Outline

Problem Definition
- SSD properties
- About FTL and Wear-Leveling

Related Work
- A low cost algorithm with minimized overhead – Lazy WL
- Improving Wear-Leveling by Proactively Moving Static Data

Proposed Method
- Regional Wear Leveling
SSD properties

• Shock resistance
• Energy conservation
• Random-access performance
• Erase before write
• Limited number of erase of each block
Wear Leveling

- Try to balance the erase distribution

(a) No wear leveling or wear leveling has no effect
(b) Wear-leveling activities introduce too much traffic
(c) The desired result. The overall lifetime is prolonged.
Wear Leveling

• Three major challenge
  ➢ Monitoring entire flash’s wear
  ➢ Algorithm tuning
  ➢ High implementation complexity
Related Work

• 1) Lazy Wear Leveling
  – Li-Pin Chang, LCTES\(^1\), April 2011
• 2) Static WL by proactively moving static data
  – Yuan-Hao Chang, IEEE transaction, Jan 2010

\(^1\) Languages, Compilers, and Tools for Embedded Systems
Figure 4. Physical blocks and their erase recency and erase counts. An upward arrow indicates that a block has recently increased its erase count.
Lazy wear leveling Properties

- Store wear info in flash, not in RAM
- Select a good threshold for good balance between overhead and evenness
- Utilize address mapping info available in the sector translating table
- Adaptive self tuning!
Lazy Wear Leveling

Figure 14. History of changes in standard deviations when using lazy wear leveling and static wear leveling.
Lazy wear leveling

- Elder block erase recency becomes high, the Lazy WL Re-locate logical blocks with low update recency blocks!

**Figure 15.** The final distribution of blocks’ erase counts under the notebook workload.
Types of Wear Leveling

• Dynamic
  ✓ achieves wear leveling by recycling blocks of dynamic data areas
  ✓ redirecting new writes to different physical blocks

• Static
  ✓ move static or infrequently updated data to other locations
Dynamic Vs Static

- Dynamic wear leveling alone cannot guarantee that all data blocks are participating in wear-leveling process.
  (Just move hot and free blocks)
- With the use of SWL, write endurance of the flash is increased more than dynamic.

<table>
<thead>
<tr>
<th>Item</th>
<th>Static</th>
<th>Dynamic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Endurance</td>
<td>Very long life expectancy</td>
<td>Long life expectancy</td>
</tr>
<tr>
<td>Performance</td>
<td>Slower</td>
<td>Faster</td>
</tr>
<tr>
<td>Design Complexity</td>
<td>More complex</td>
<td>Less complex</td>
</tr>
</tbody>
</table>
Flash Expected Lifetime

- Try to compare expected lifetime of NWL\(^1\) and SWL\(^2\) and DWL\(^3\)

**TABLE 1**
Settings for the Expected Lifetime Example

<table>
<thead>
<tr>
<th>Storage capacity</th>
<th>256MB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Storage block number</td>
<td>16K</td>
</tr>
<tr>
<td>Block size</td>
<td>16KB</td>
</tr>
<tr>
<td>Erase cycles per block (Endurance)</td>
<td>100K</td>
</tr>
<tr>
<td>Formatted file system</td>
<td>FAT16</td>
</tr>
<tr>
<td>Cluster size</td>
<td>8KB</td>
</tr>
<tr>
<td>Size of each entry of File Allocation Table</td>
<td>2B</td>
</tr>
<tr>
<td>File size</td>
<td>16MB</td>
</tr>
<tr>
<td>File cluster number</td>
<td>2K clusters</td>
</tr>
<tr>
<td>File block number</td>
<td>1K blocks</td>
</tr>
<tr>
<td>Data transmission rate</td>
<td>0.1 MB/sec</td>
</tr>
</tbody>
</table>

\(^1\) Non Wear Leveling  
\(^2\) Static Wear Leveling  
\(^3\) Dynamic Wear Leveling
Flash Expected Lifetime

<table>
<thead>
<tr>
<th>NWL</th>
<th>DWL</th>
<th>SWL</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.09 days</td>
<td>177.77 days</td>
<td>987.56 days</td>
</tr>
</tbody>
</table>

DWL disadvantages:
- Runtime overhead
- RAM space required

SWL disadvantages:
- Both of above
- Moving static data overhead
SWL algorithm properties

• Address Translation Time

• Space Utilization

• Main memory Requirements
Moving static data proactively

• Block erasing table
  ➢ Remember each block has been erased in a predetermined time frame

• SW leveler
  ➢ Update BET when Garbage Collecting (GC) runs
Typical System Architecture
Block Erase Table

The mapping mechanism between flags and blocks. (a) One-to-one mode. (b) One-to-many mode.
SWL Experimental Results

The ratio of average block erases. (a) FTL. (b) NFTL. (c) BL.

BAN = Ban and Hasbaron’s algorithm
T = Threshold for Garbage Collecting
BL = Block Level
Regional Wear Leveling

• It’s time to change the boundaries!
• No need to save history of erasures
• Dynamically change the GC threshold
Regional Wear Leveling
QUESTIONS? ANY IDEA?