The Introduction to FEMU
and
its newly related research

Presented by Chen Haodong

HDU – Center of Cloud computing

Outline

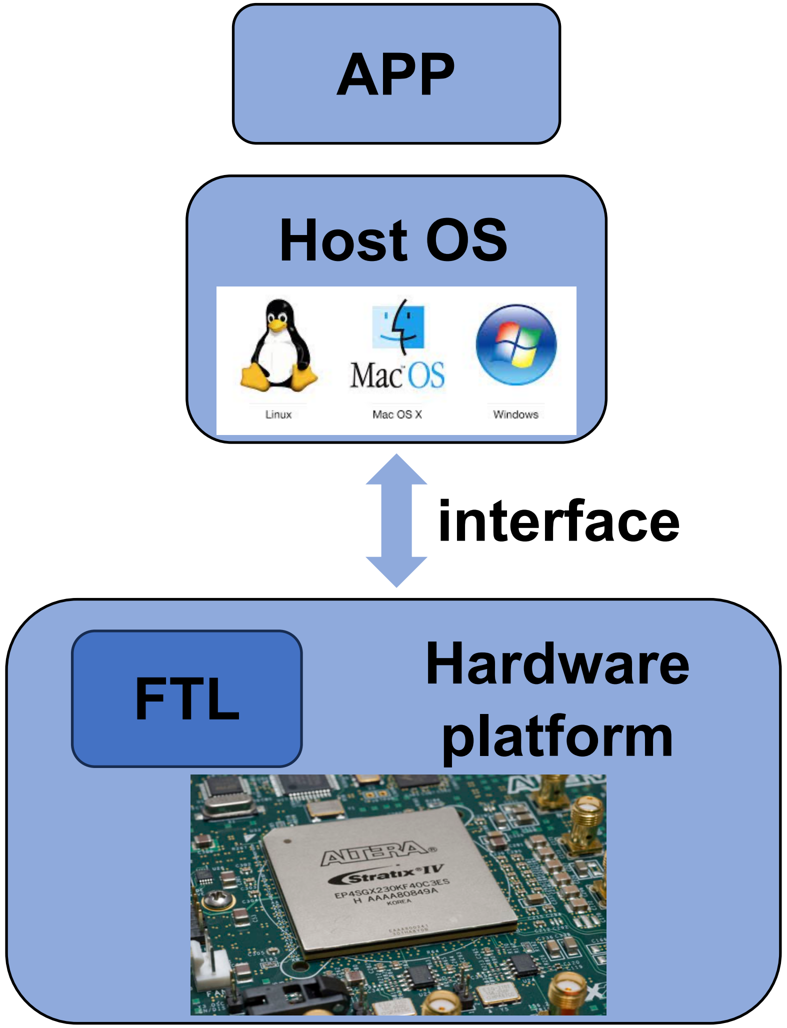
- 1. Backgrounds
- 2. Existing SSD platform
- 3. Case of FEMU
- 4. Newly related work in 2023
- 5. Future work

1. Backgrounds

SSD research mainly focus on 3 parts:

1. kernel changes
2. Interface changes
3. FTL changes

Typical full-stack research



2. Existing SSD platforms

Simulator

Emulator

Hardware platform

2. Existing SSD platforms

Simulator

DiskSim’s SSD;
FlashSim; SSDSim;

Emulator

Hardware platform

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Hardware platform

simple

Time-saving

internal-SSD research

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- **Time-saving**
- **internal-SSD research**
- **kernel-level research**

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OpenSSD; FPGA;
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- ☺ **simple**
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- ☺ **internal-SSD research**
- ☹ **kernel-level extension**

- ☺ **Full-stack research**
- ☺ **Accurate**

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Hardware platform

OpenSSD; FPGA;
OpenChannel SSD;

- Full-stack research
- Accurate
- high costs
- complex to use

2. Existing SSD platforms

Simulator	Emulator	Hardware platform
DiskSim's SSD; FlashSim; SSDSim;	FlashEm; LightNVM QEMU; QEMU based VSSIM;	OpenSSD; FPGA; OpenChannel SSD;

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- ☺ **simple**
- ☺ **Time-saving**
- ☺ **internal-SSD research**
- ☹ **kernel-level extension**

Hardware platform

- ☺ **Full-stack research**
- ☺ **Accurate**
- ☹ **high costs**
- ☹ **complex to use**

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DiskSim's SSD;
FlashSim; SSDSim;

- simple
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Emulator

FlashEm;
LightNVM QEMU;
QEMU based VSSIM;

- Full-stack research
- Low costs

Hardware platform

OpenSSD; FPGA;
OpenChannel SSD;

- Full-stack research
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DiskSim's SSD;
FlashSim; SSDSim;

- ☺ **simple**
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- ☺ **internal-SSD research**
- ☹ **kernel-level extension**

Emulator

FlashEm;
LightNVM QEMU;
QEMU based VSSIM;

- ☺ **Full-stack research**
- ☺ **Low costs**
- ☹ **Not scalability**
- ☹ **Not accurate**

Hardware platform

OpenSSD; FPGA;
OpenChannel SSD;

- ☺ **Full-stack research**
- ☺ **Accurate**
- ☹ **high costs**
- ☹ **complex to use**

3. The CASE of FEMU

FEMU is a software (QEMU-based) flash emulator for fostering future full-stack software/hardware SSD research.

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FEMU is a software (QEMU-based) flash emulator for fostering future full-stack soft- ware/hardware SSD research.

Cheap

Open source,

download from:

https://github.com/vtess/FEMU

3. The CASE of FEMU

FEMU is a software (QEMU-based) flash emulator for fostering future full-stack soft- ware/hardware SSD research.

Cheap

(relatively) Accurate

Produce an advanced openChannel SSD Model

The error of resulting latencies drops to only 0.5-38%

3. The CASE of FEMU

FEMU is a software (QEMU-based) flash emulator for fostering future full-stack soft- ware/hardware SSD research.

- **Cheap**
- **(relatively) Accurate**
- **Scalable**

support 32 channels/chips

3. The CASE of FEMU

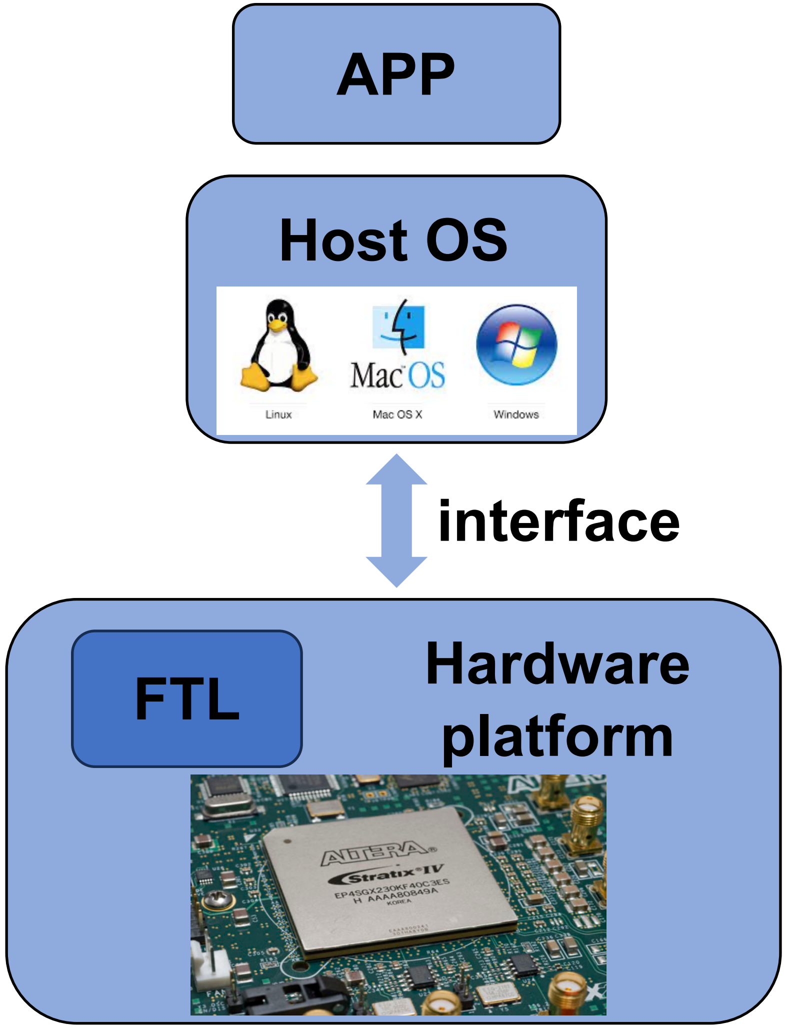
FEMU is a software (QEMU-based) flash emulator for fostering future full-stack soft- ware/hardware SSD research.

- Cheap
- (relatively) Accurate
- Scalable
- Extensible

- modifiable interface
- modifiable FTL
- modifiable SSD
- modifiable kernel

3. The CASE of FEMU

Typical full stack research .vs FEMU full stack research



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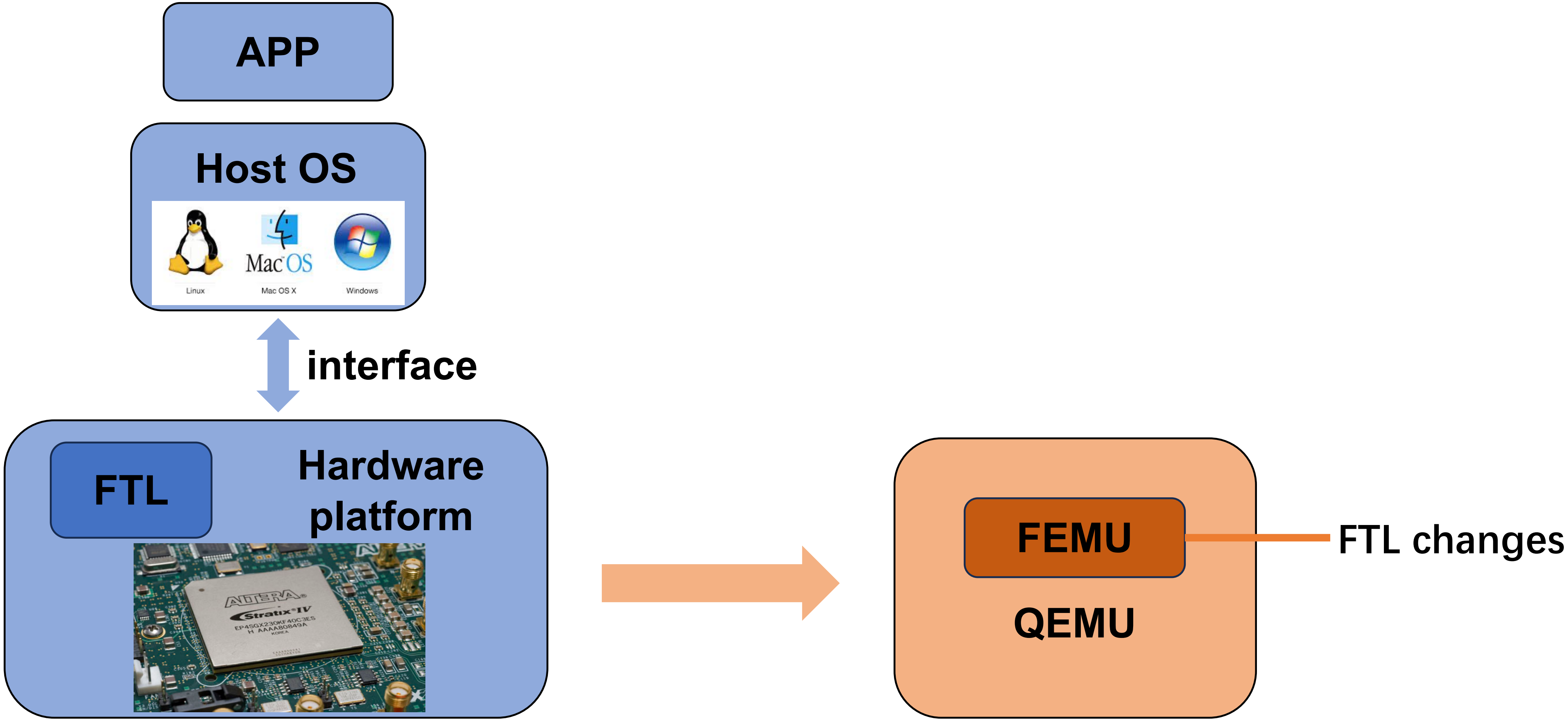

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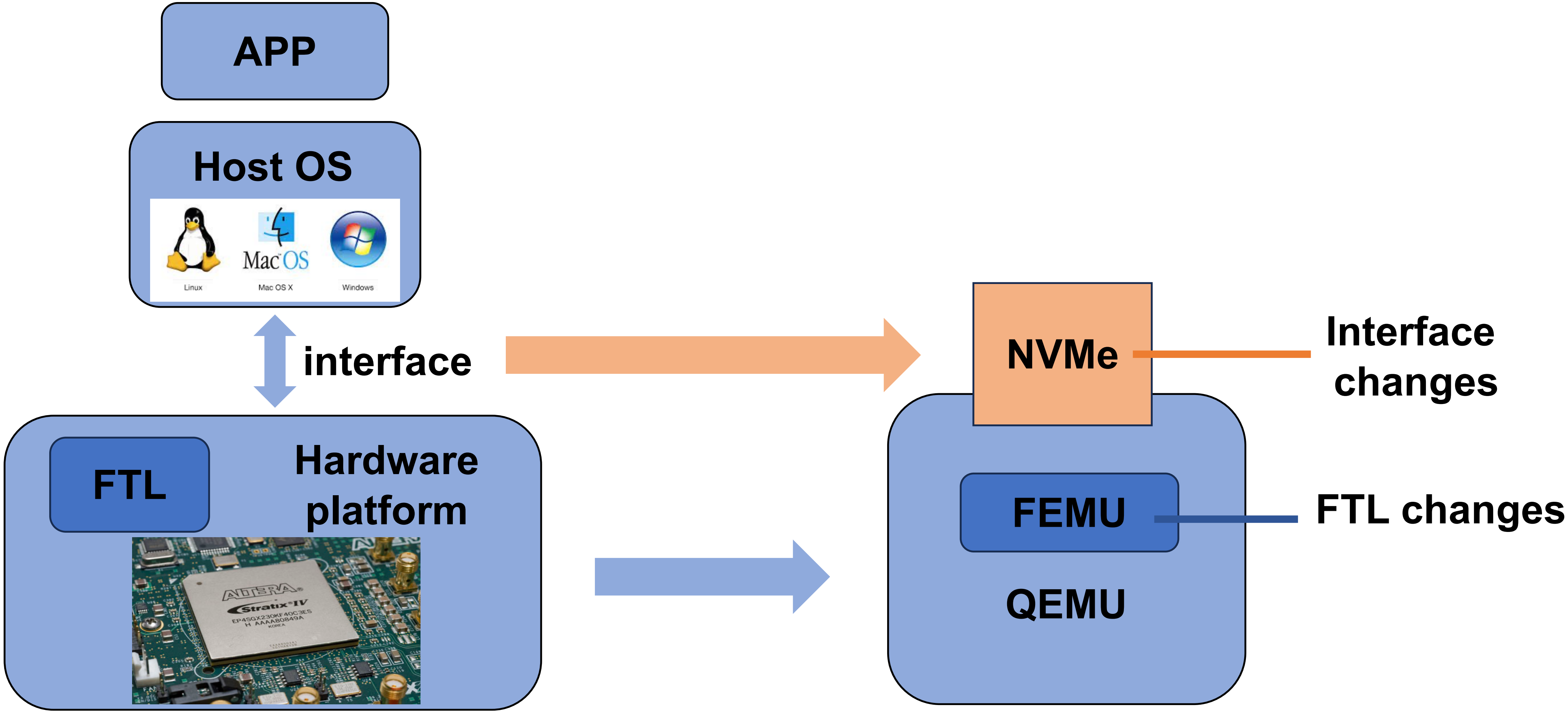

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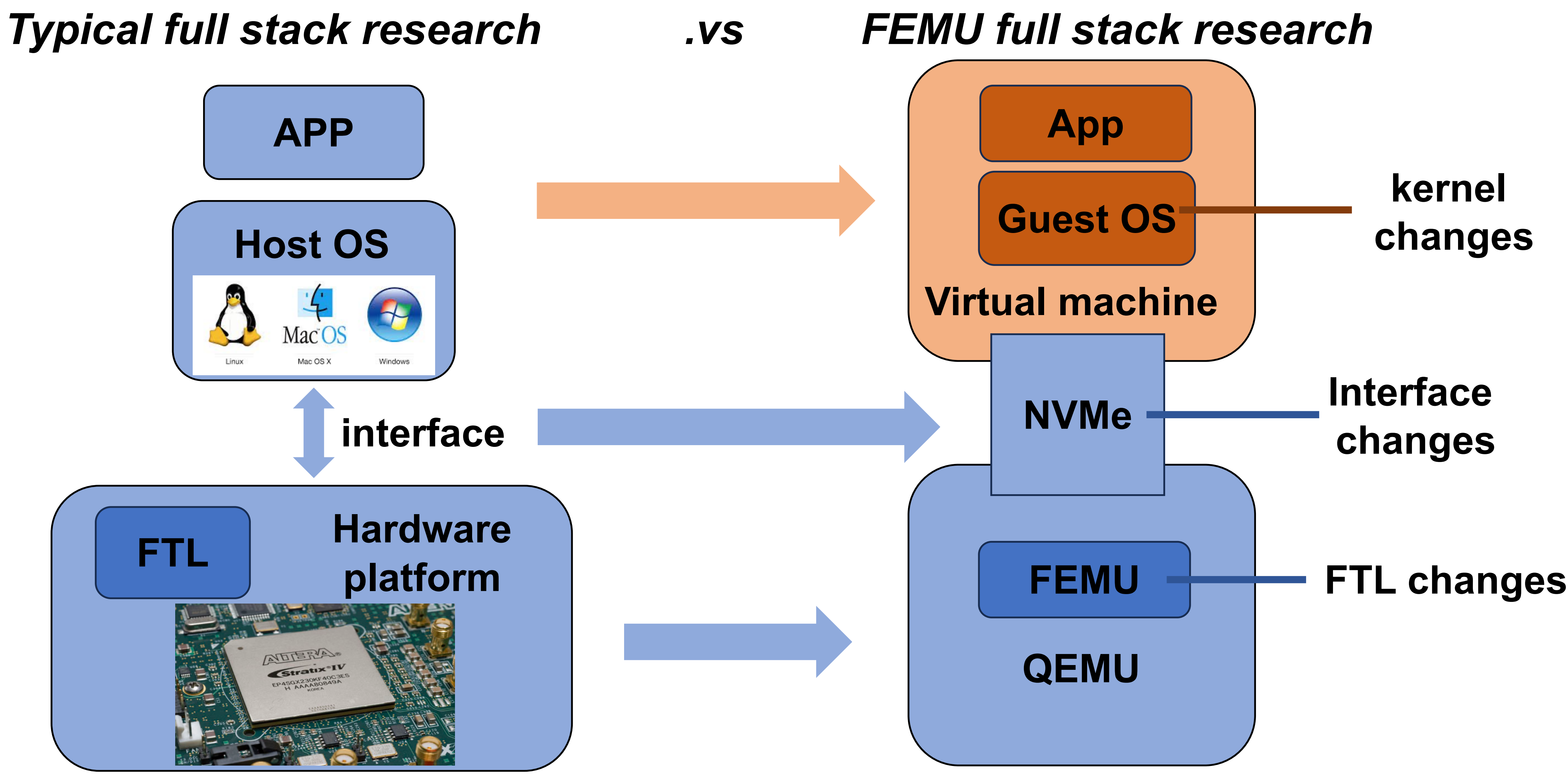
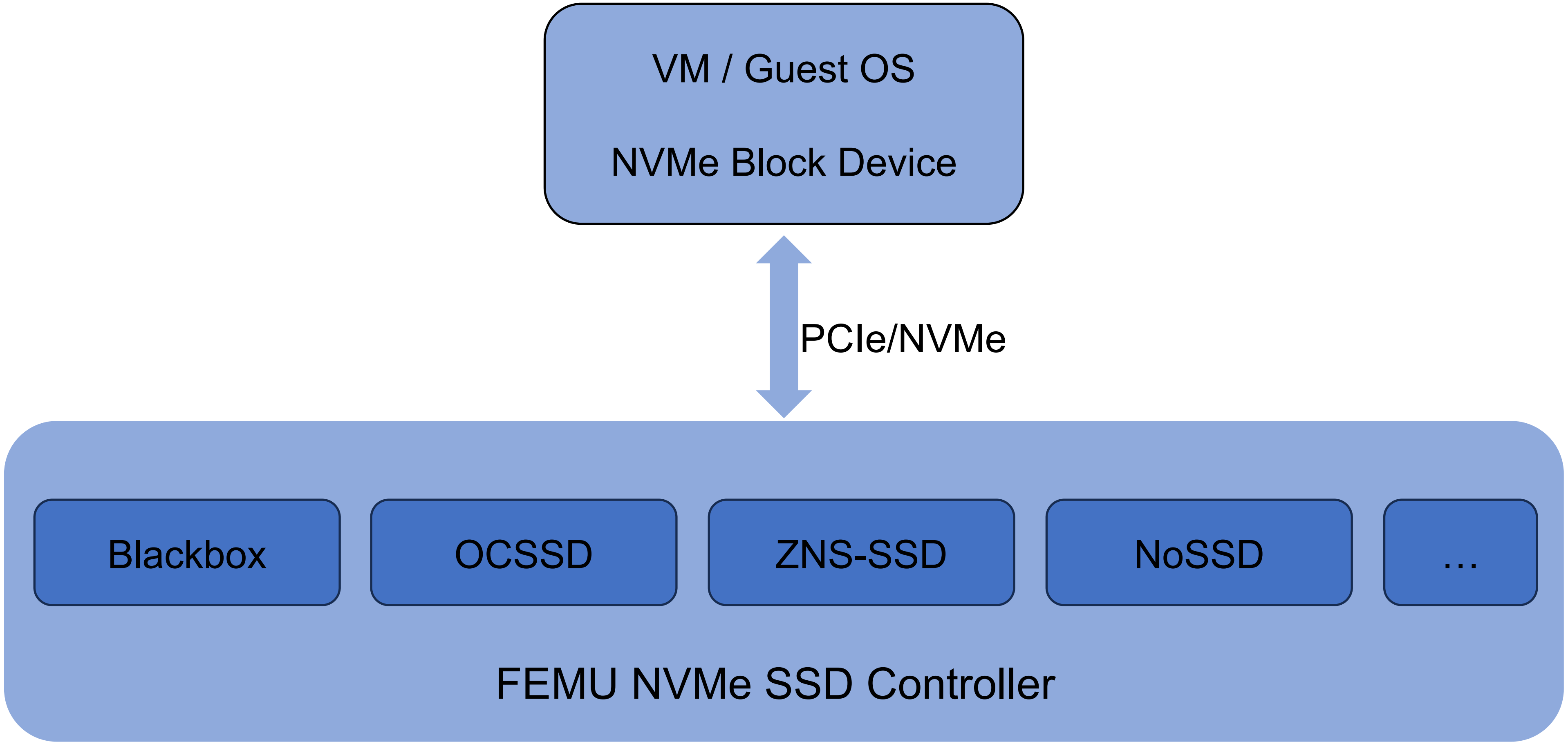


3. The CASE of FEMU

Project Description



4. Newly related work in 2023

*1. **Holistic and Opportunistic Scheduling of Background I/Os in Flash-based SSDs. (TC'23).** Yu Wang, You Zhou, Fei Wu, Yu Zhong, Jian Zhou, Zhonghai Lu, Shu Li, Zhenghong Wang, Changsheng Xie*

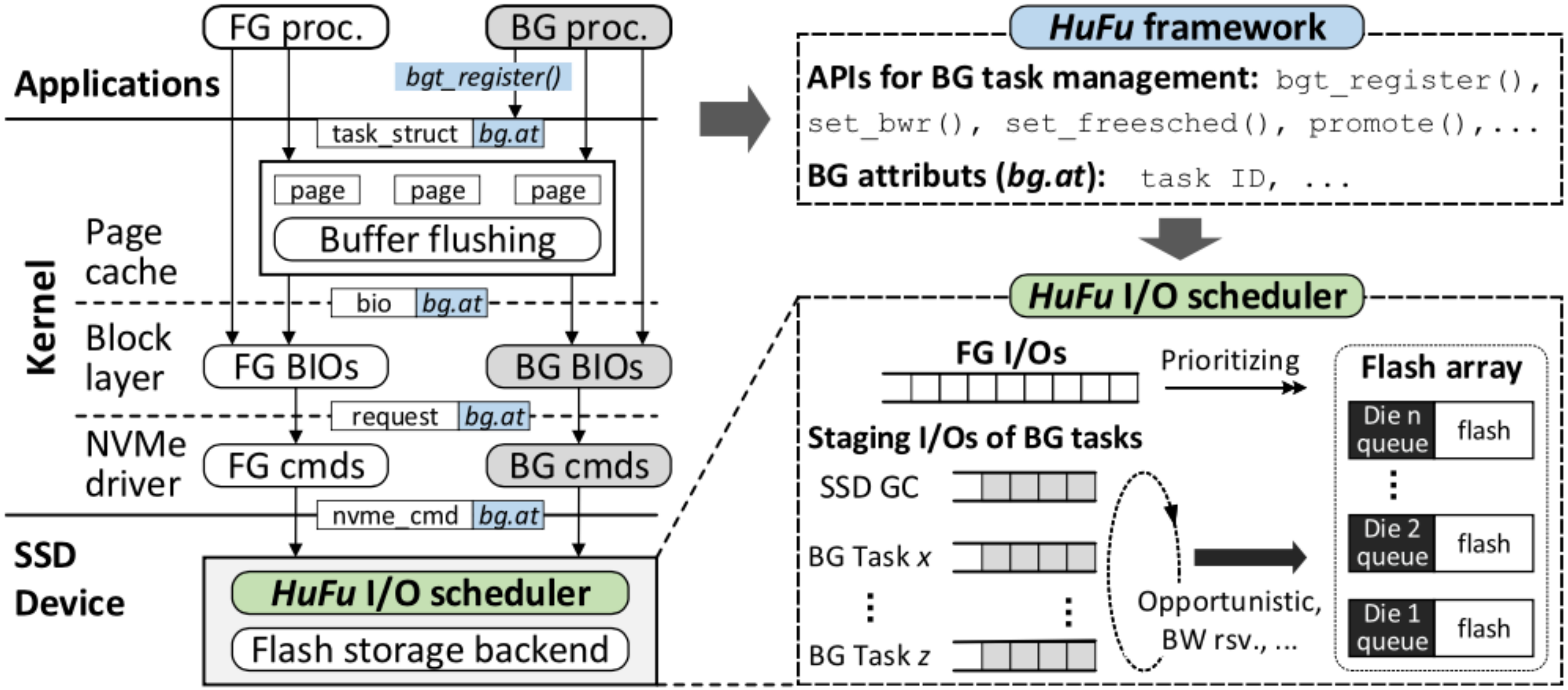


Fig. 3. Design overview of *HuFu*. The core components include a framework, which allows host software to offload I/O scheduling of BG tasks into the SSD, and an SSD-internal I/O scheduler, which prioritizes FG I/Os while processing system-wide BG I/Os opportunistically.

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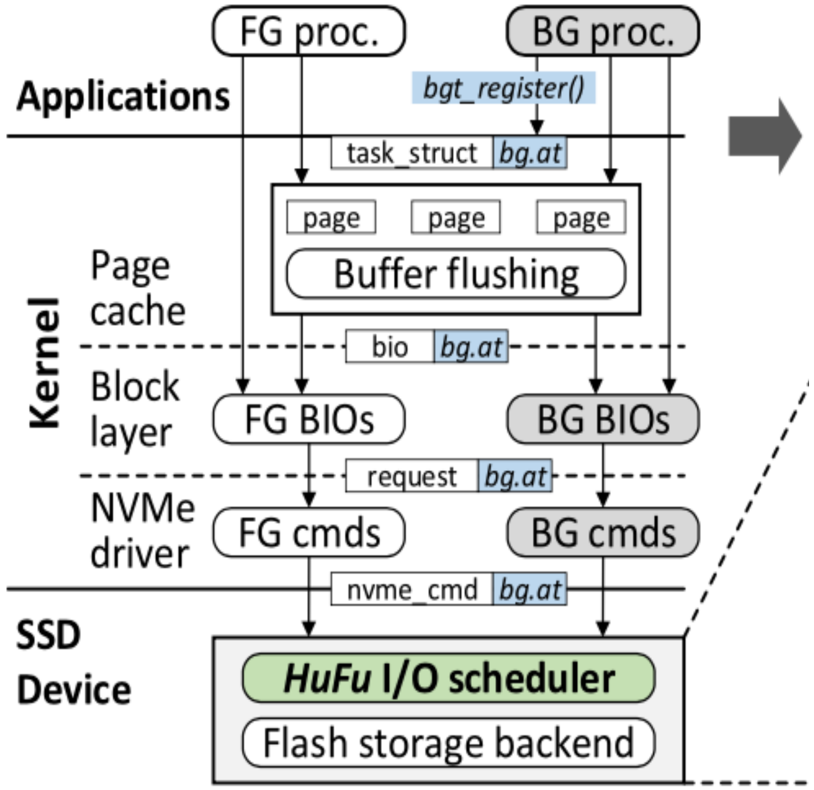

Fig. 3. Design overview of *HuFu*. The core components include a framework and an SSD-internal I/O scheduler, which prioritizes FG I/Os while processing s

FEMU

Kernel changes

FTL changes

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*2. **NVMeVirt: A Versatile Software-defined Virtual NVMe Device. (FAST'23).** Sang-Hoon Kim, Jaehoon Shim, Seongyeop Jeong, Jin-Soo Kim*

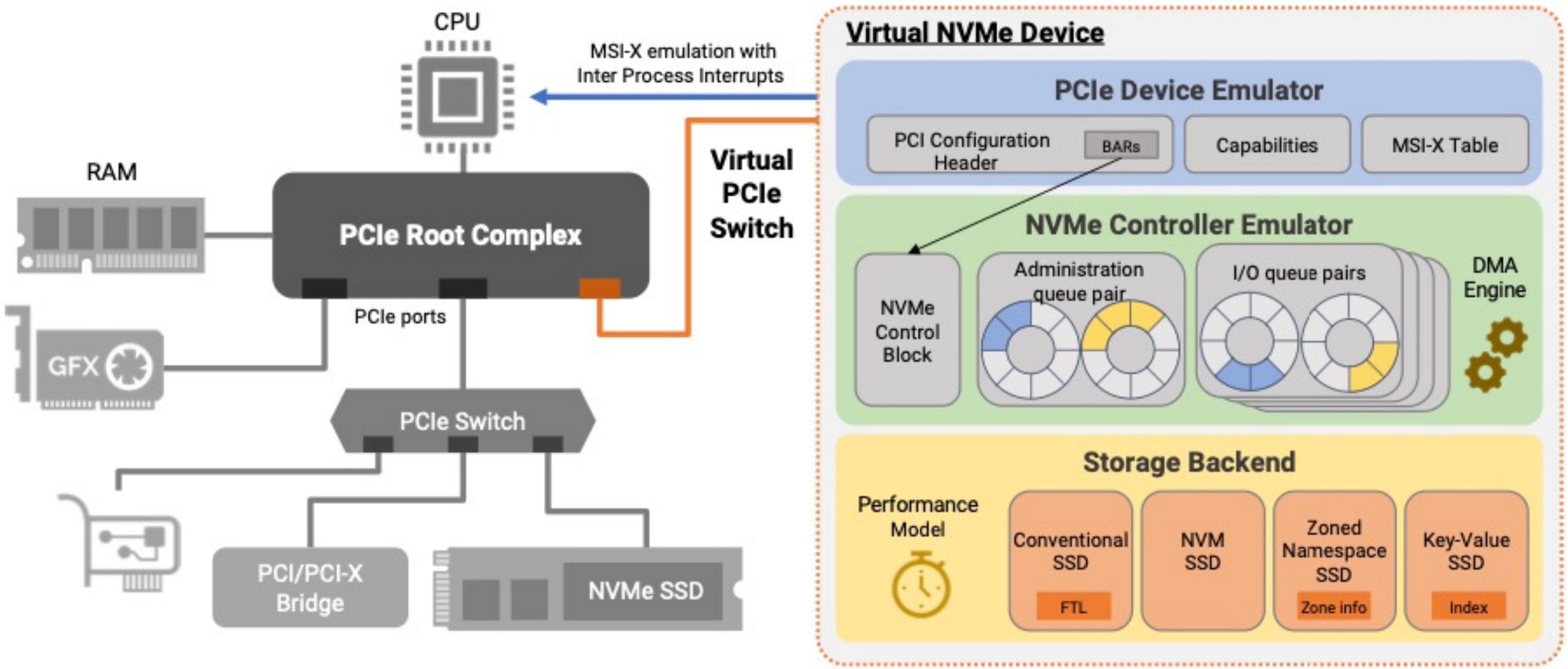


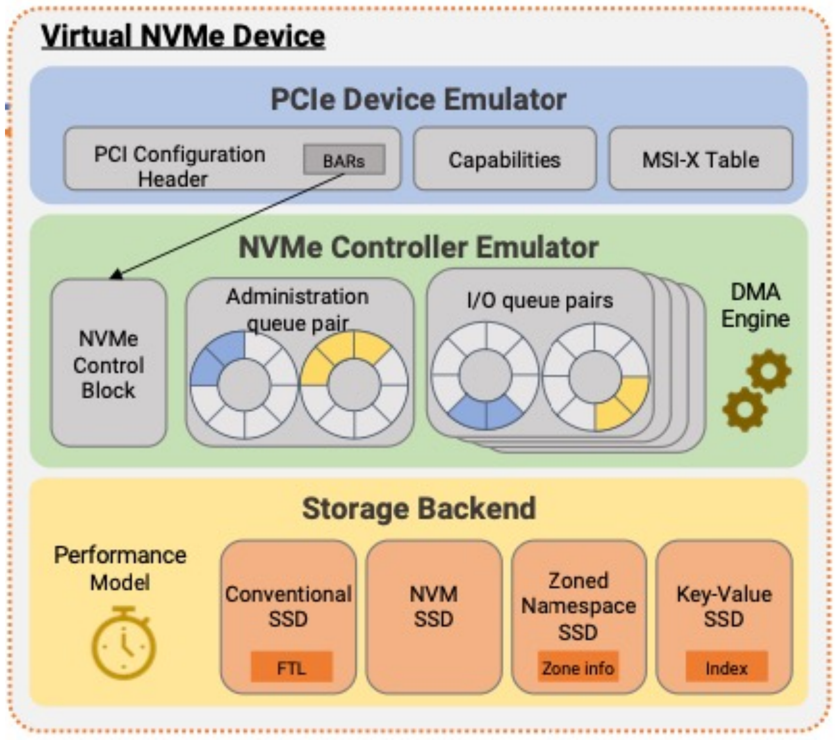
Figure 1: The overall architecture of NVMeVirt. NVMeVirt virtualizes a virtual NVMe device through the PCI bus and switch, so the device is seen as a native PCIe device from the host.

4. Newly related work in 2023

2. ***NVMeVirt: A Versatile Software-defined Virtual NVMe Device. (FAST'23). Sang-Hoon Kim**, Jaehoon Shim, Seongyeop Jeong, Jin-Soo Kim*

FEMU NVMe interface

.VS



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3. ***DECC: Differential ECC for Read Performance Optimization on High-Density NAND Flash Memory.*** *(ASPDAC '23). Yunpeng Song, Yina Lv, Liang Shi*

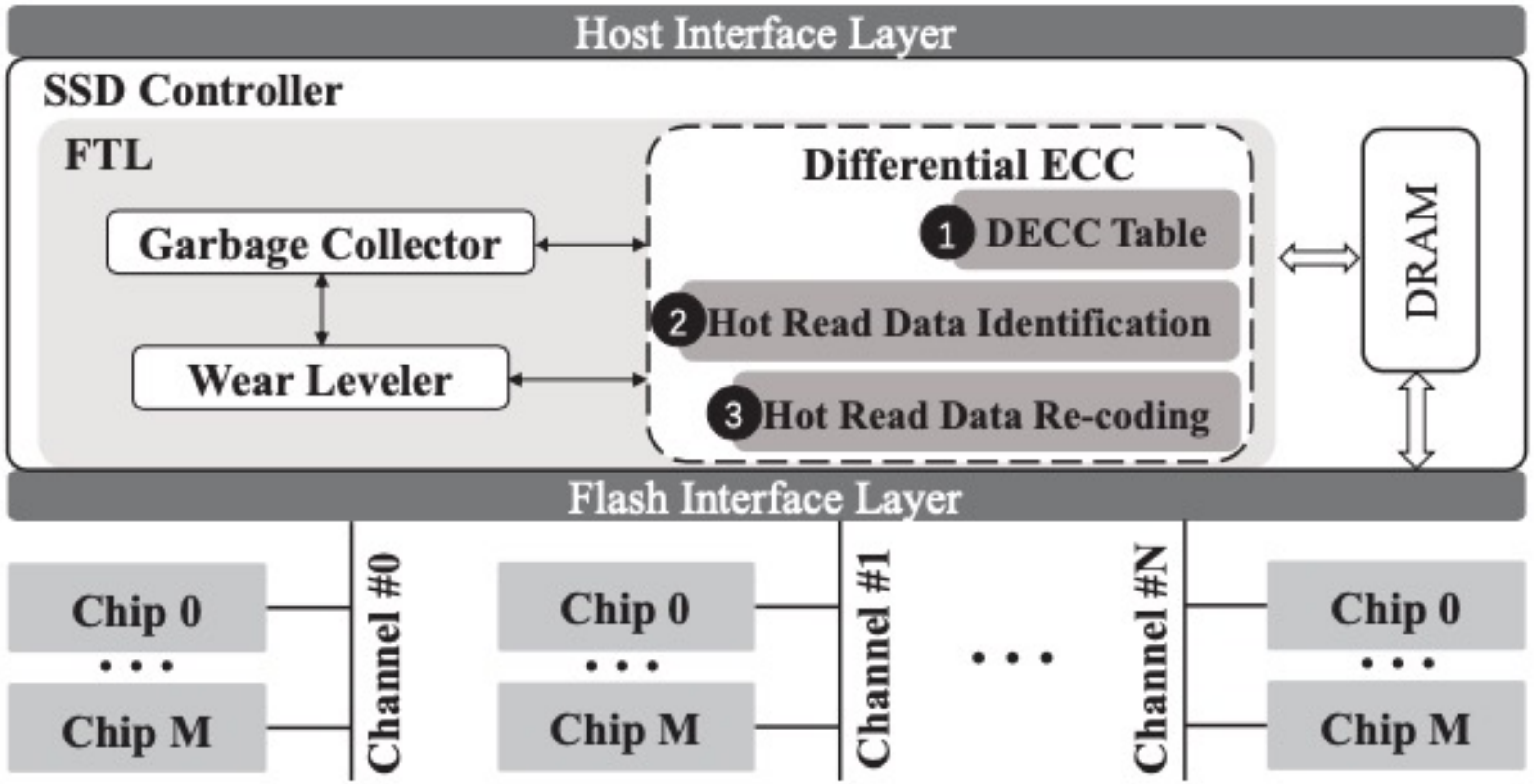

Figure 4: Overview of differential ECC.

4. Newly related work in 2023

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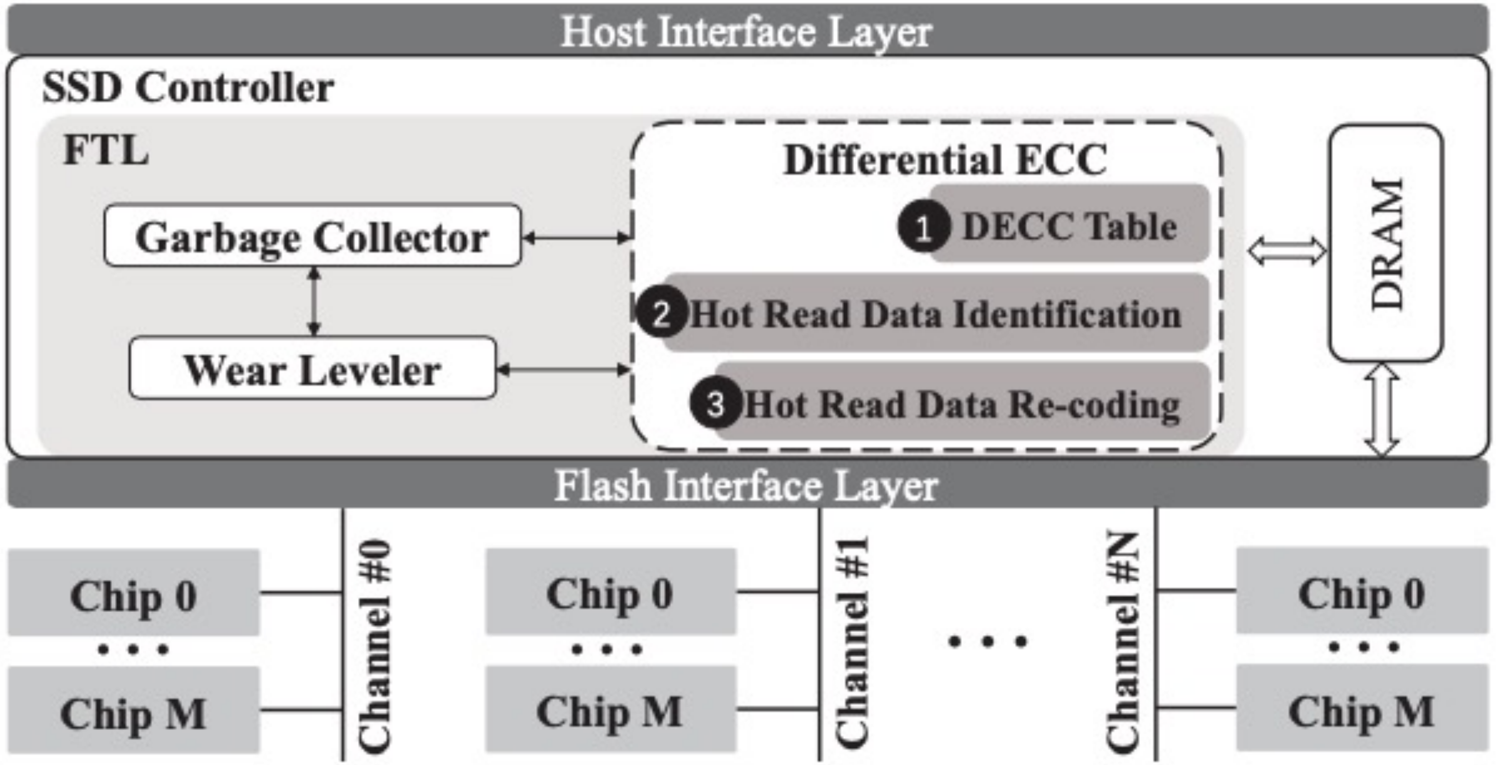

Figure 4: Overview of differential ECC.

FEMU

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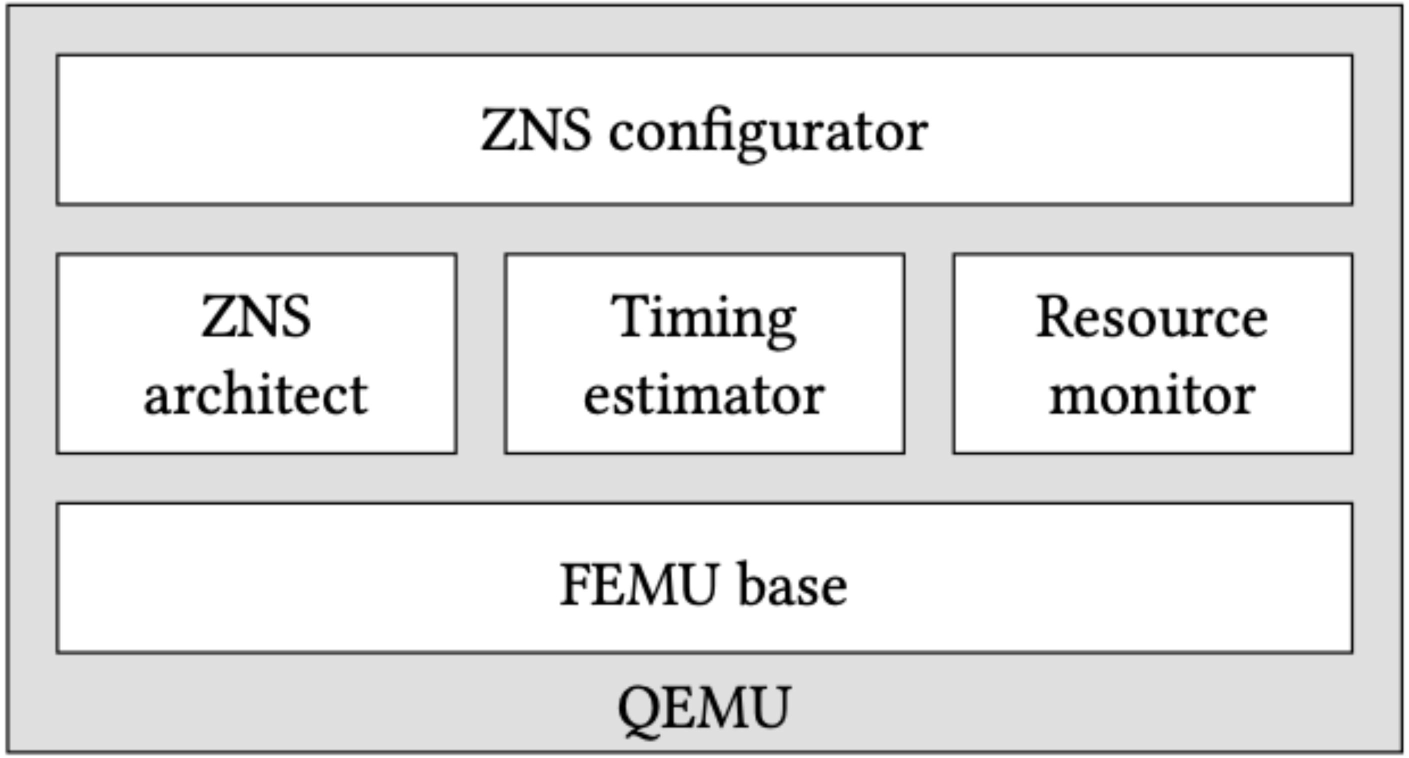
FTL changes

4. Newly related work in 2023

4. **ConfZNS : A Novel Emulator for Exploring Design Space of ZNS. (SYSTOR'23).** *Inho Song, Myounghoon Oh, Bryan S. Kim, Seehwan Yoo, Jaedong Lee, Jongmoo Choi*



An advance ZNS emulator based on FEMU

Figure 1: Key components of ConfZNS.

4. Newly related work in 2023

*5. **Optimizing Data Migration for Garbage Collection in ZNS SSDs. (DATE'23).** Zhenhua Tan, Linbo Long, Renping Liu, Congming Gao, Yi Jiang, Yan Liu*

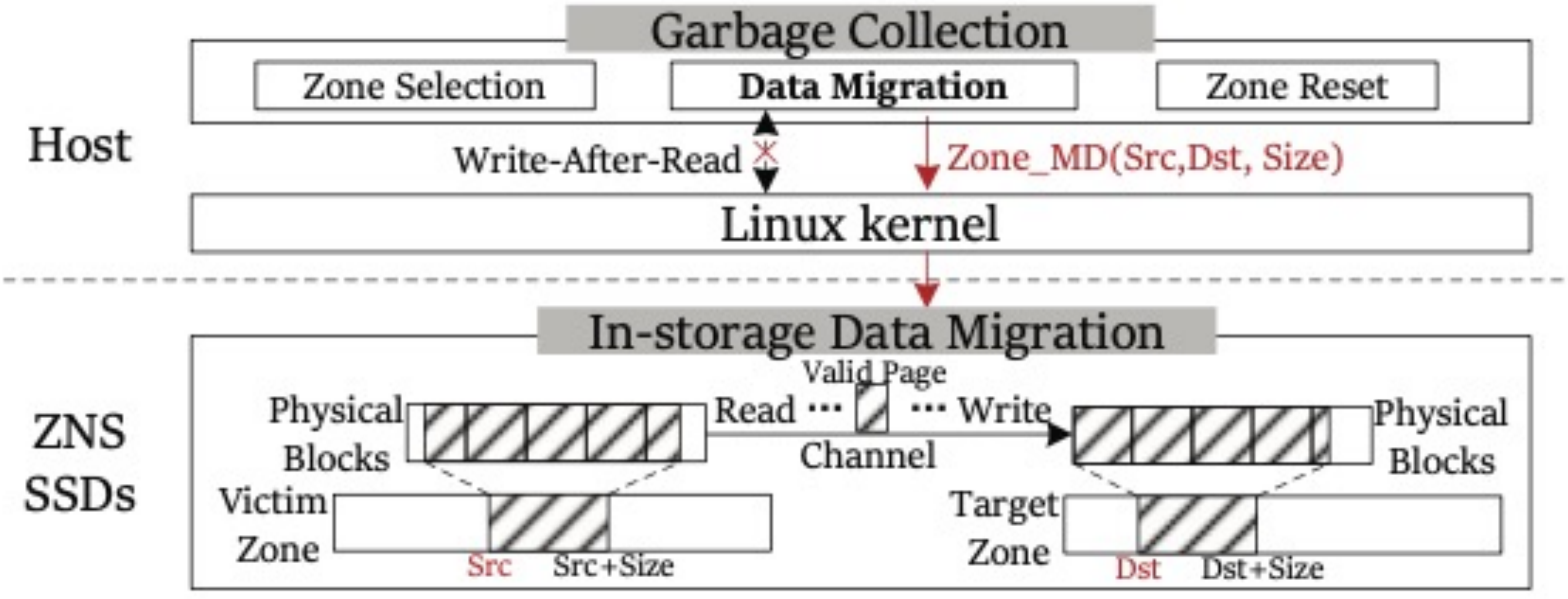


Fig. 1. The method of in-storage data migration.

4. Newly related work in 2023

*5. **Optimizing Data Migration for Garbage Collection in ZNS SSDs. (DATE'23).** Zhenhua Tan, Linbo Long, Renping Liu, Congming Gao, Yi Jiang, Yan Liu*

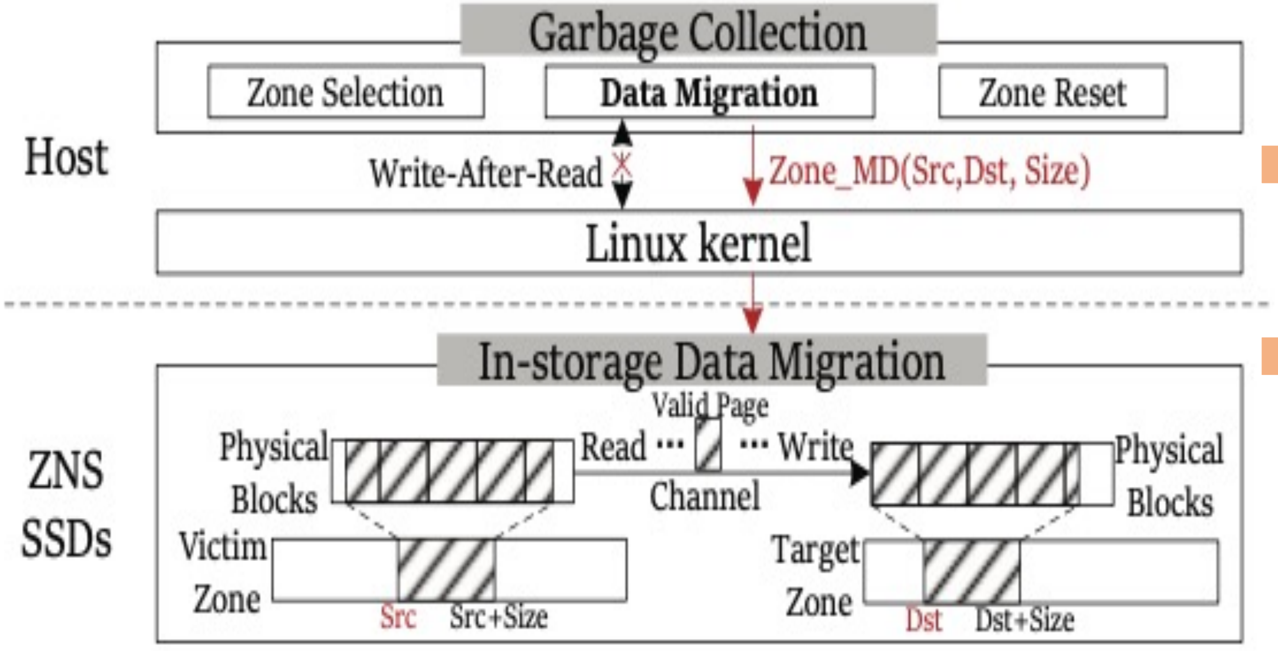


Fig. 1. The method of in-storage data migration.

FEMU

Kernel changes

Interface changes

4. Newly related work in 2023

6. ***Design of a High-Performance, High-Endurance Key-Value SSD for Large-Key Workloads**. (IEEE CAL'23).*
Chanyoung Park, Chun-Yi Liu, Kyungtae Kang, Mahmut Kandemir, Wonil Choi

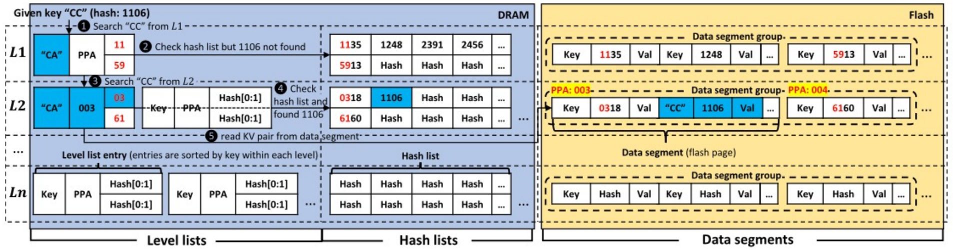


Fig. 4. Internal architecture of LK-SSD.

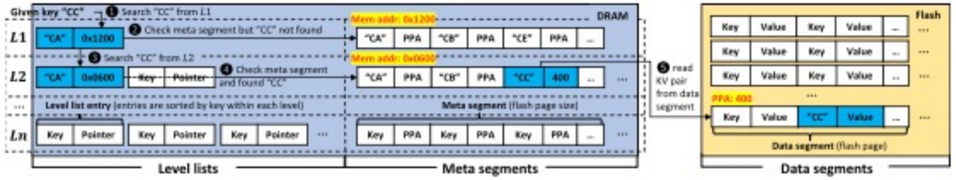


Fig. 2. Internal architecture of PinK.

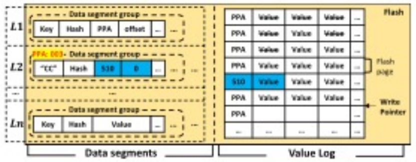


Fig. 5. Relocating a set of values to the value log in LK-SSD+.

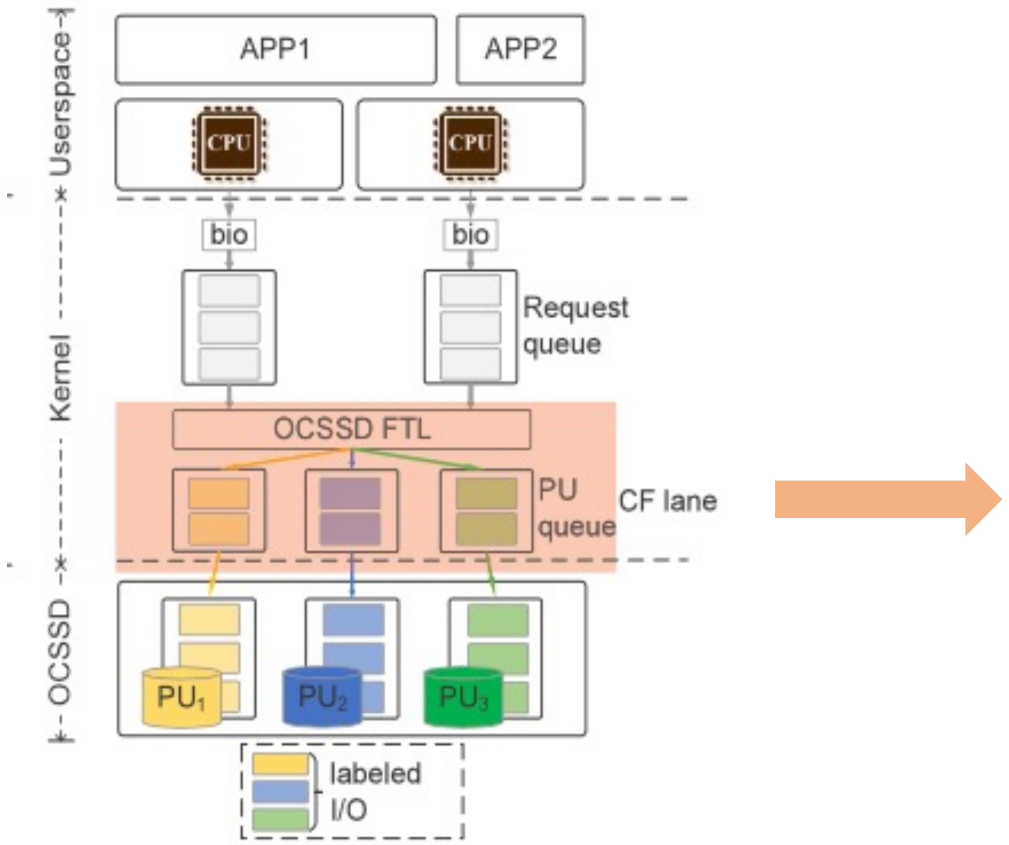
Emulate three architecture on

FEMU,

Compare their performance

4. Newly related work in 2023

7. ***CFIO: A conflict-free I/O mechanism to fully exploit internal parallelism for Open-Channel SSDs. (JSA'23).***
Jinbin Zhu, Liang Wang, Limin Xiao, Lei Liu, Guangjun Qi



(b) The optimized I/O stack with CF lane.

FEMU

FTL changes:

Optimized I/O stack with CF line based on original FEMU OC-SSD

4. Newly related work in 2023

*8**. An Efficient F2FS GC Scheme for Improving I/O Latency of Foreground Application. (ICCE'23).** Manjong Lee, Jonggyu Pa, Young Ik Eom*

IV. EVALUATION

A. Experimental Setup

Table 1. Experiment Setup

Host Spec.	CPU: Intel(R) Xeon(R) CPU E5-2620 v4 @ 2.10GHz Memory: DDR4 64GB OS: Ubuntu 18.04.6 LTS
VM Spec.	Emulator: FEMU-v5.2 CPU: 4 SMP CPU Memory: 4GB OS: Ubuntu 20.04.4 LTS Kernel Version: Kernel v5.17 Storage: 12GB ZNS SSD

The detailed experiment setup is described in Table 1. To emulate ZNS storage, we use FEMU [15] with the default setting. To test various situations, we set various zone size from 16MB to 128MB. We use FIO [16] as the background application issuing write operations. The background application repeatedly creates/deletes 32KB ~ 64KB small files and 256KB ~ 1MB big files. For the foreground application, we use a program that issues 4KB write operations followed by fsync every 30ms.

Emulate different zone size on

FEMU,

Compare their performance

5. Future work

- 1. make FEMU running on my computer
- 2. Read the Friendly Source Code of FEMU
- 3. Find research direction

Thank you for listening

Presented by Chen Haodong