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FSMAC: A File System Metadata Accelerator with Non-Volatile Memory

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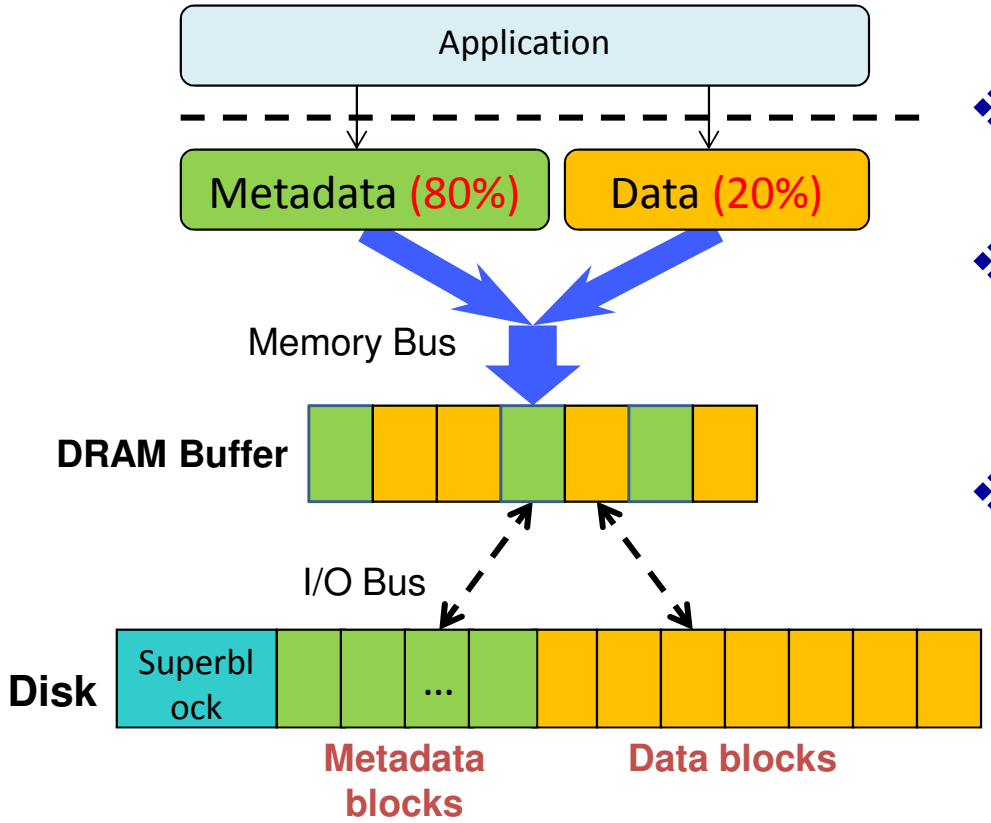
Agenda

- Introduction
- FSMAC: Design of A File System Metadata Accelerator using NVM
- System Implementation
- Evaluation
- Conclusion

1. Introduction

- File system metadata
  - Popular: which is about **60%-80%** of I/O accesses.
  - Small and random

Workloads	Data I/O(%)	Metadata I/O(%)
Varmail	15	**85**
Webserver	44	**56**



- **Metadata and data are stored /accessed in block.**
- **Metadata and data share and compete for I/O resource.**
- **Lots of fetch and flush between DRAM buffer and disk.**

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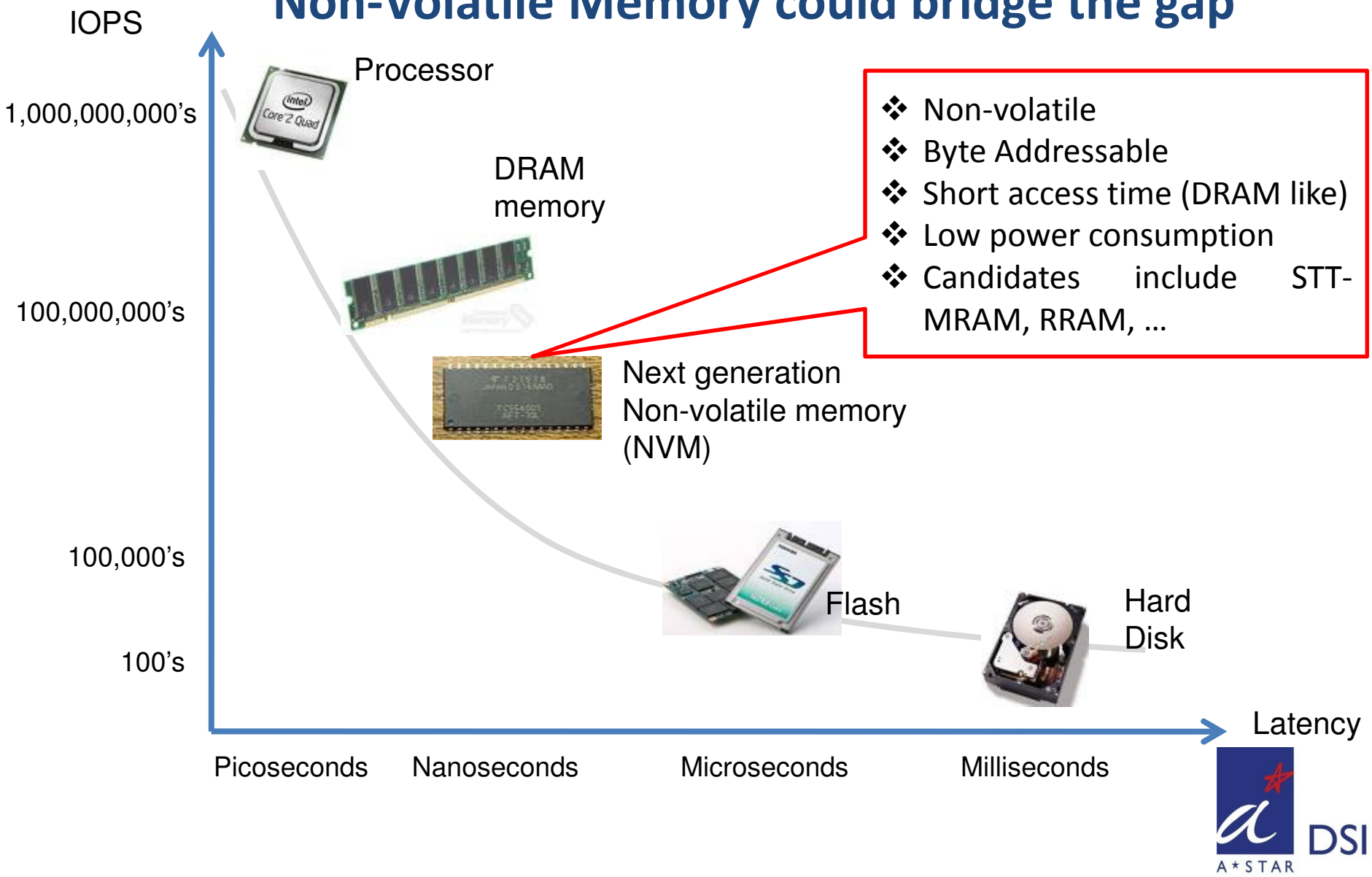
1. Introduction

Non-Volatile Memory could bridge the gap



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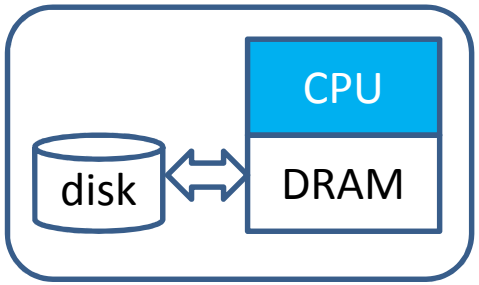
1. Introduction

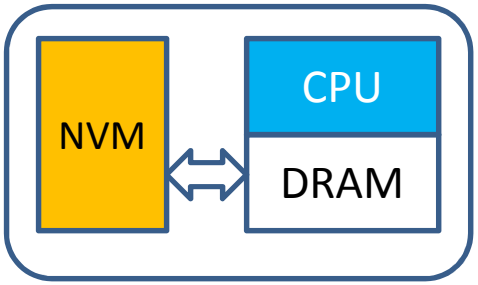
NVM System Integration



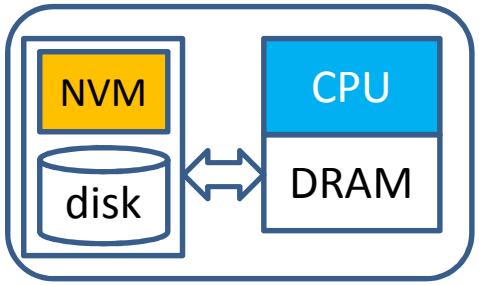
a, Current system

Slow IO bus
Long data path

NVM as Block Device



b, Replace disk



c, Hybrid disk

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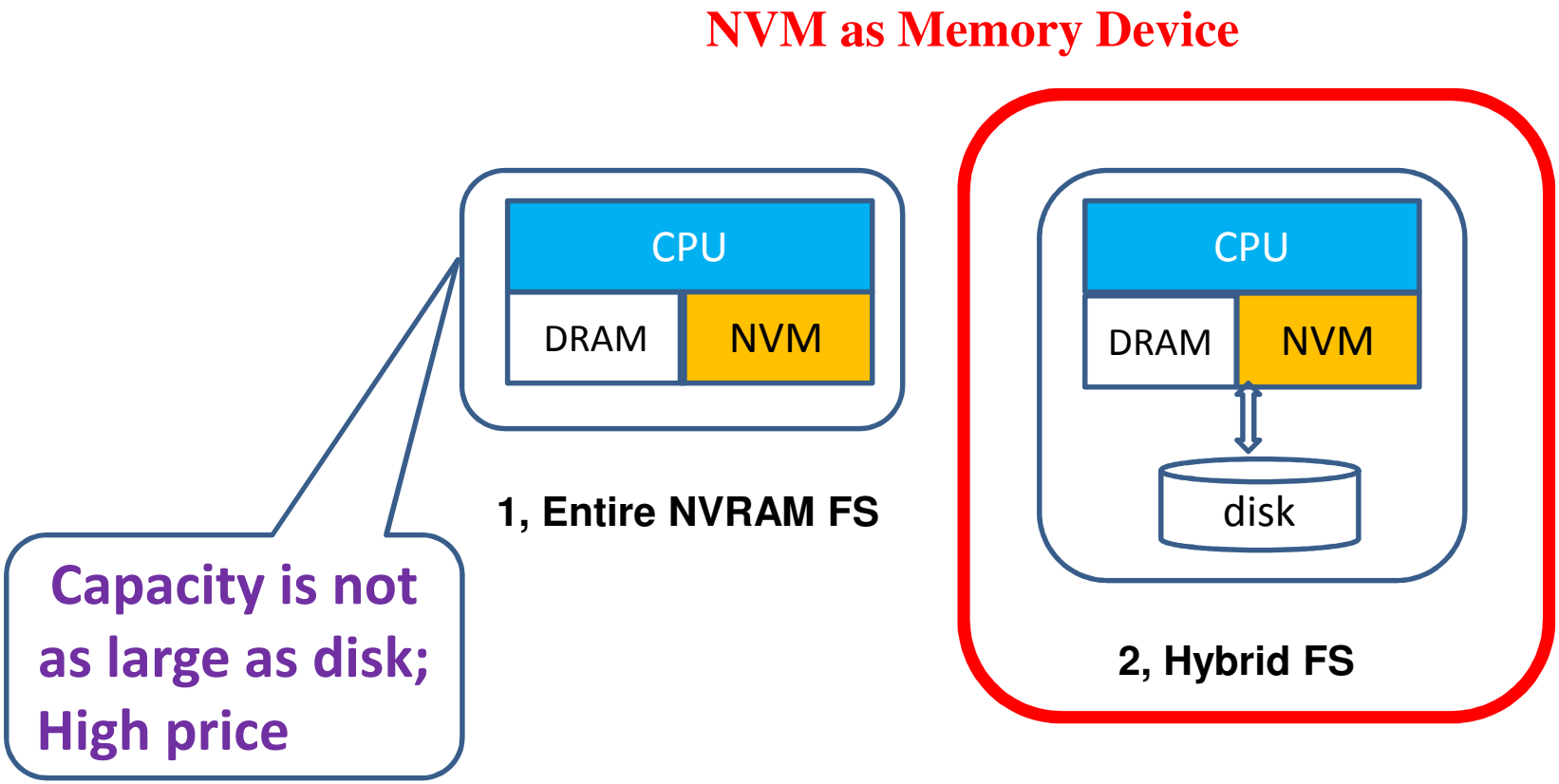
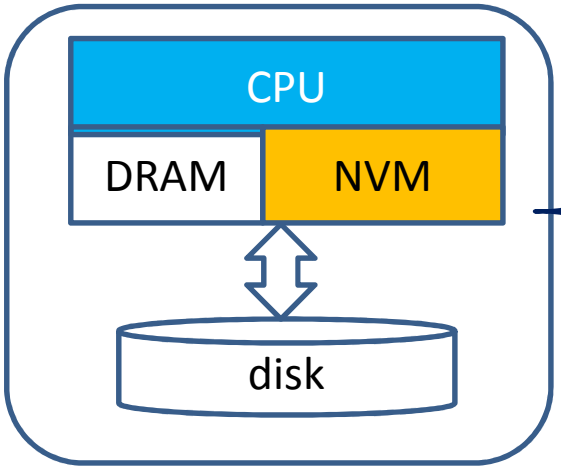
1. Introduction

NVM System Integration



1. Introduction

Current Solutions on Target System



- **NVM as persistent storage:**
  Data and metadata are separated,
  data on disk, metadata on NVM
  incompatible, difficult to porting FS data

- **NVM as buffer or non-volatile buffer:**
  replaced frequently → **lots disk I/Os**
  buffer pollution → **low performance**

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1. Introduction

Our solution——NVM as Metadata Accelerator

- NVM is used as both persistent storage and buffer for file system metadata
  - As storage for metadata, no necessary to write dirty block to disk **at runtime**, but keep original version on disk, compatible and portable
  - As buffer: in-memory computing, updating in-place, byte-addressable, but no replacement except deleting.

Compatible and portable,

Avoid frequent small random metadata IO

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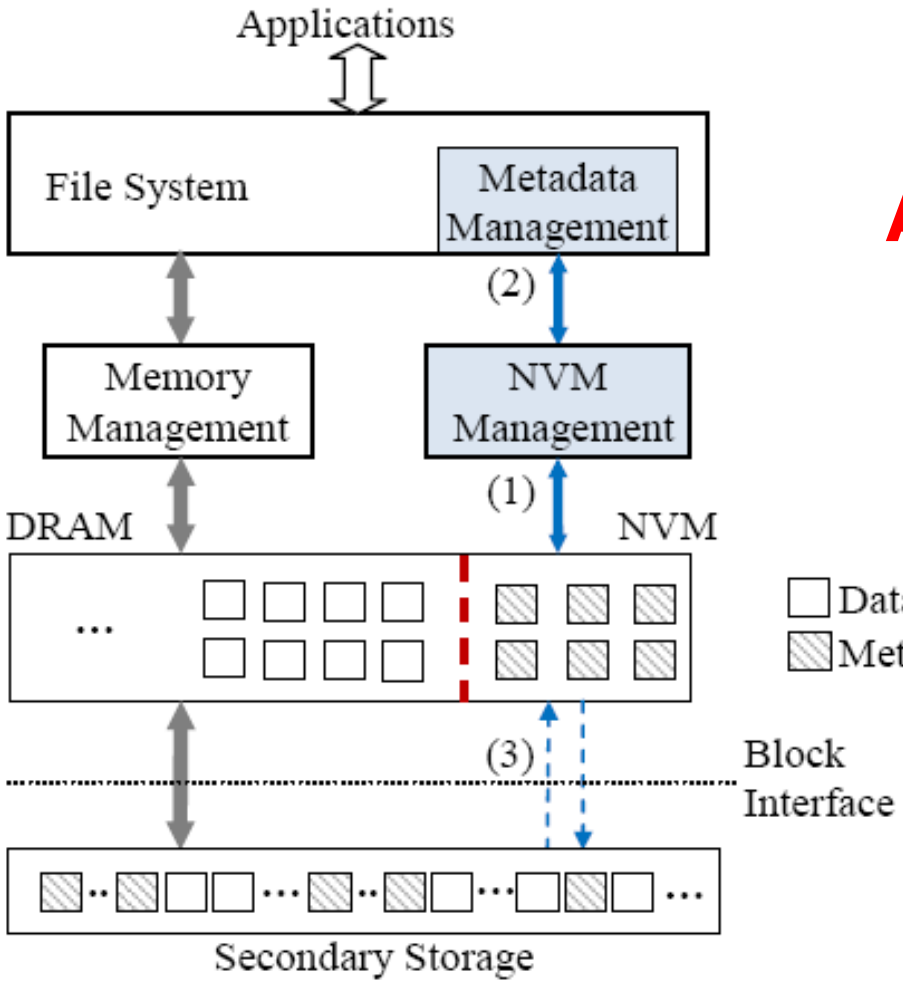
2. Design of FSMAC



Architecture:

(1)NVM management

(2)Metadata management

(3)Consistency mechanism & metadata Sync.

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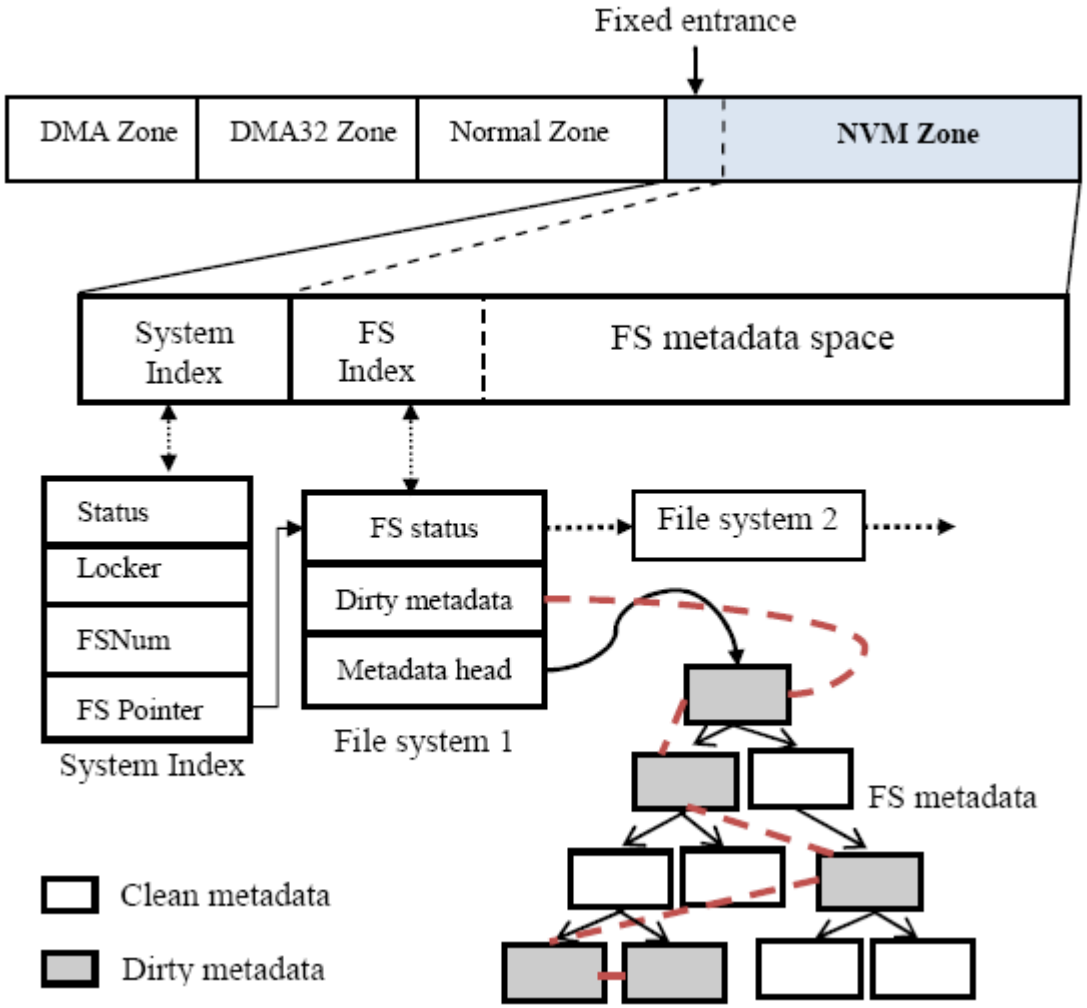
2. Design of FSMAC



NVM & metadata management

(1)A dedicated NVM Zone only for FSMAC

(2)Fixed entrance to reach all metadata

(3)Status for recovery

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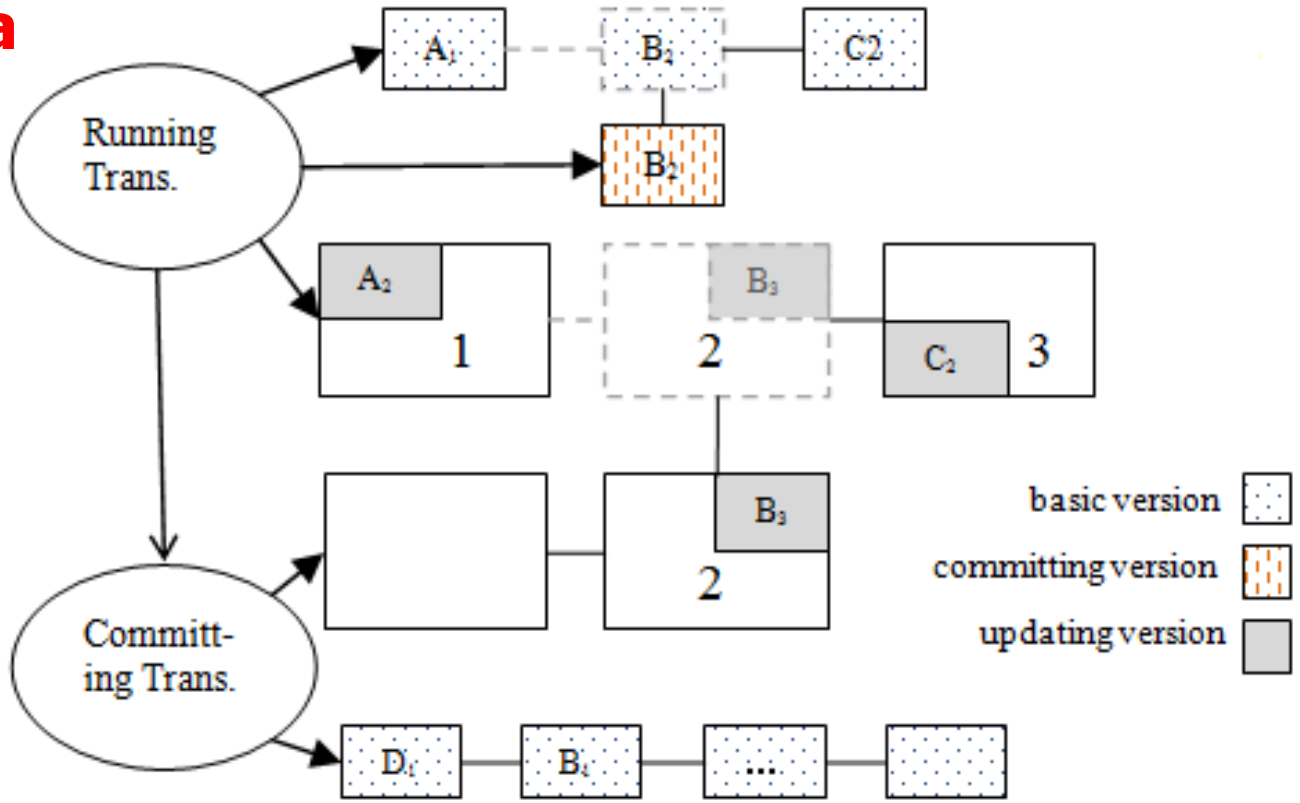
2. Design of FSMAC

Maintain data consistency



- Block is divided into fine-granularity sub-block
- Sub-block is duplicated on the first update
- Updating on committing sub-block, additional copy is reserved

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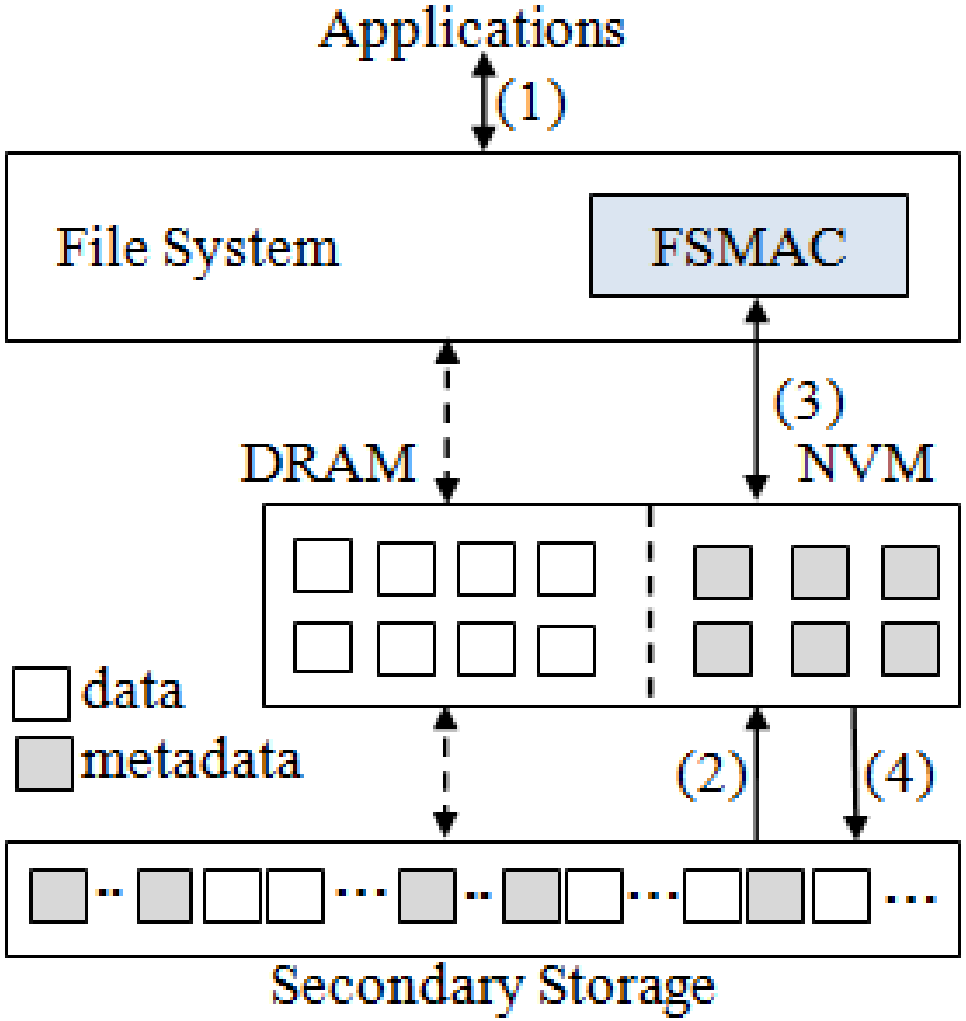
2. Design of FSMAC



Decouple metadata and data path:

(1) Request reaches and is processed normally

(2) Load metadata to NVM, never write back till unmount

(3) Flush out at unmount time with options

Data operation path is not changed

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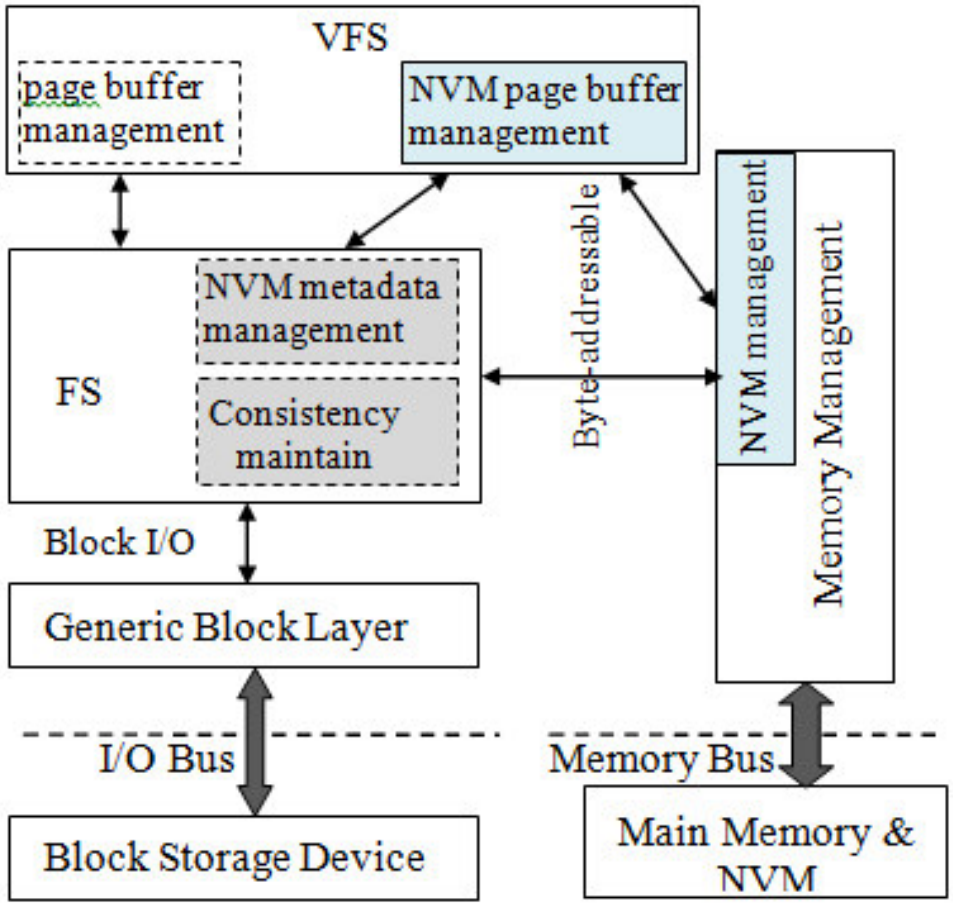
3. System Implementation



- **Two modules are added:**
  - NVM management
  - NVM page buffer management
- **Two modules are modified:**
  - metadata management
  - consistency maintain

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4. Evaluation

Evaluation Setup:

- Intel duo-core CPU
- DRAM simulated as NVDIMM (NVM)
- Intel 64GB SSD with SATA Interface
- 160GB HDD with PATA Interface
- Linux kernel version 2.6.34
- ext4 V.S. ext4 with accelerator (ext4-fsmac)

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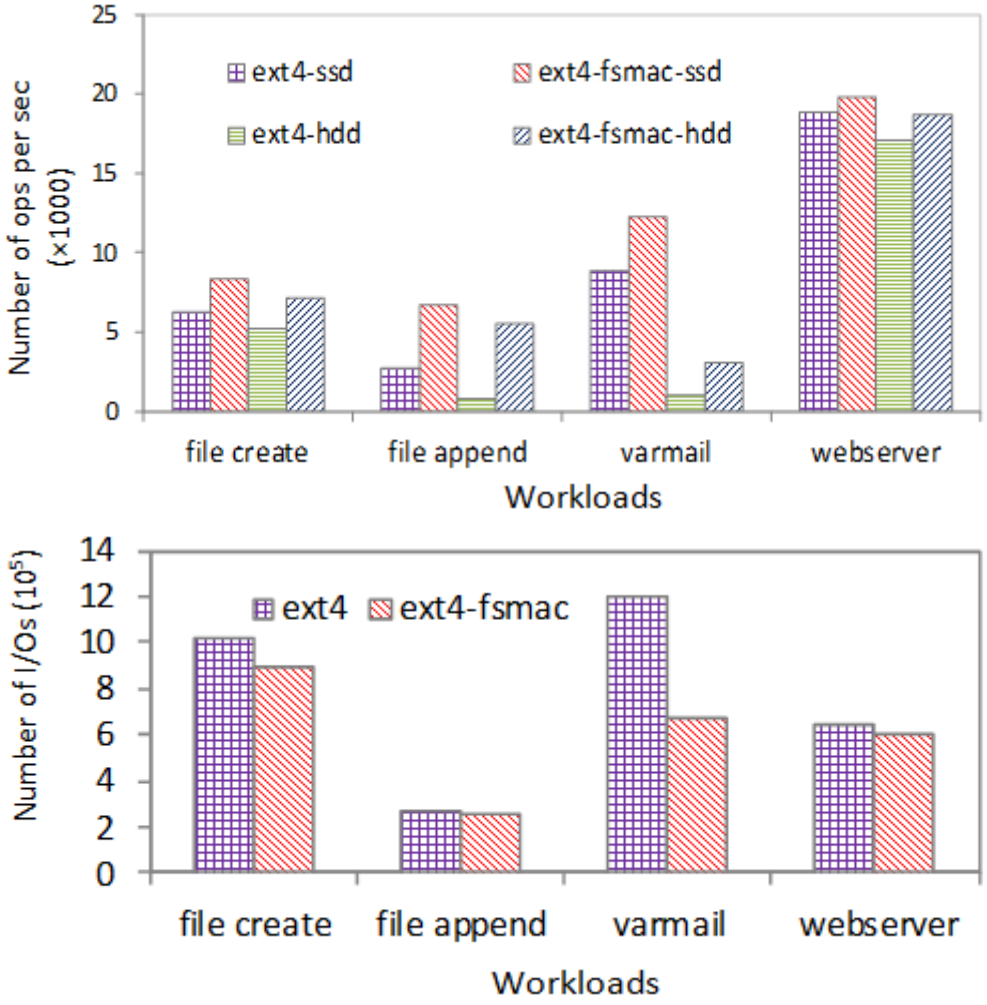
4. Evaluation

(1) Filebench



- FS on SSD and HDD are evaluated
- On SSD, performance improved from 5.4% to 147.4% in different workloads
- On SSD, performance improved from 10.9% to 621.7%
- Disk IO reduced (see second plot)

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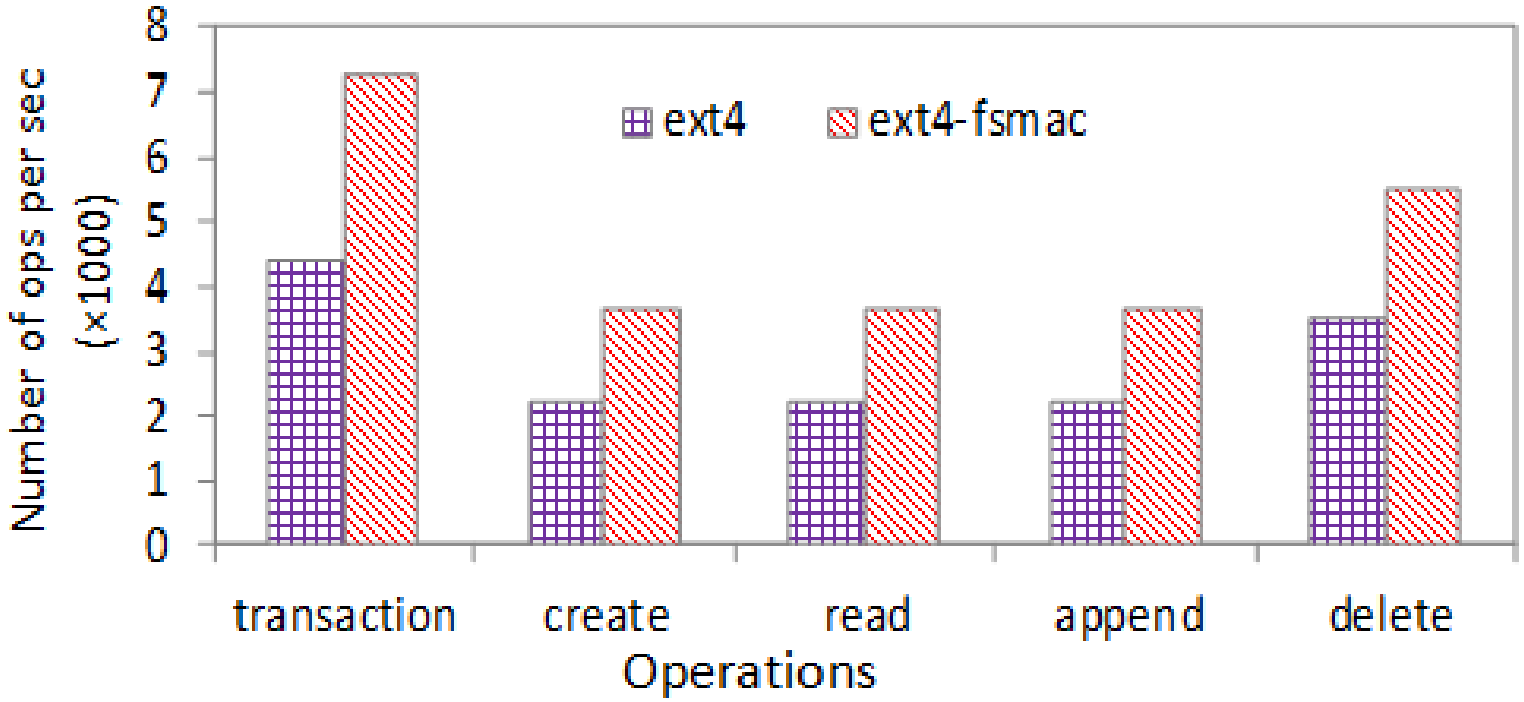
4. Evaluation

(2) PostMark



❖ **1.67× performance speedup achieved**

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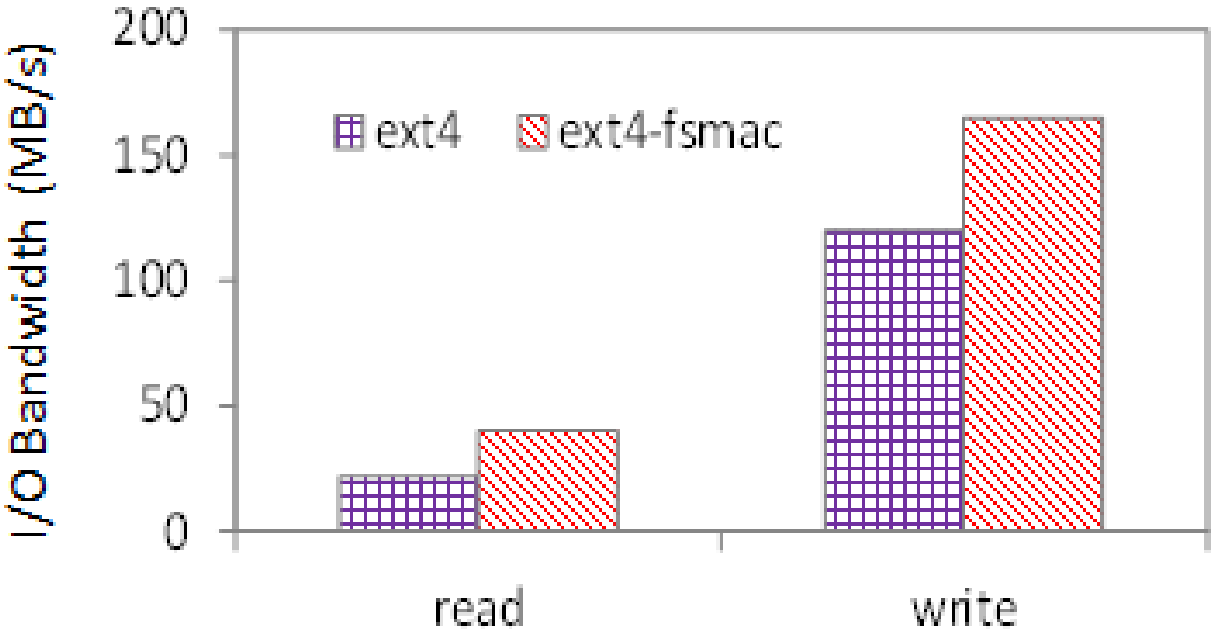
4. Evaluation

(3) FFSB



- **Ext4-FSMAC improves read performance by 82% and writes performance by 35%**

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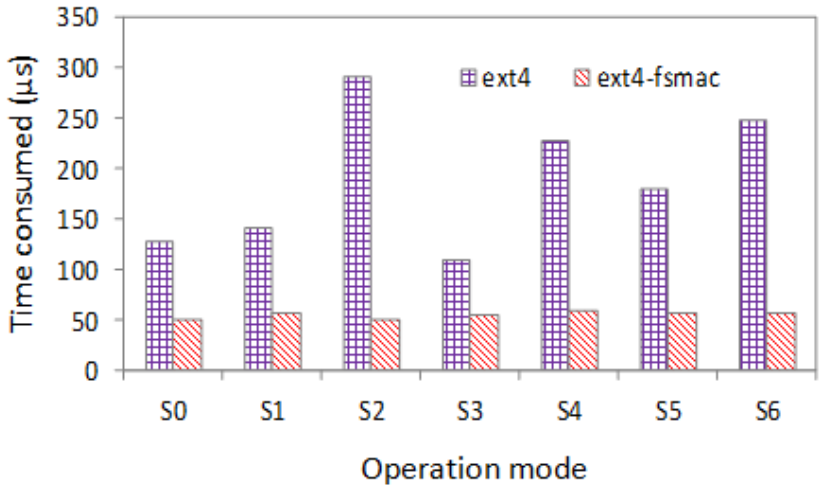
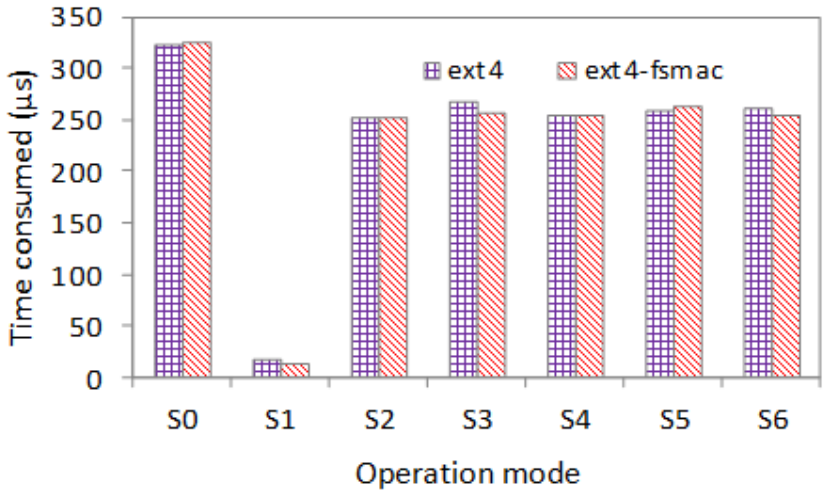
4. Evaluation

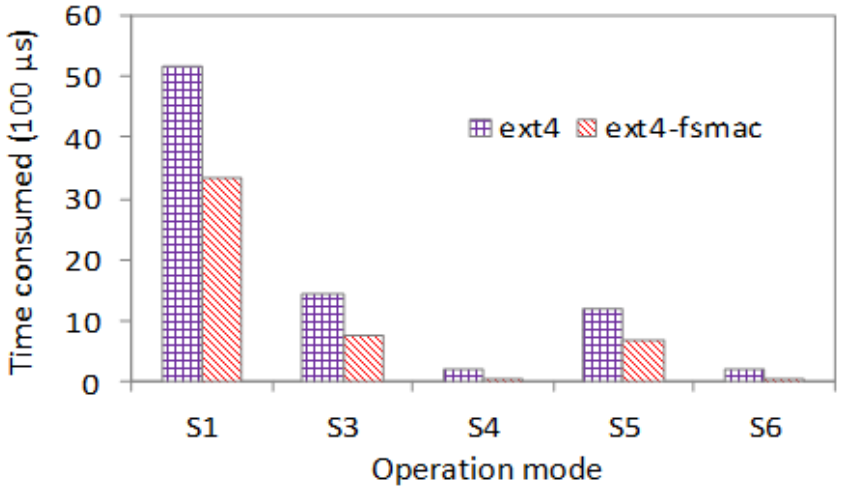
(4) Micro-benchmark (FS_Mark)



(a) Time for creation



(b) Time for write



(c) Time for fsync

- ***Fcreate*** **and** ***fsync*** **are improved significantly**

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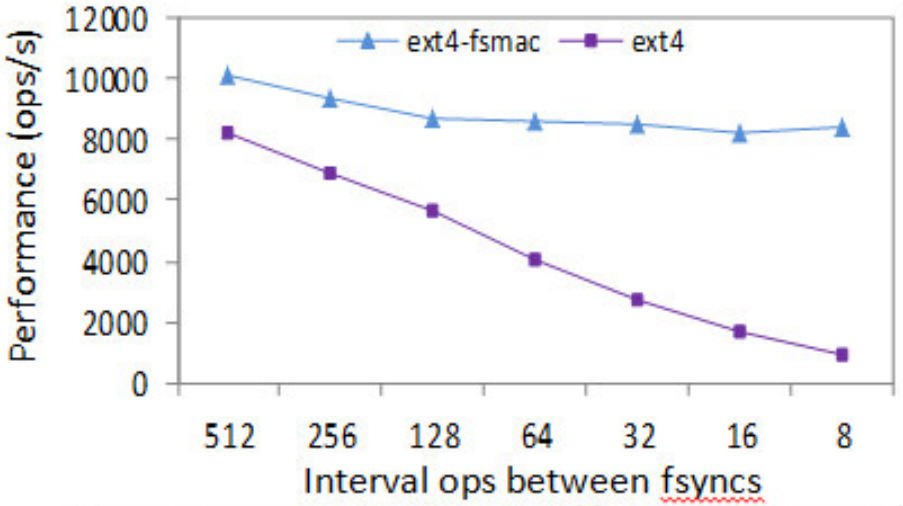
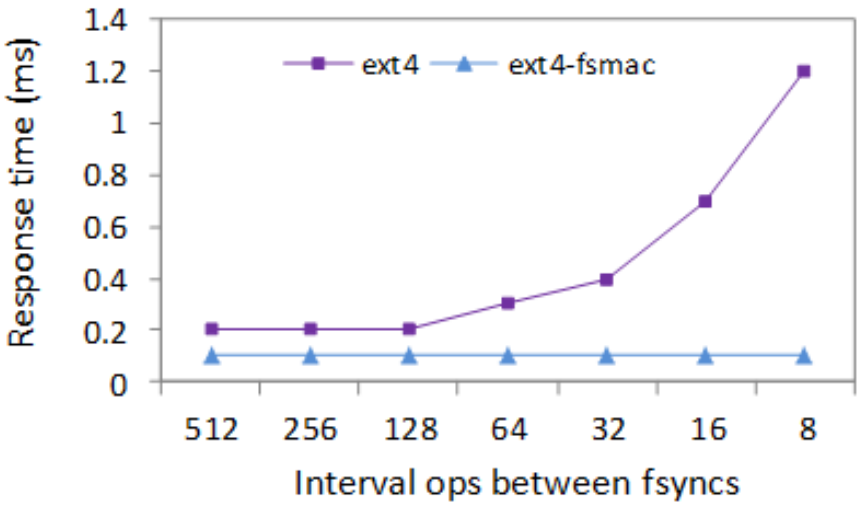
4. Evaluation

(5) Effect of Synchronization Frequency



(a) Write operations per second by varying interval operations between 2 fsyncs.



(b) Write response time by varying interval operations between 2 fsyncs.

- **frequent file synchronizations degrade Ext4 file system performance significantly but do not affect ext4-fsmac so much**

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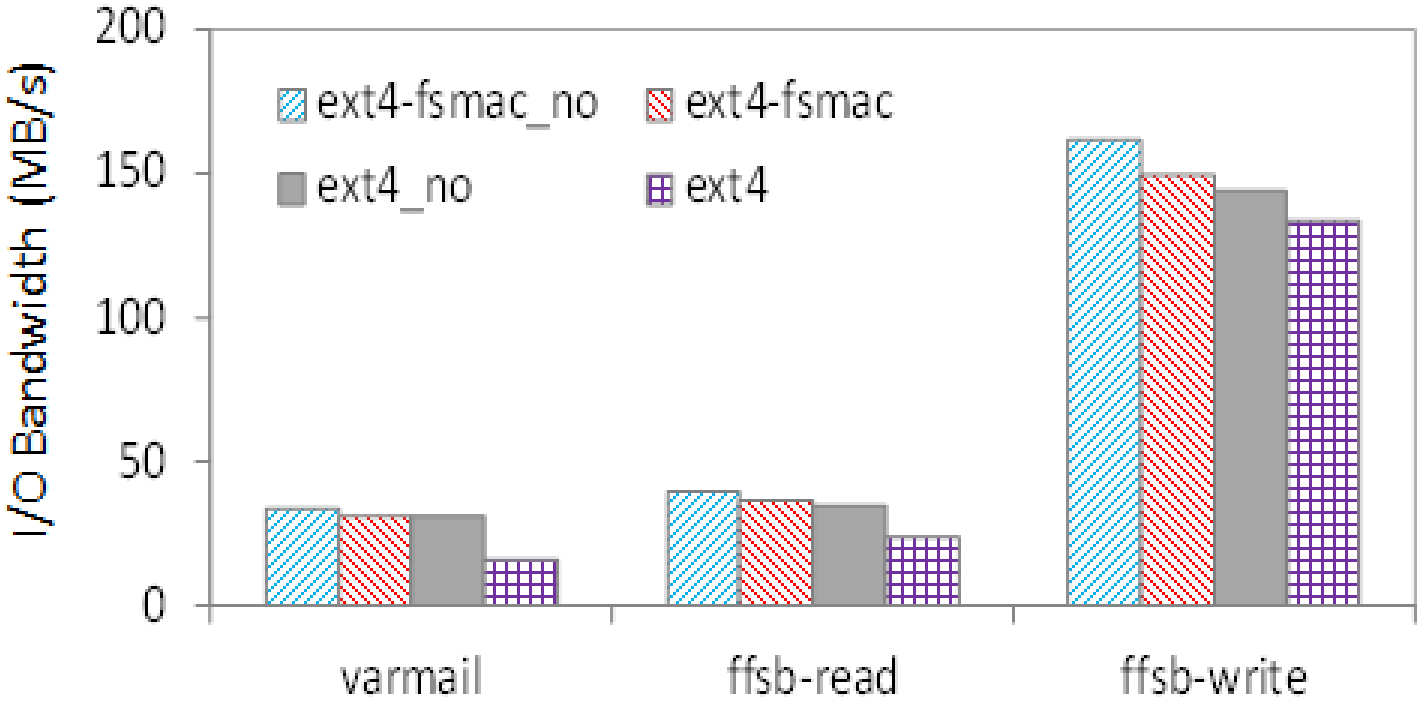
4. Evaluation

(6) Overhead of Consistency Maintain



❖ **Overhead is much smaller than journal in ext4**

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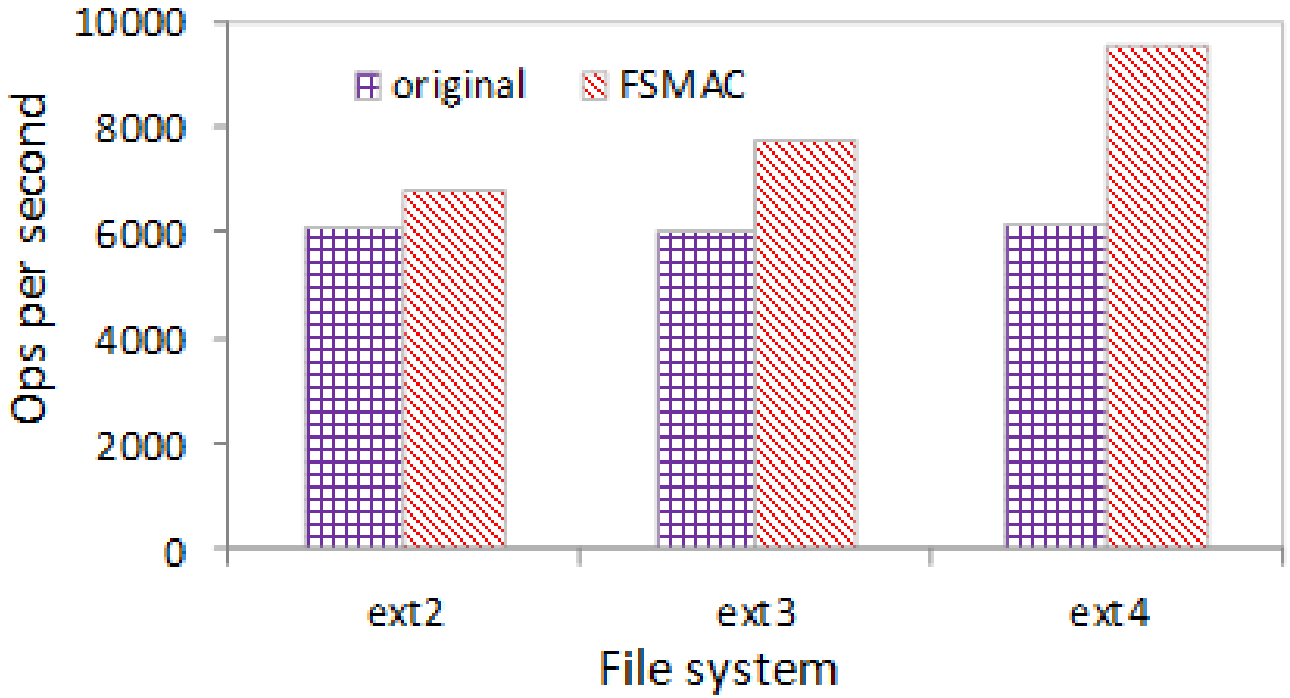
4. Evaluation

(7) For Different File Systems (FFSB)



- The metadata accelerator works better on ext4 than on ext2 and ext3 file system

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5. Conclusion

- A file system metadata accelerator is designed by using NVM to accelerate metadata accessing
  - Metadata and data accesses is decoupled.
    - Metadata is stored in NVM and accessed in byte-addressable through memory bus
    - Data is stored in Disk and accessed in block manner through I/O path.
  - A method combined fine-grained metadata versioning and transaction mechanism is introduced to overcome the problem of consistency
- It accelerates ext4 file system
  - Up to 7.22 times for asynchronous I/O
  - Up to 49 for synchronous I/O

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THANKS!

For further query, please contact:
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