Performance Evaluation Study of NAND Flash memory-based Storage Systems

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Purpose

- Simulate complete flash memory-based storage systems

Motivation

- Ever growing use of the flash memories
- Master the performance aspects of such devices
- Very few works published so far

Methodology

- Investigate NAND flash memory characteristics (theoretically and practically)
- Study state-of-the-art flash memory-based storage systems
- Assess existent simulators
Outline

1 Background
   - Flash Memories
   - Flash memory types

2 NAND Flash Memory
   - Basic structure
   - Wear Levelling

3 Performance Evaluation
   - Benchmarking
   - Simulation

4 Conclusion
Flash Memories

Flash Memory

- Electrically Erasable Programmable Read Only Memory

Characteristics (compared to classical HDD):

- faster access time
- low power-consumption
- vibration-resistant
- compact physical size

Usage

- Embedded in mobile devices (e.g. PDAs)
- Mass-storage devices (e.g. USB flash drives, SSDs)
### Background

#### NAND Flash Memory

#### Performance Evaluation

#### Conclusion

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## Flash Memories

### Flash memory types

#### NOR vs NAND Flash

**NOR Flash memory**
- good random access performance
- execute-in-place (XIP)
- fine grain memory management
- expensive price

**NAND Flash memory**
- fast sequential access performance
- no in-place modification
- coarse grain memory management
- cheaper than NOR

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### Market segment and use

**Market segment and use**

- **Code storage**
  - Computer BIOS

- **Data (mass) storage**
  - SSD, USB flash drive
Basic structure

**operations**
- read/write at page-level
- erase at block-level

**limitations**
- erase before rewrite
- limited number of erases
  - blocks wear out

**Figure**: ONFi Specifications
Wear Levelling

**Block-mapping**
- Translates LBA to physical address
- maintains translation tables
- performed at:
  - block-level [Gal05]
  - page-level [Gal05]
  - hybrid [Kim02]

**Garbage Collection**
- distribute writes throughout the memory
- execute a cleaning policy
  - Greedy [Kawa95]
  - Cost-benefit [Kawa95]

**Implementation**
- Flash Translation Layer (FTL)
- Flash File System (FFS)
Performance Evaluation

Complexity

- Wear levelling algorithms modify flash memory performance (intrinsic)
- OS and IO interface alter flash-based storage system performance (extrinsic)
- Particular characteristics of the NAND flash memory

Approaches

- Benchmarking
- Simulation
Methodology

Context
- [Boug09] characterize context-free flash
- [Bouk09] take into account the OS and IO interface
- [Ajwa08] study flash behaviour for algorithms design

Workload
- time and space distribution of unitary IO requests (workload schemes)
- request size
- access modes
  (OS specific : e.g. buffered, direct, synchronous)
Some Benchmarking Results and Conclusions

Benchmarking Results

- Role of the OS (prefetching buffered reads) [Bouk09]
- Limitations due to the Interface (USB command size) [Bouk09]
- Impact of the access modes [Bouk09]
- Influence of the writing alignment [Ajwa08]
- Importance of the initial state [Boug09, Ajwa08]
- Sequential requests are faster than random ones [Boug09]
- Parallel IO requests do not improve the performance [Boug09]
Simulation

Motivation
- Least cost storage system dimensioning
- Study different kinds of flash-based storage devices
- Better understanding of the benchmarking results

Methodology
- Modelling of a flash-based storage system
- Theoretical and practical workloads modelling
- Simulator validation (comparison with benchmarking results)

Existents Simulators
- Flash simulator for FTL characterization [Chia08]
- FlashSim, generic SSD simulator [Kim09]
Object Oriented Design

- **Hardware classes**
  - package, die, plane, block, page
- **Software classes**
  - ftl, garbage collector, wear leveller
- Controller links hardware and software
- RAM, calculates operations response time
- SSD, interface FlashSim with DiskSim

**FlashSim Modules**

- Controller
- RAM channels
- Hardware
  - NAND Structure
- Firmware
  - Garbage Collector
  - Wear leveller
- DiskSim
Conclusion

NAND Flash Memory
- Interesting characteristics but limited lifespan
- Need extra layer to be used (FFS or FTL)

Performance Evaluation
- Workload characterization is a complex task
- Existent simulators are mainly field-related

Current Study
- Attempt to create a generic simulator
- Simulate flash-based storage devices (SSD, USB flash drive)
- Implement theoretical and practical workloads
A flash-memory based file system.

E. Gal and S. Toledo.
Algorithms and data structures for flash memories.

A space-efficient flash translation layer for compactflash systems.


Thank you for your attention.
Any questions?
FTL vs FFS

FTL

Host System

Applications

read/write (file)

operating system

File Systems

read/write (sectors)

read/program (page)

erase (block)

NAND Flash memory

FFS

Host System

Applications

operating system

File Systems

JFFS2

UBIFS

YAFFS

Blockdevices

SquashFs

CramFs

Ext2

vFAT

UBI volume

raw

NAND Flash memory

NAND Hardware driver

NOR Flash memory

NOR Hardware driver

other flash hardware drivers

UBI Volume

MTD

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