Junchao CHEN, Guangyan ZHANG, Junyu WEI, 2023. A survey on design and application of open-channel solid-state drives. *Frontiers of Information Technology & Electronic Engineering*, 24(5):637-658.
https://doi.org/10.1631/FITEE.2200317

A survey on design and application of open-channel solid-state drives

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Key words: Domain-specific storage; Flash translation layer; Garbage collection; Internal parallelism; Open-channel solid-state drives (OCSSDs)

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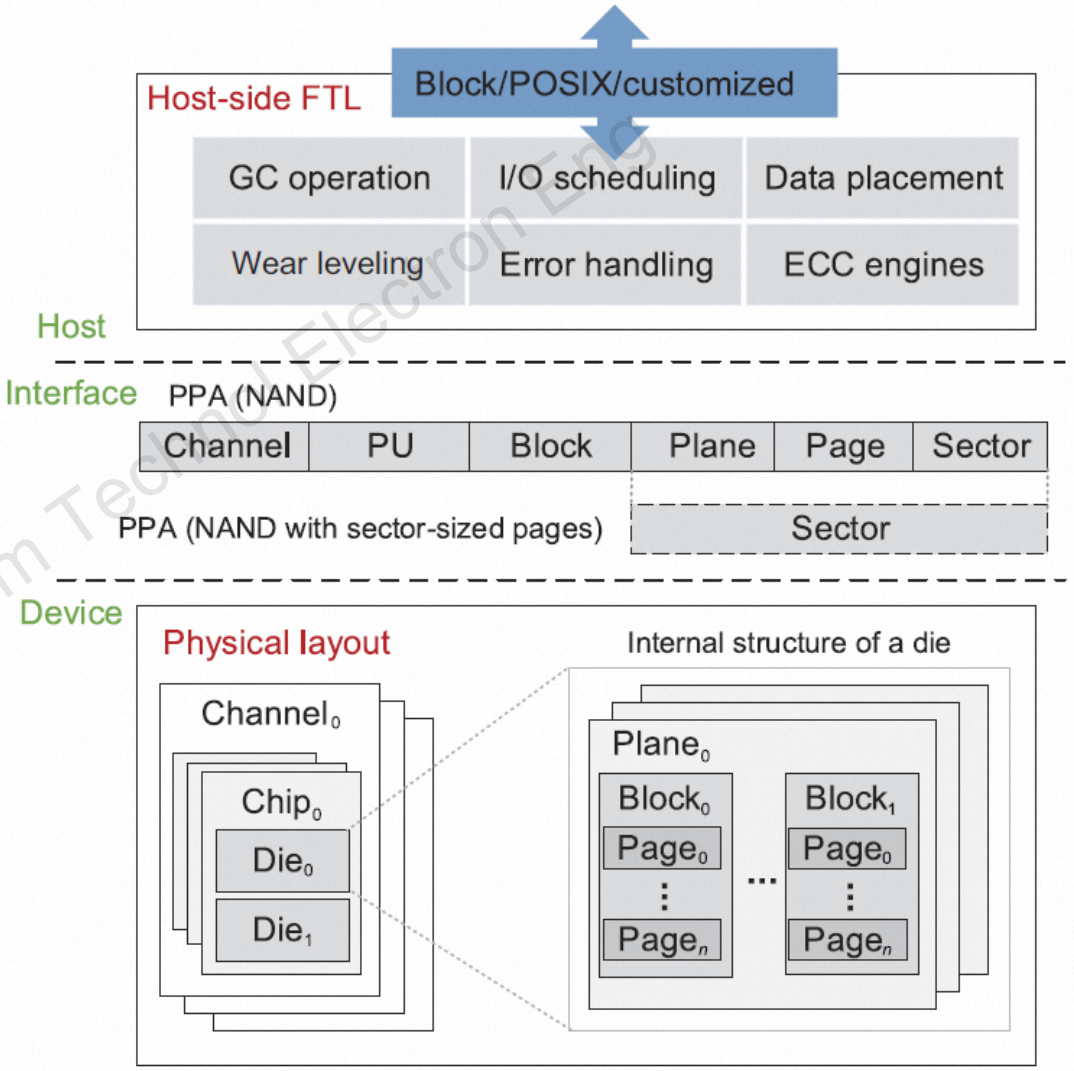
Motivation

1. Traditional solid-state drives (SSDs) have several well-documented shortcomings such as write amplification, long tail latency, and log-on-log problems because they are managed by the built-in flash translation layer (FTL).
2. Open-channel SSDs (OCSSDs) can achieve better performance due to the exposure of their physical layout and the host-side well-designed FTL.
3. The survey on design and application of open-channel SSDs can provide fundamental knowledge to researchers and promote better research on emerging flash memory.

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Overview of open-channel SSDs

1. Move the FTL to the host side
2. A hierarchical address space for hardware accessing
3. The exposure of physical layout



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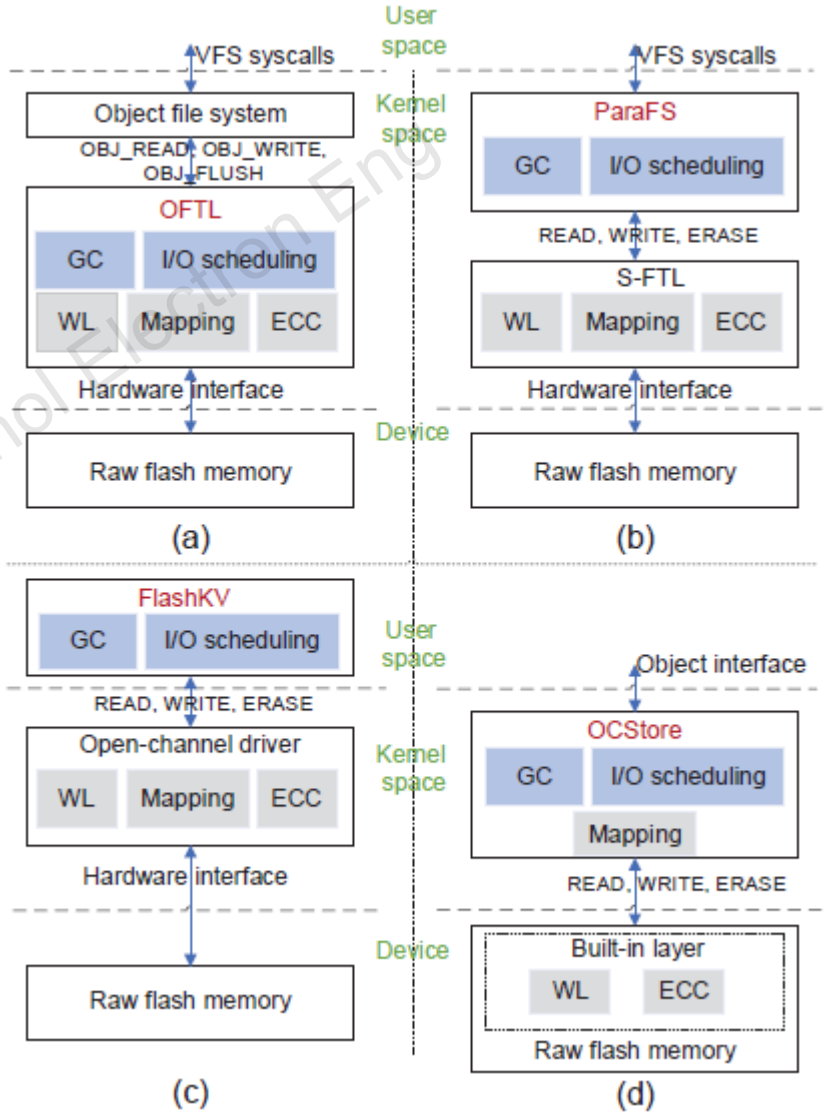
Opportunities

1. OCSSDs bring many opportunities for researchers in academia and industry to achieve specific performance goals or address practical problems in different scenarios.
2. Performance opportunities:
   - High throughput
   - Low latency
   - Long flash lifetime
   - Strong performance isolation
   - High resource utilization

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Methodologies

1. Interface design
   - High-level I/O interface
   - Co-design with host side
   - Physical page addresses (PPAs)
2. FTL design
   - Design dedicated FTLs with different placement strategies to achieve specific performance.



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Methodologies (Cont'd)

1. Interface design
2. FTL design
3. Internal parallelism exploitation
   - Independent channel parallelism
   - Coarse-grained striping
   - Channel-level parallelism with hotness grouping
   - Fine-grained parallelism

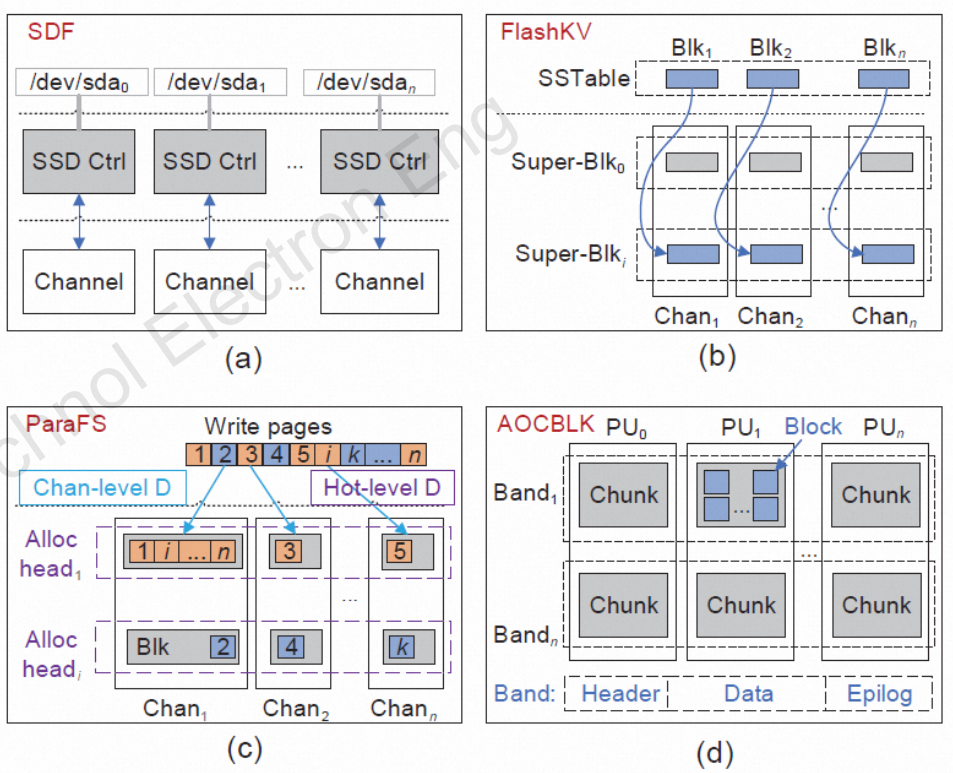


Fig. 6 Four instances of exploiting OCSSD's internal parallelism: (a) SDF; (b) FlashKV; (c) ParaFS; (d) AOCBLK. Chan: channel; Blk: block; D: dimension; PU: parallel unit; OCSSD: open-channel solid-state drive (References to color refer to the online version of this figure)

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Methodologies (Cont'd)

1. Interface design
2. FTL design
3. Internal parallelism exploitation
4. I/O scheduling optimization
   - For overall throughput
   - For read throughput
   - For latency

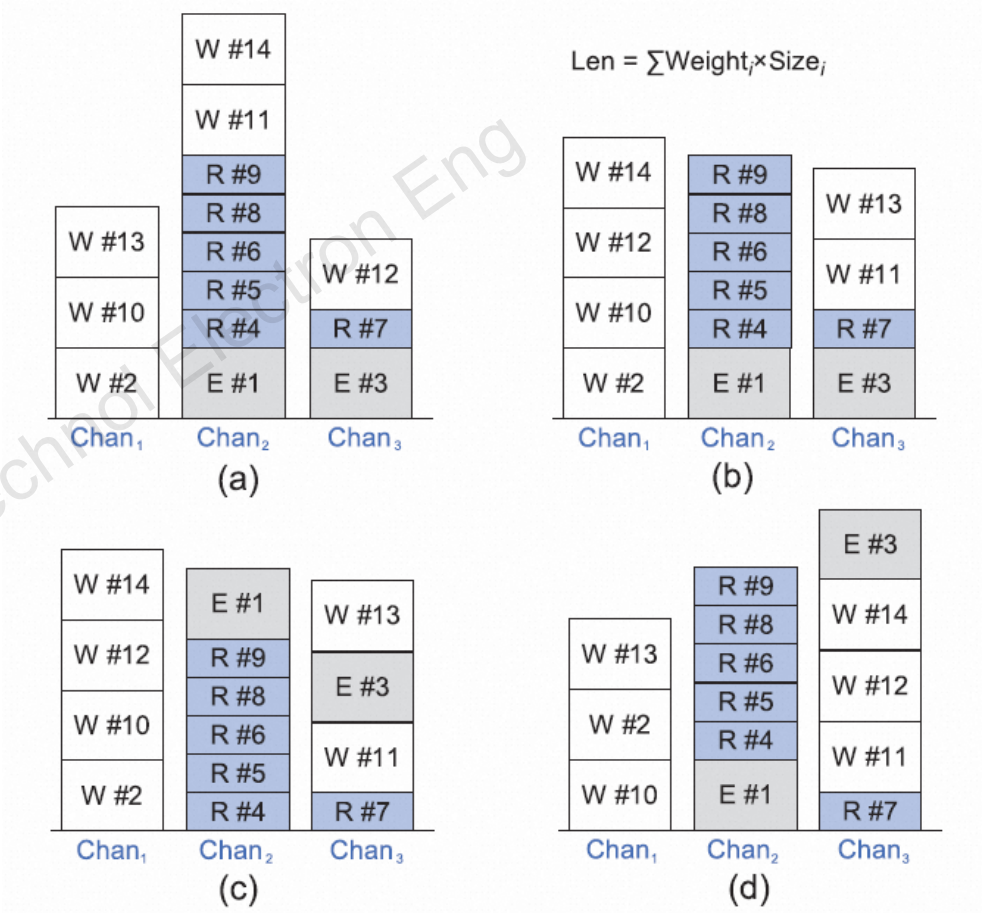


Fig. 7 I/O scheduling policies in LOCS and FlashKV: (a) round-robin dispatching; (b) least weighted-queue-length; (c) scheduling optimization for erase; (d) priority-based scheduling. I/O: input/output; Op: operation; Chan: channel; Pri: priority

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Methodologies (Cont'd)

1. Interface design
2. FTL design
3. Internal parallelism exploitation
4. I/O scheduling optimization
5. Garbage collection (GC) optimization
   - Data locality
   - Hotness grouping
   - Write granularity adjustment
   - Coordinated GC mechanism
   - …

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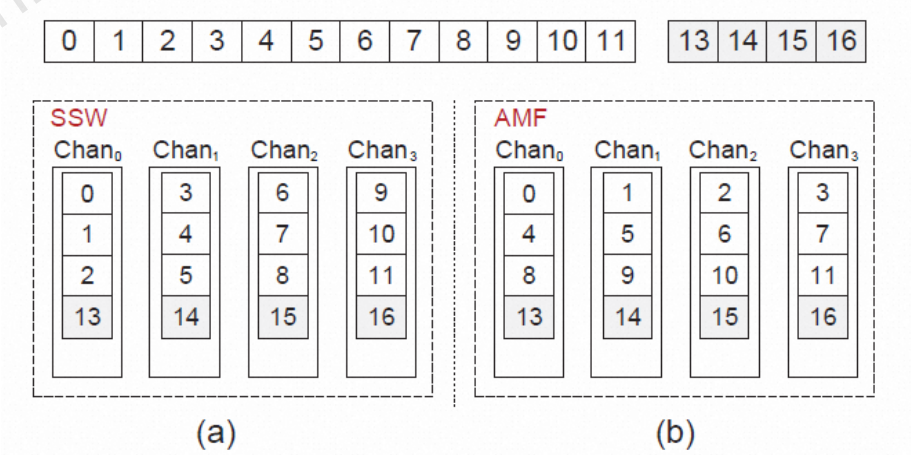


Fig. 9 Data placement strategies in SSW (a) and AMF (b). Chan: channel

Challenges and future directions

1. Challenges
   - Complexity and nonversatility of the FTL design
   - Lack of standards
   - Flexibility, security, and universality
2. Future development
   - NVMe SSDs and multi-stream SSDs earn a great application prospect for their standard and semi-open design
   - Despite facing many huge challenges, users can have more choices to leverage OCSSD’s features for optimal performance and specific goals
   - OCSSDs should form their own standards and norms to better promote their research and application

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Conclusions

1. By moving the FTL to the host side and co-designing with host-side software, open-channel SSDs can achieve better performance such as higher throughput, lower latency, and better resource utilization.
2. Existing studies give us many insightful ideas such as rich FTL co-design at different software layers, full parallelism exploitation at different parallel levels, rational I/O scheduling policies to improve performance, and efficient GC mechanism to reduce performance overhead.
3. Some research issues are still open, and future research efforts especially in domain-specific areas, need to take all factors into consideration, including standards, universality, products, and performance.

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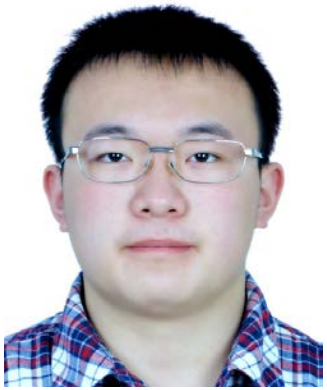


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