ Visualize the statistics of SSD energy consumption
    - ➢ Update the power mode into idle, sleep or active.
- Host interface layer, flash translation layer and NAND flash chips.

Fig.2 energy flow of sequential/random read-write operations



- ▪ Energy flow of sequential/random read-write operation using proposed model
  - ✓ Data pages are segmented into large chunks
  - ✓ Use power switching of SSDs after writing of each chunk is done.
    - ➢ After reading-writeing of current chunk in SSD ***Sj***, IO operation of next chunk is performed in SSD ***Sj*+1**
    - ➢ Measure SSD reliability and choose the parity SSD ***Sj*+4** and ***Sj*+5** with less utilization level.
  - ✓ Read operation needs to access four disks from ***Sj*** to ***Sj*+3** sequentially and skips two parity SSDs
    - ➢ When one disk fails, 1st parity SSD is "active" and 2nd parity SSD is in "sleep"
    - ➢When two disk failure occurs, both SSDs are in "active" mode
  - ✓ Write operation requires accessing six SSDs using power switching modes

Table 1: pseudo code of reliable energy-fault aware algorithm

Table 1: reliable energy-fault aware algorithm

```
1. Generate SSDs matrix
2. Initialize the estimated power modes and Set current mode as "idle"
3. Initialize utilization level and average data loss
4. Initialize Δ t_delay
5. Define Page with Chunk Matrix: P [p0, p1, p2, p3, p4, p5]
6. Define Page address : Pa[a0, a1, a2, a3, a4, a5]
7. if (current event == read)
8.   Initialize Pa[] list
9.   While ( Not end of Pa [] list) then
10.  If normal state then Set read state = 0
11.    Switch current SSD power mode from "idle" to "active"
12     read data in Pa[0]...Pa[3] and store them into current Page P[]
13.    Switch current SSD power mode from "active" to "idle"
14.  If first failure happen then read state =1, Increase t rebuild
15.    Set power mode of 1st parity as active and 2nd parity as sleep
16.    Set read state = 0
17.    Replace the failed SSD with 1st parity, Stop t rebuild
18.  If Second failure happen then Set read state =2,Increase t rebuild
19.    Set both 1st and 2nd parity SSDs power mode as active
20.    Set read state = 0
21.    Replace the failed SSD with 2nd parity, Stop t rebuild
22. if (current event == write )
24.    Create Pa[]
25.    While ( Not end of Pa[] list) then
26.      Switch the SSD power mode from "idle" to "active"
27       Write data in Pa [0]...Pa [5] into corresponding SSDs
28.      Switch the SSD power mode from "active" to "idle"
29.      if SSD corresponding to Pa[] is full, then update Pa[]
30.  Estimate total power consumption(E Total)
```

Preliminary Result

- ▪ Estimate power consumption manually for each SSD
  - ✓ Multiple power modes - waken(1.2w), active(2.4w), sleep(0.06w), idle(0.5w) and off
  - ✓ Average delay time between switching power mode smaller than that of traditional model
  - ✓ Dynamic SSD scheduler can activate each disk adaptively and minimize time of waken mode of SSDs.
  - ✓Average data loss is calculated based on the Markov model and utilization level
- SSD energy consumption for busy sever-like workload
  - ✓ The estimation period is 2 sec.
  - ✓ 60% energy saving for read operation and 48% for write operation compared to the general model
  - ✓ We can see that the proposed model significantly reduces the energy consumption by controlling the power switch of SSDs adaptively.

Table 2: SSD energy consumption for busy sever-like workload

	Power Modes	Idle	Sleep	Active	Waken	Total
Proposed Model	Read operation	0.5w*0.8s	0.06w*0.2s	2.4w*0.8s	1.2w*0.2s	2.572w
	Write operation	0.5w*0.4s	0.06w*0.2s	2.4w*1.2s	1.2w*0.2s	3.332w
General model	Read operation	0.5w*0.4s	-	4.8w*1.2s	1.2w*0.4s	6.44w
	Write operation	0.5w*0.4s	-	4.8w*1.2s	1.2w*0.4s	6.44w

Contribution

- Improved approach for periodic estimating the energy consumption of SSDs
- The reliability estimation considered to enhance the energy efficiency on the SSD based RAID-6 system
- A layered architecture for reliable energy-aware RAID-6 system
- Reduce energy consumption of parallel access of SSDs
  - ✓Dynamically switching of SSD power modes among active, idle, waken and sleep
  - ✓ Allowing one of parity SSDs in safe zone to be sleep mode
  - ✓ Segmenting data pages into large chunks
  - ✓ Using the power switching of SSDs after writing or reading of each chunk is done.
- Reduce energy consumption during active mode
  - ✓ Activating SSDs sequentially and minimizing delay time of power switching of SSDs
  - ✓ Avoiding repetitive accessing of same SSD by using large chunks
  - ✓ Increasing number of disks in idle mode

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