DISKSHIELD: A Data Tamper-Resistant Storage for Intel SGX

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Motivation: The dangers of ransomware

Motivation: Two characteristics of powerful ransomware

1. Ring-0 level rootkit malware

- Disabling the system (OS) using the latest exploits.

2. Backup data attack

- Deleting all local or remote backup files of infected computer.

Motivation: Two characteristics of powerful ransomware

1. Ring-0 level rootkit malware

- Disabling the system (OS) using the latest exploits.

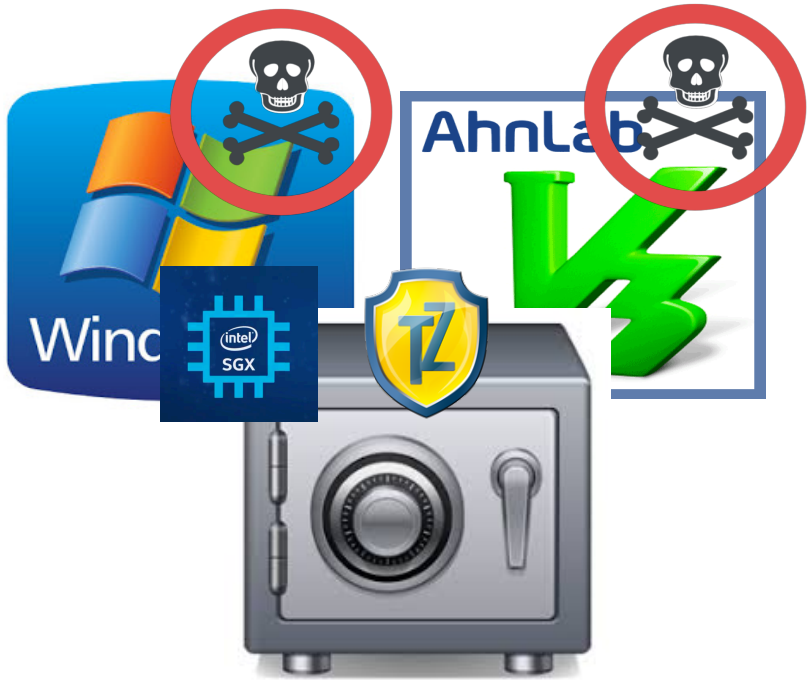
Defense against data tampering attack:
Isolation from OS + Safe Disk Partition from Malware

- Deleting all local or remote backup files of infected computer.

Opportunity: TEE and Storage devices

Trusted Execution Environment(TEE)

TEE provides code and data areas isolated from the OS.

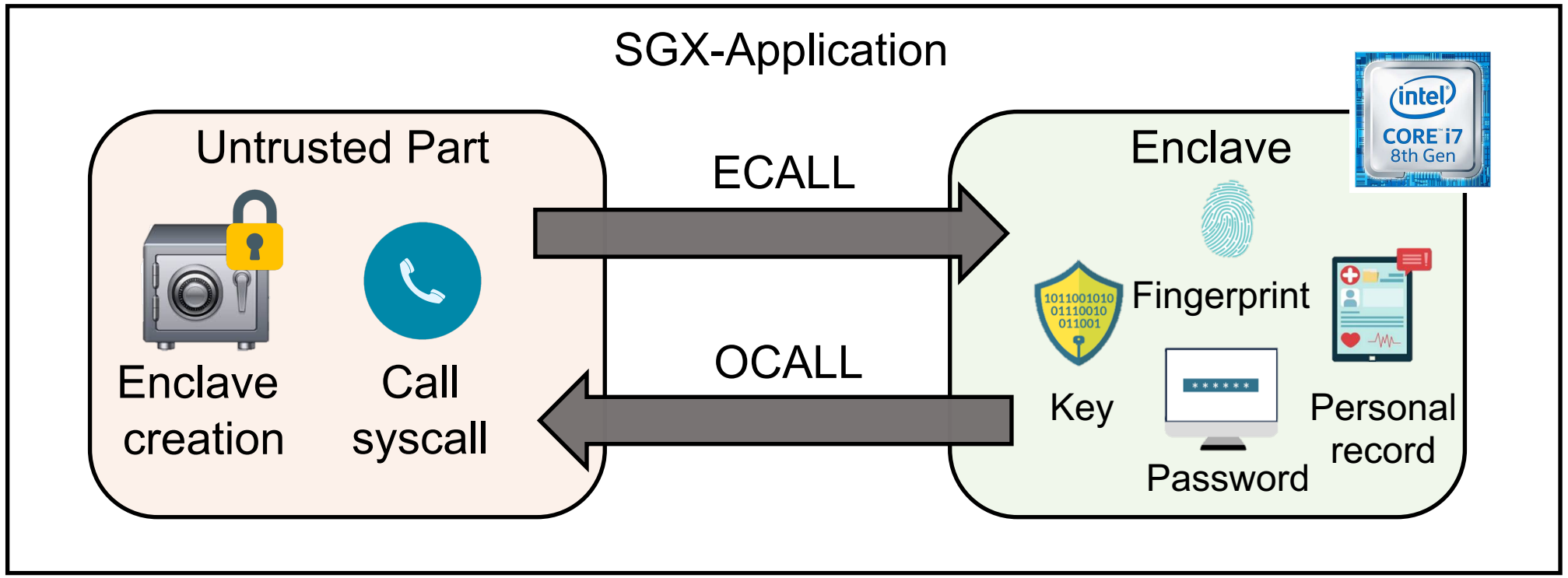


Defense on storage devices

Storage is the last barrier to storing data

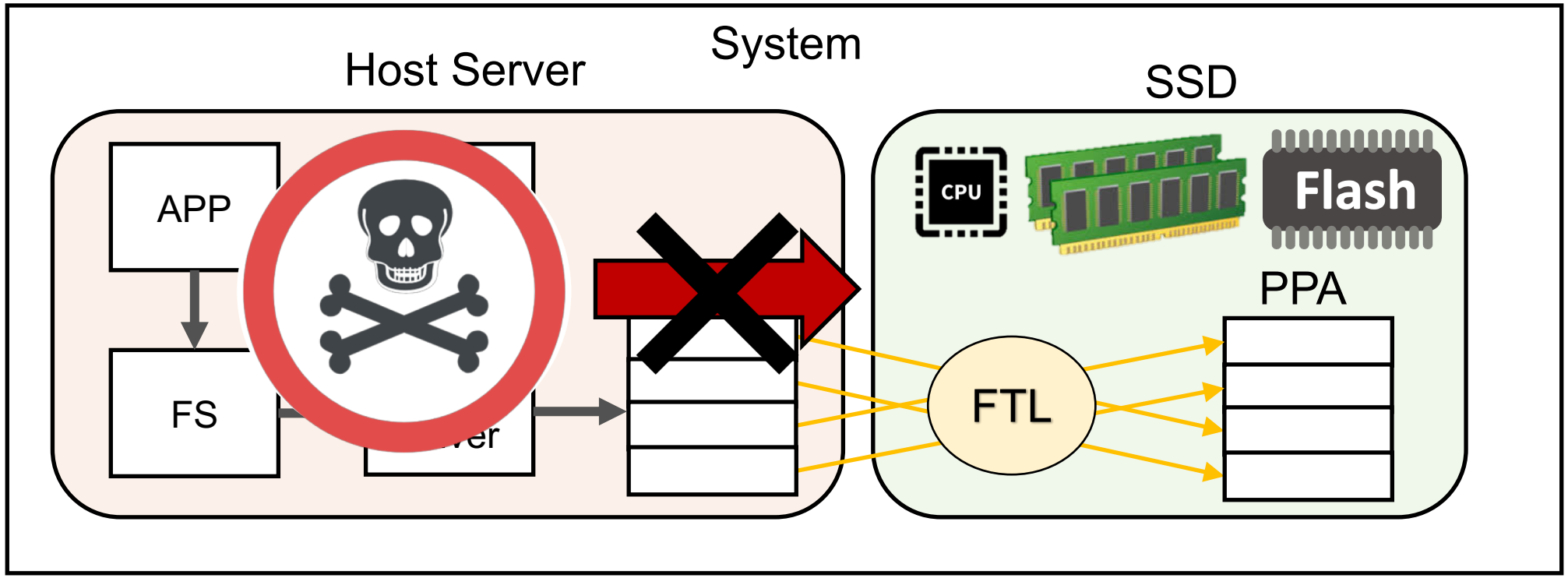
Background: Intel SGX

- Intel SGX guarantees the **confidentiality** and **integrity** of applications even if system components such as OS are damaged.



Background: Solid State Drive

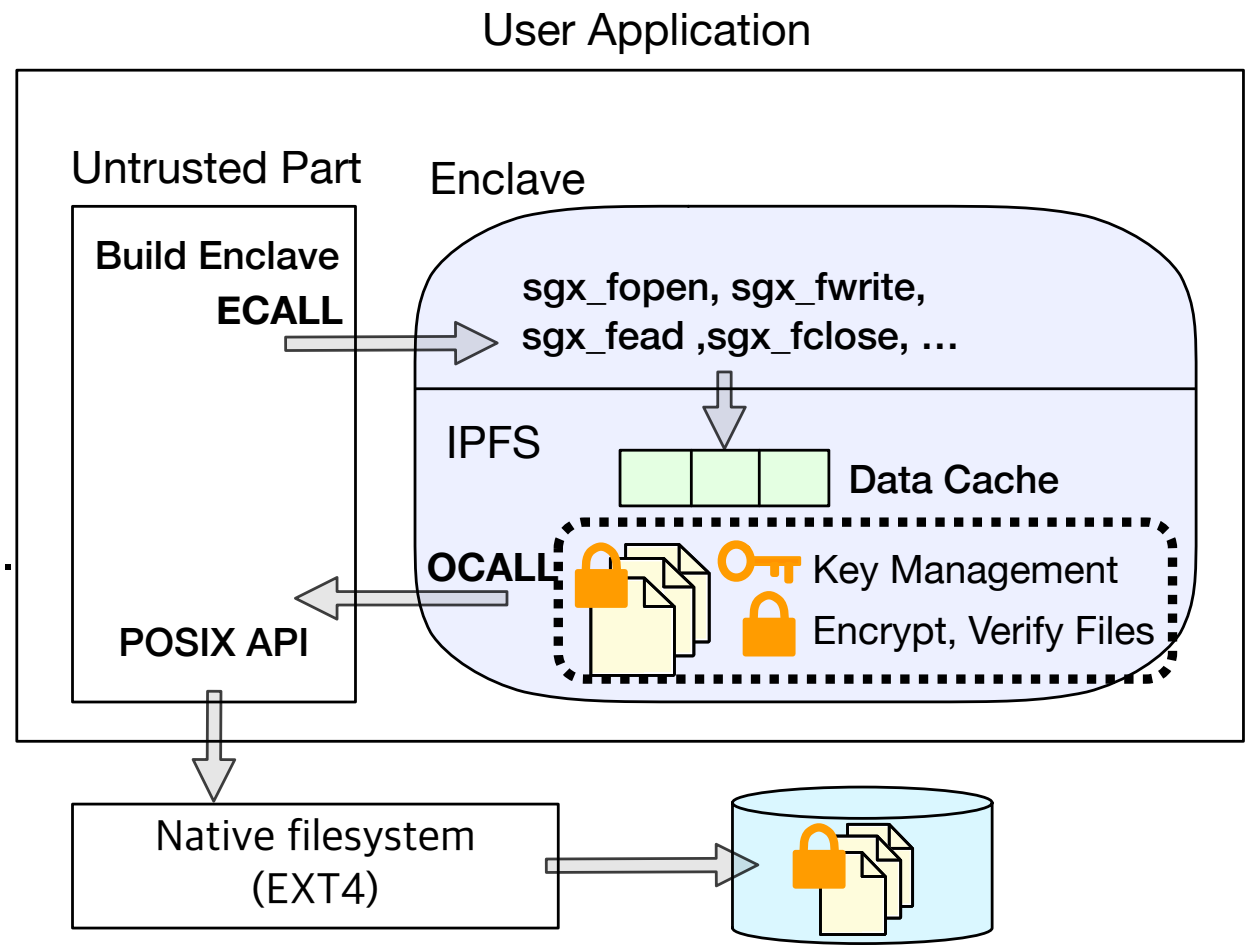
1. In-device computation capability
2. Isolated space from host server



Related work: Intel Protected File System(IPFS)

1. TEE-based solution: IPFS
   - IPFS guarantees the confidentiality and integrity of files created by SGX application.
   - IPFS is a user-level file system dependent on native filesystem(EXT4).

- **WRITE : Encrypt & Sign Data**
- **READ : Decrypt & Verify Data**

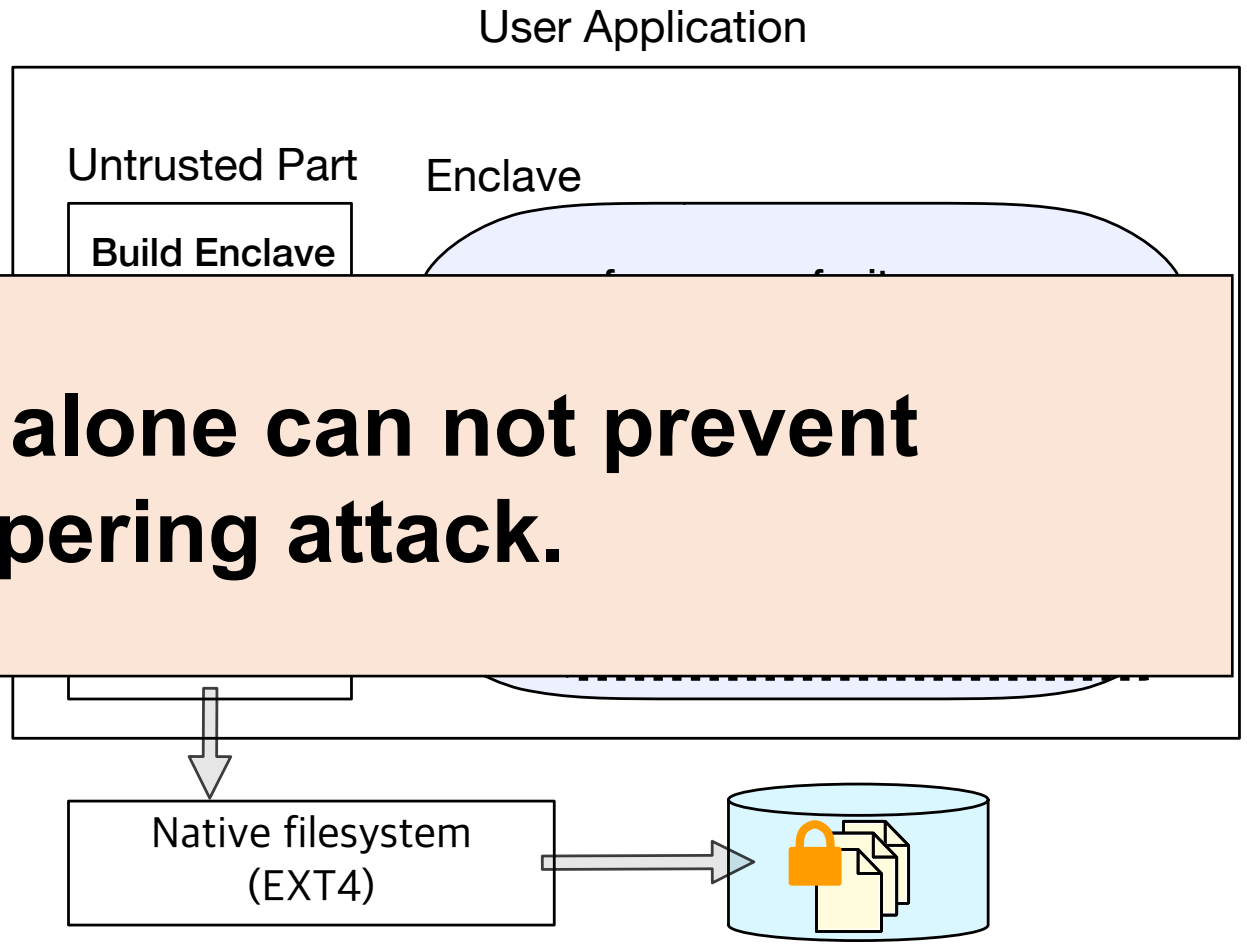


Related work: Intel Protected File System(IPFS)

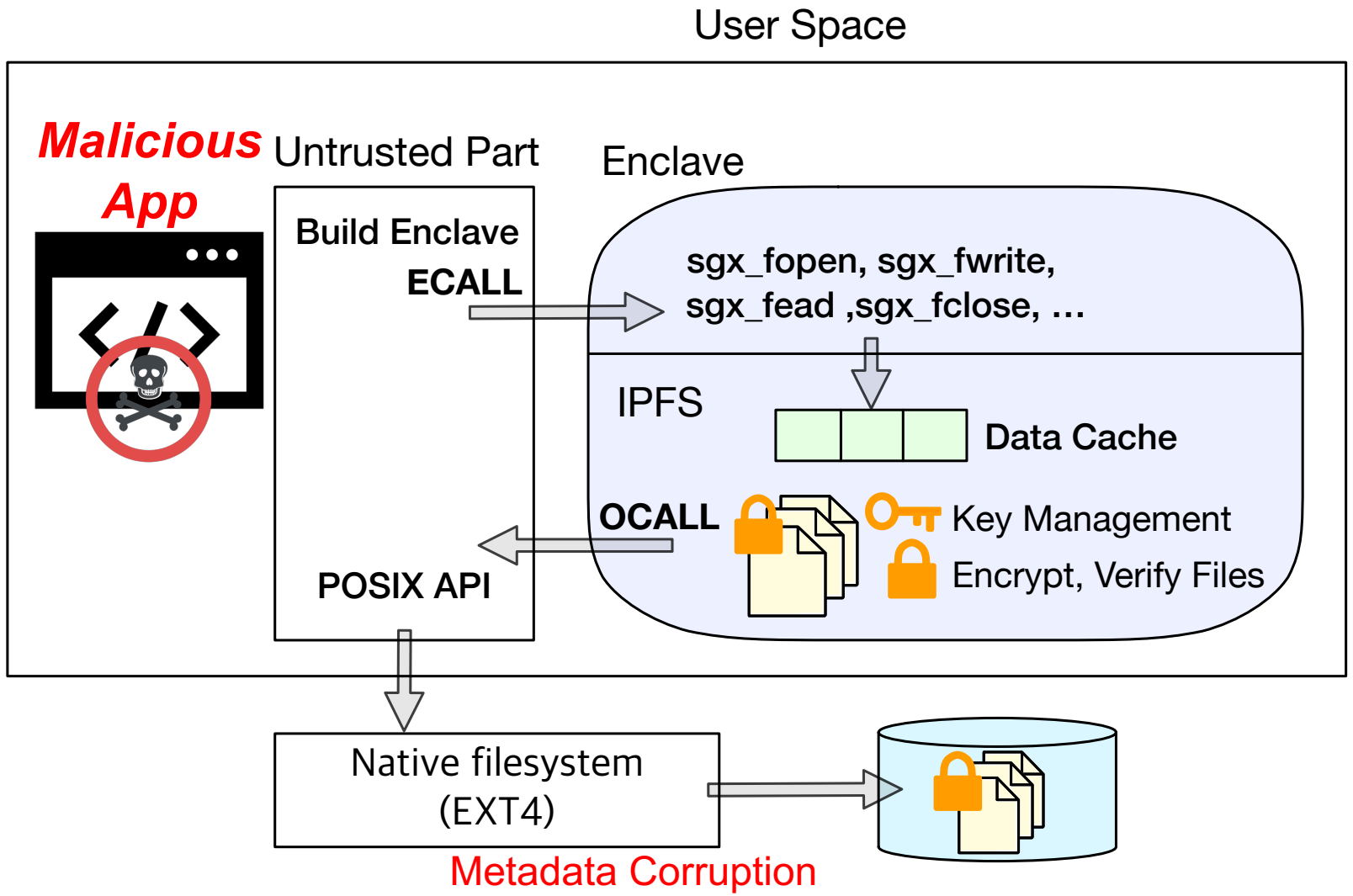
1. TEE-based solution: IPFS
   - IPFS guarantees the confidentiality and integrity of files created by SGX

Read verification alone can not prevent data tampering attack.

- **WRITE : Encrypt & Sign Data**
- **READ : Decrypt & Verify Data**



Related work: limitation of IPFS



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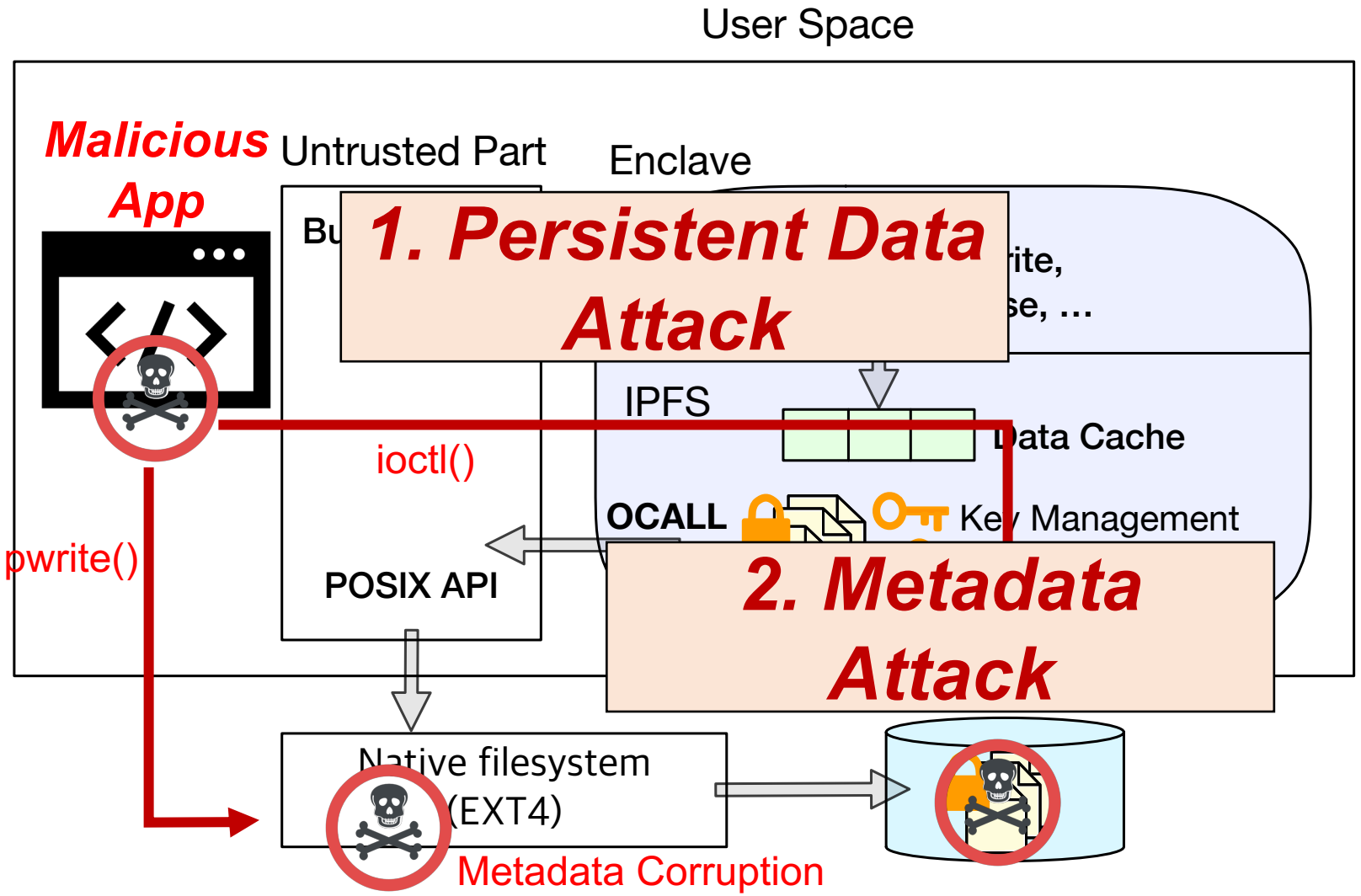
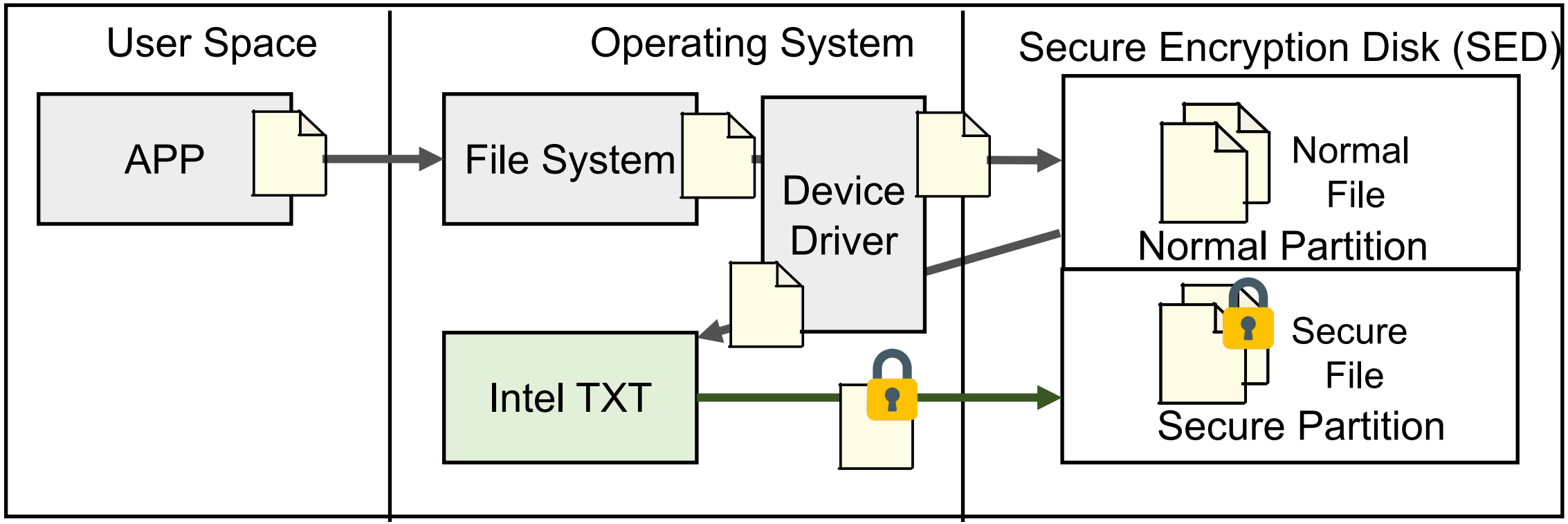


Related work: Inuksuk

2. TEE + Disk based solution: 2. Inuksuk



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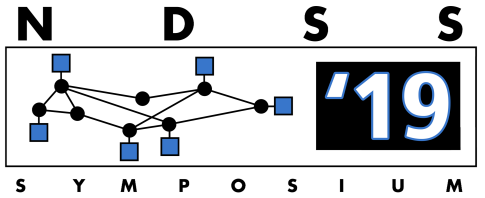
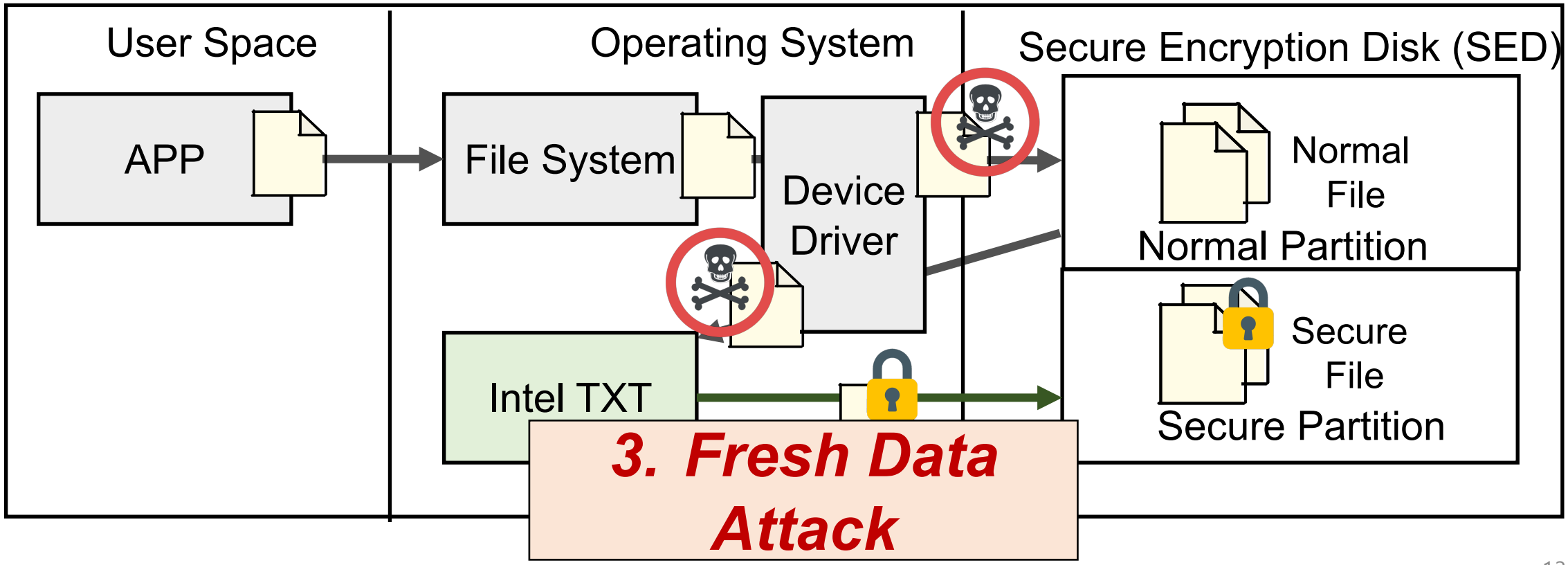
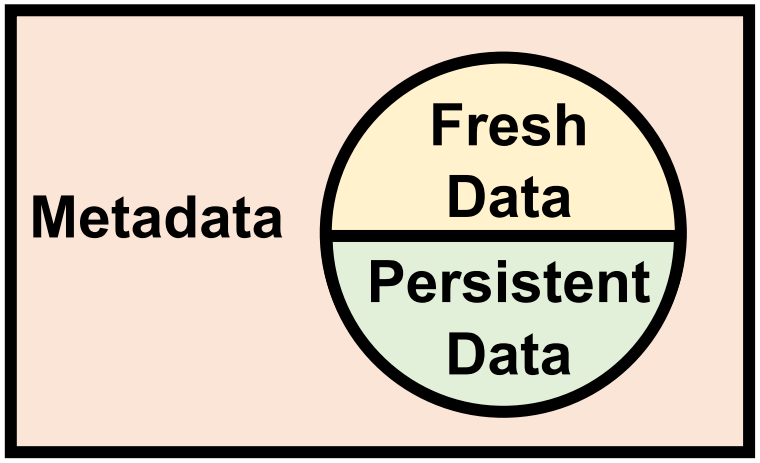




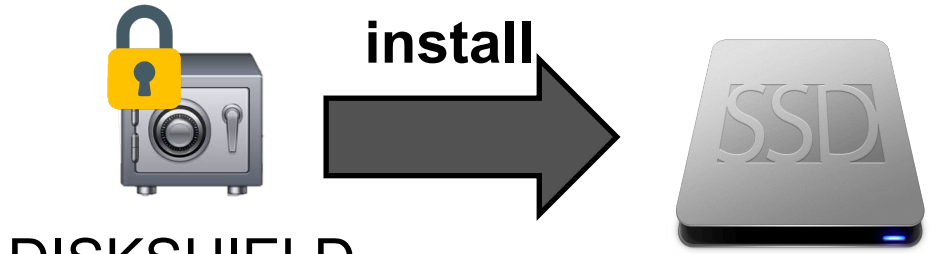
System proposal: DISKSHIELD

- Robust data-tampering resistant storage system from privileged malware.
  - Protect all kinds of data: persistent data, fresh data, metadata.
- It runs without additional disks in local environment.
  - No additional cost is required for purchasing external disk.

File attack surface:



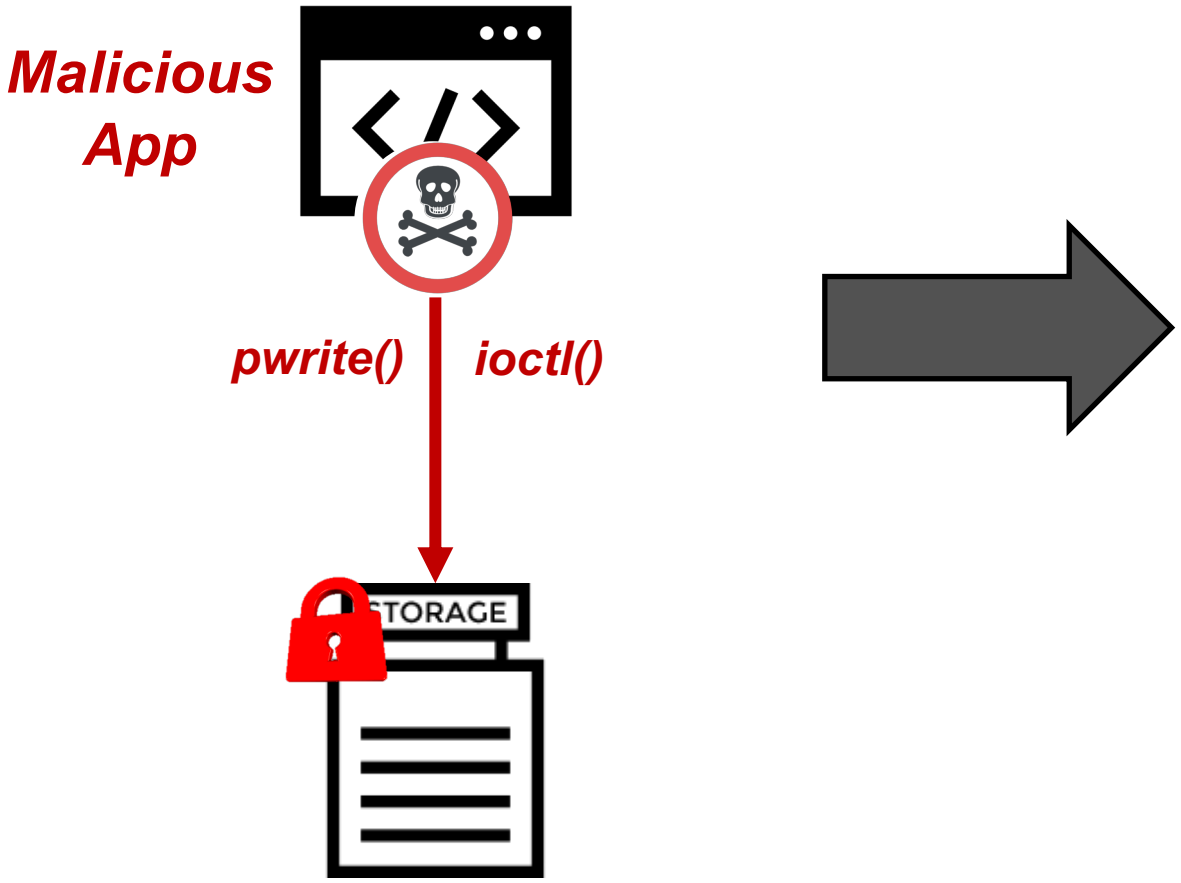
Firmware update to existing SSD!



DISKSHIELD

System proposal: Data protection from any attack surface

Persistent data attack



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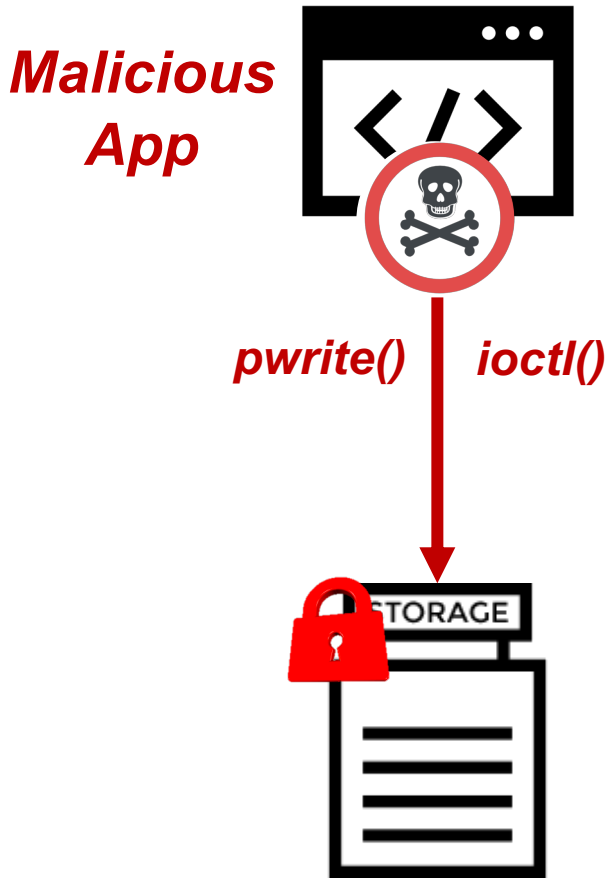
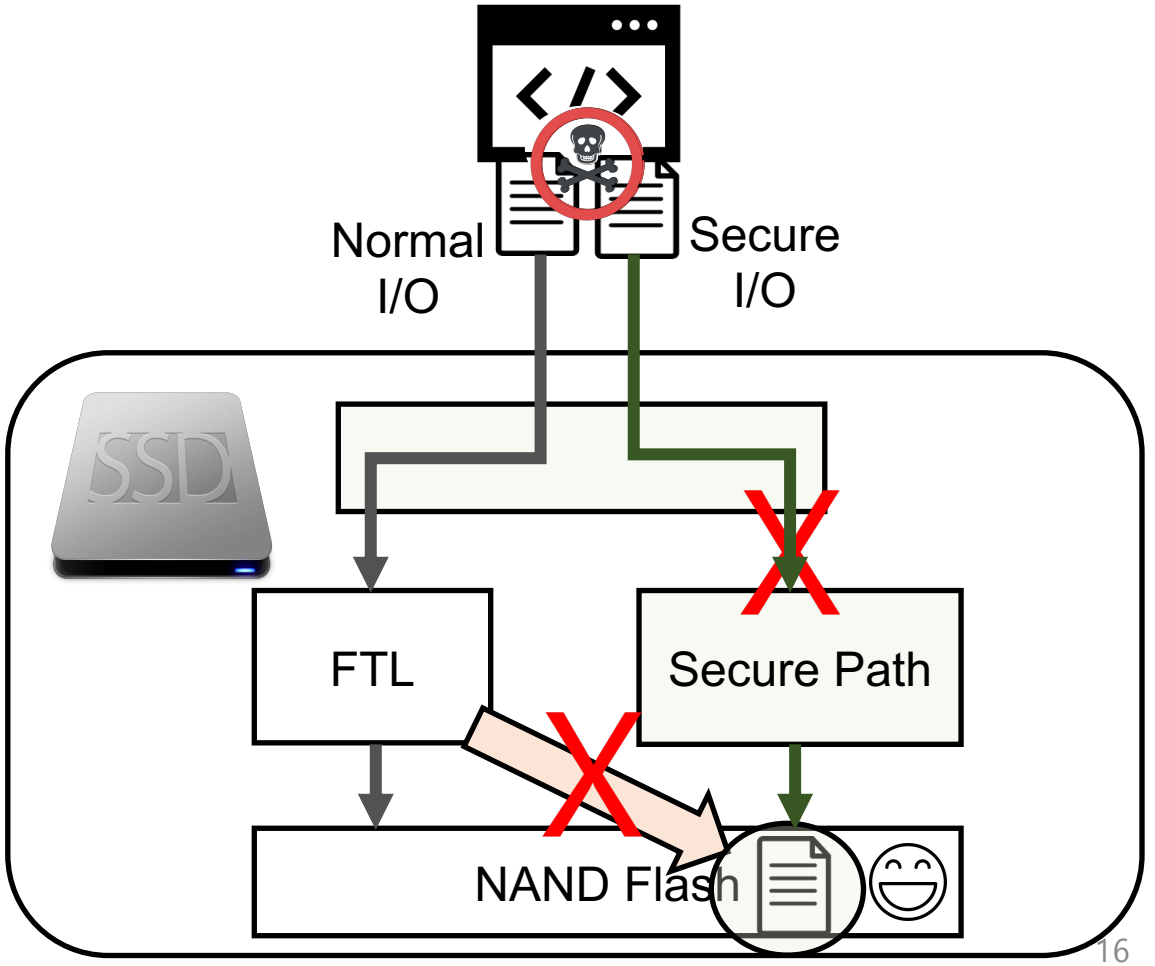


Access control in device



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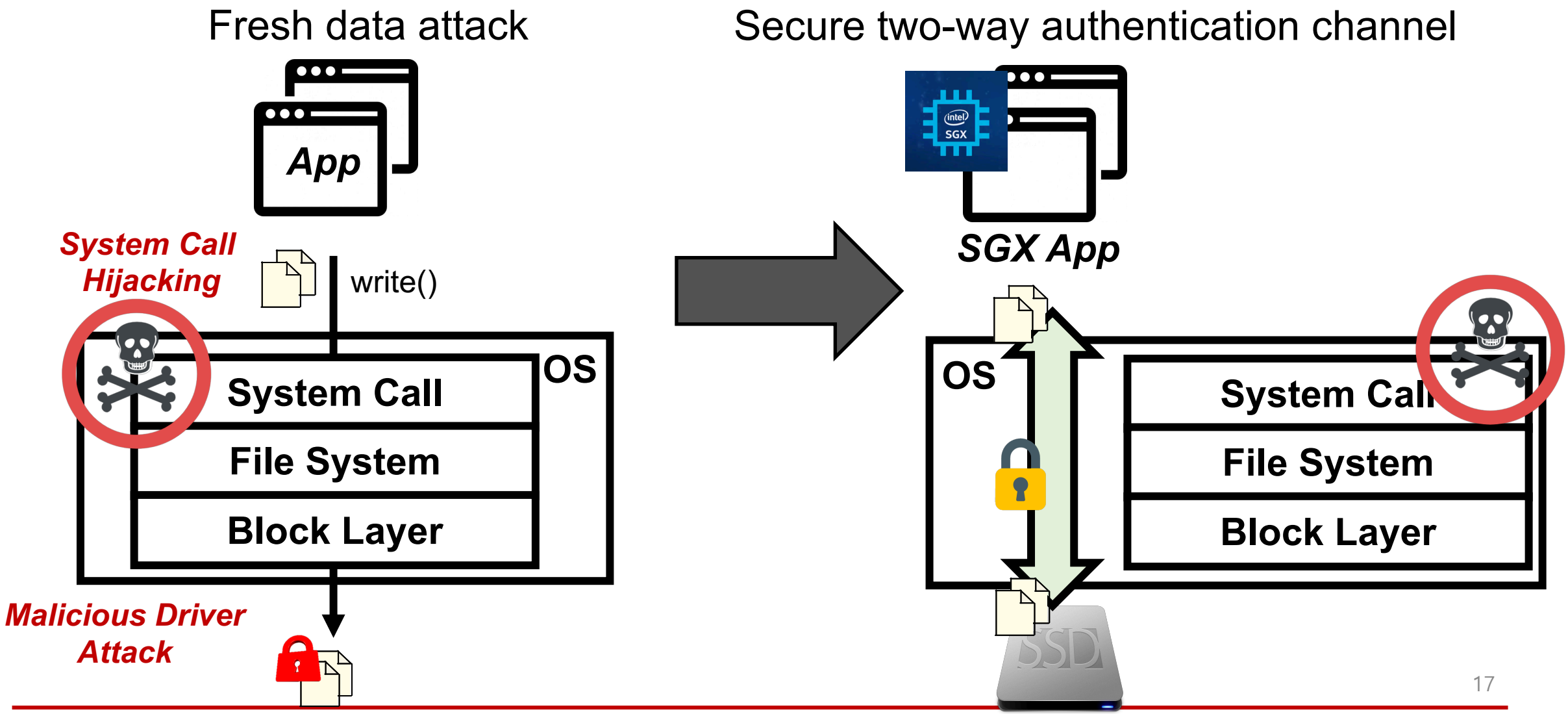

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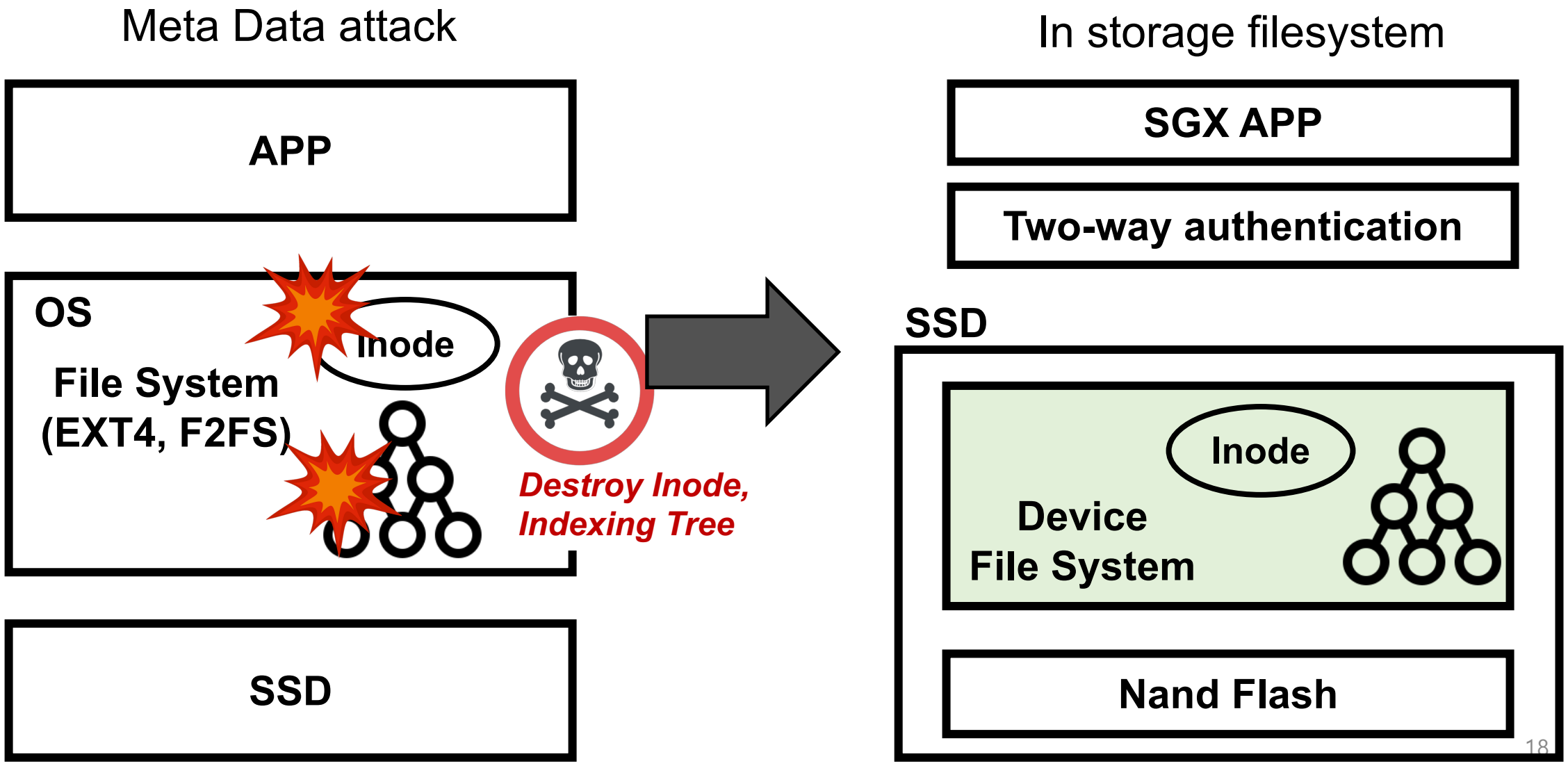
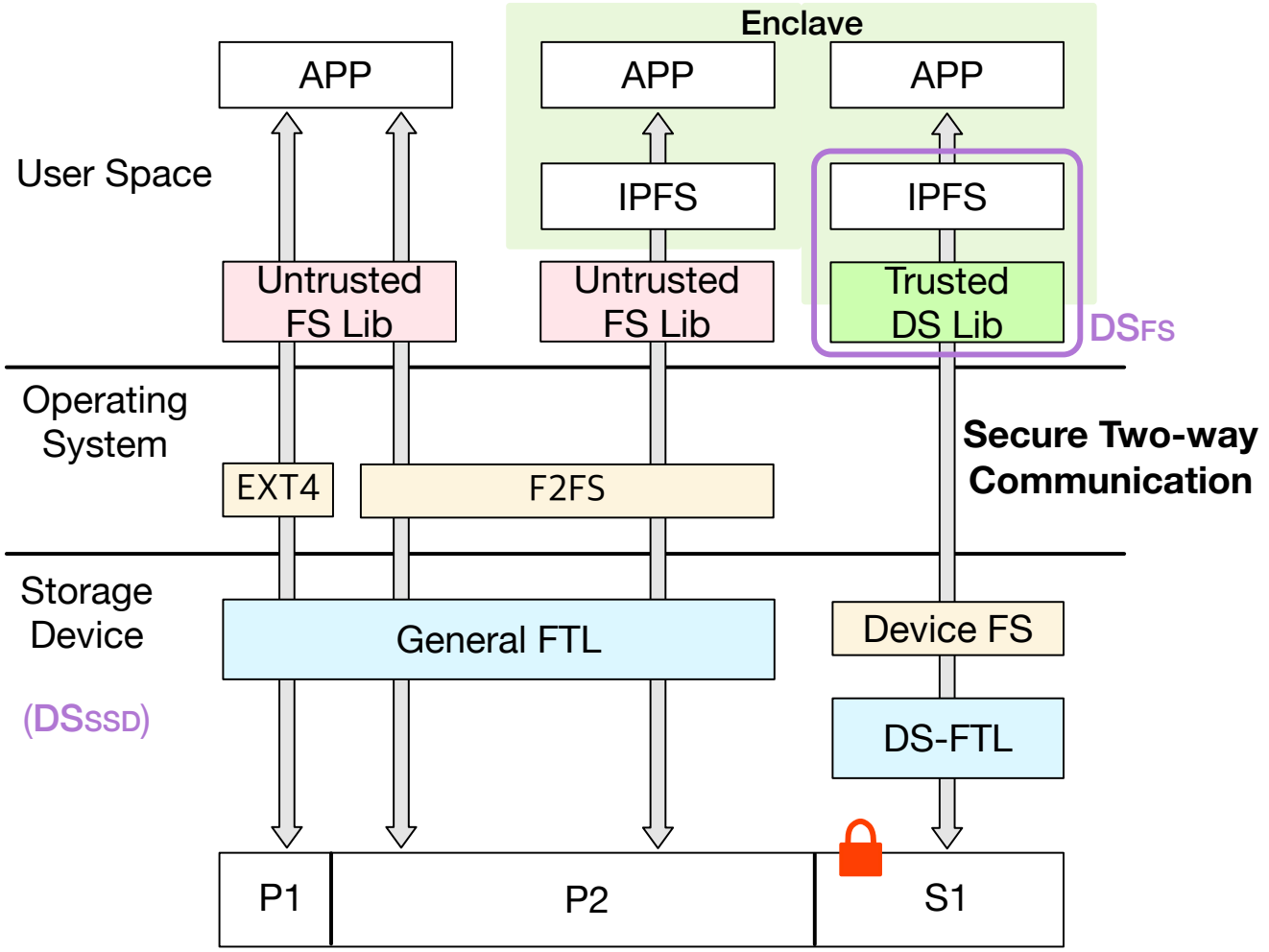


Design & Implementation: system components



DSFS :
-Extension of IPFS in SGX
-Two-way authentication module

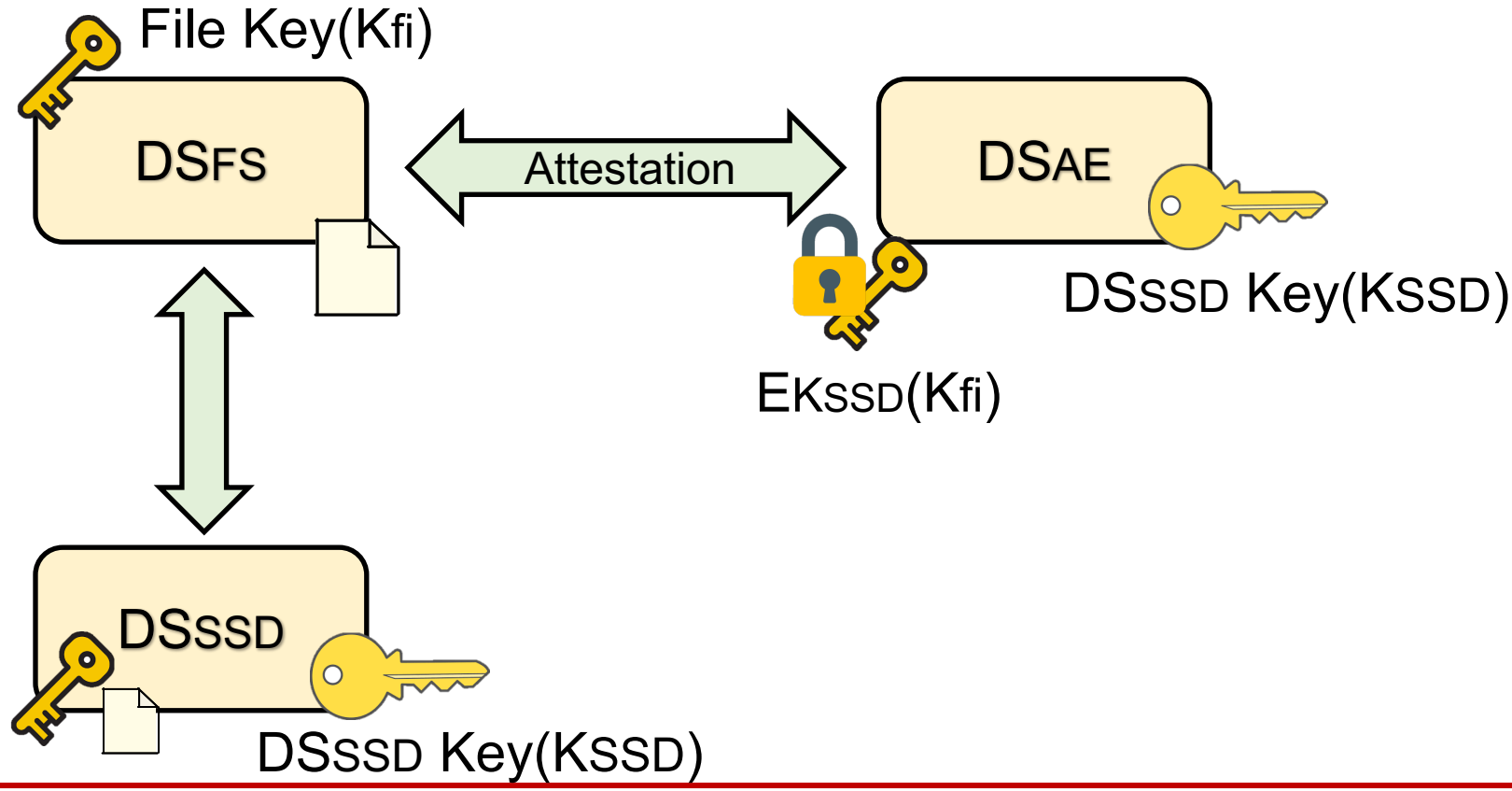
DSSSD :
-SSD Firmware implmentation
-Device filesystem
-Device level authentication system

DSAE :
-Key manager between DSFS and DSSSD

Design & Implementation: ***DSAE***

DSAE enables two-way authentication by sharing a file key between DSFS and DSSSD.

When creating a file, the key generated by DSFS is securely shared with DSSSD.



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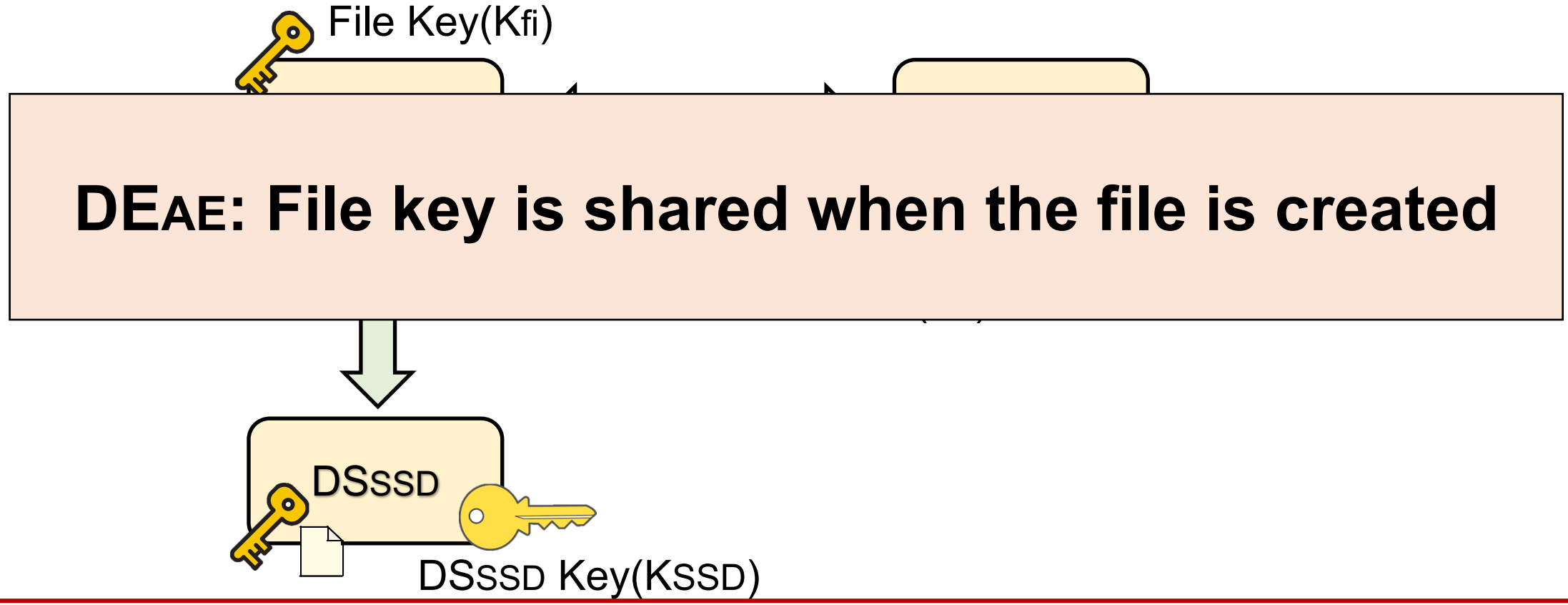
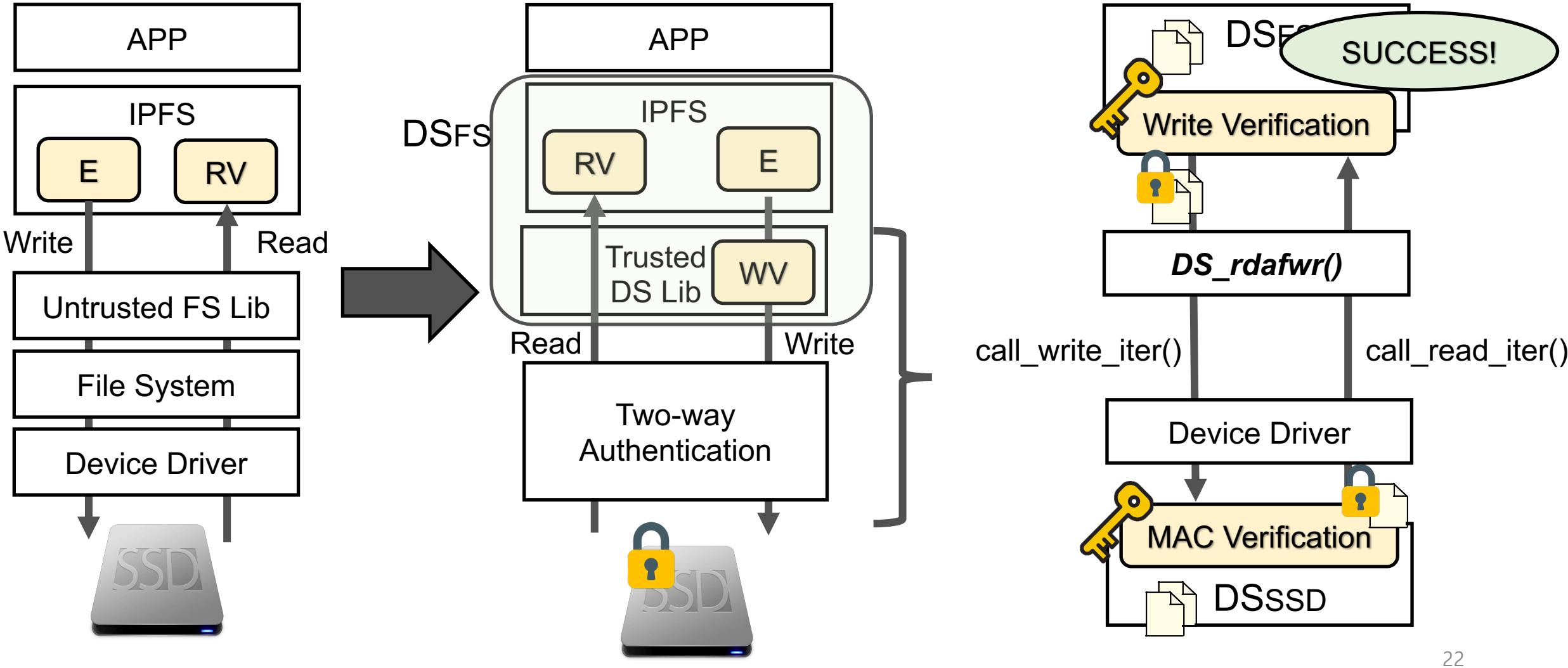
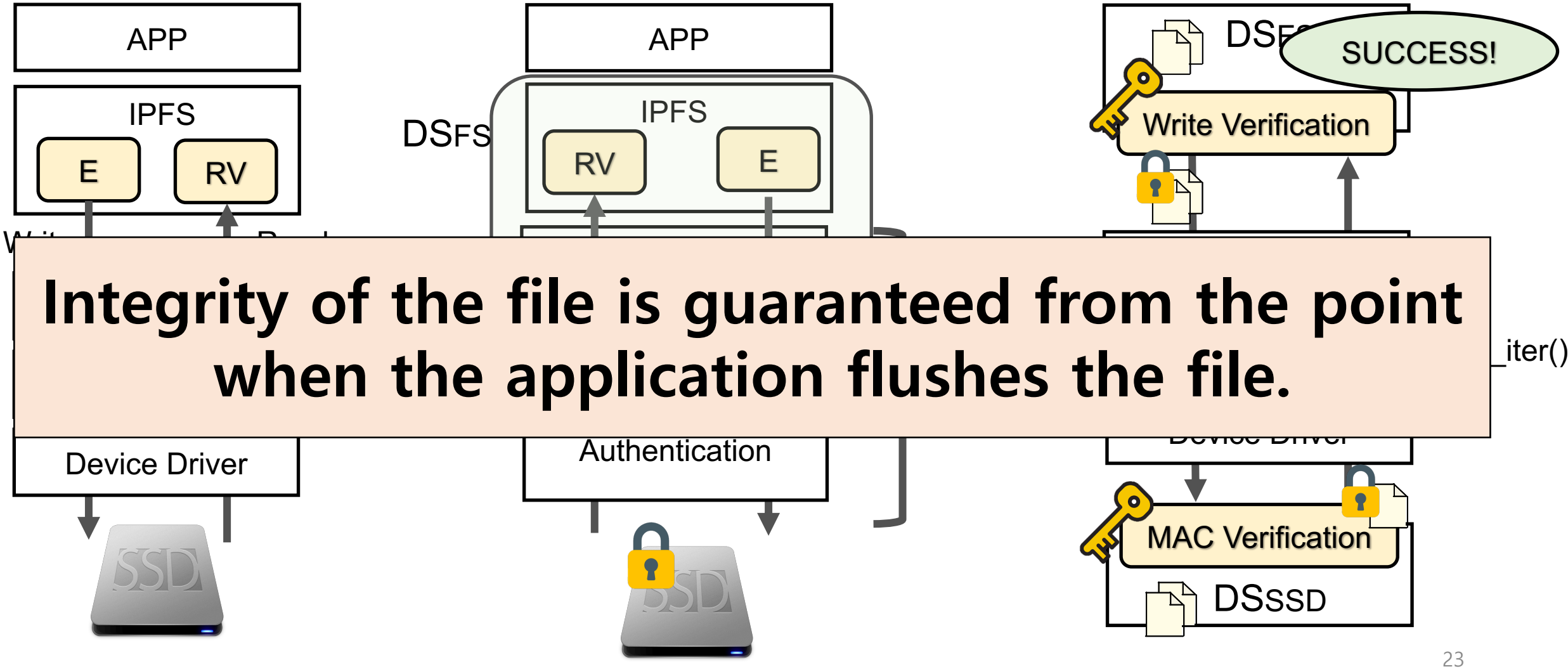


Design & Implementation: ***DSFS***

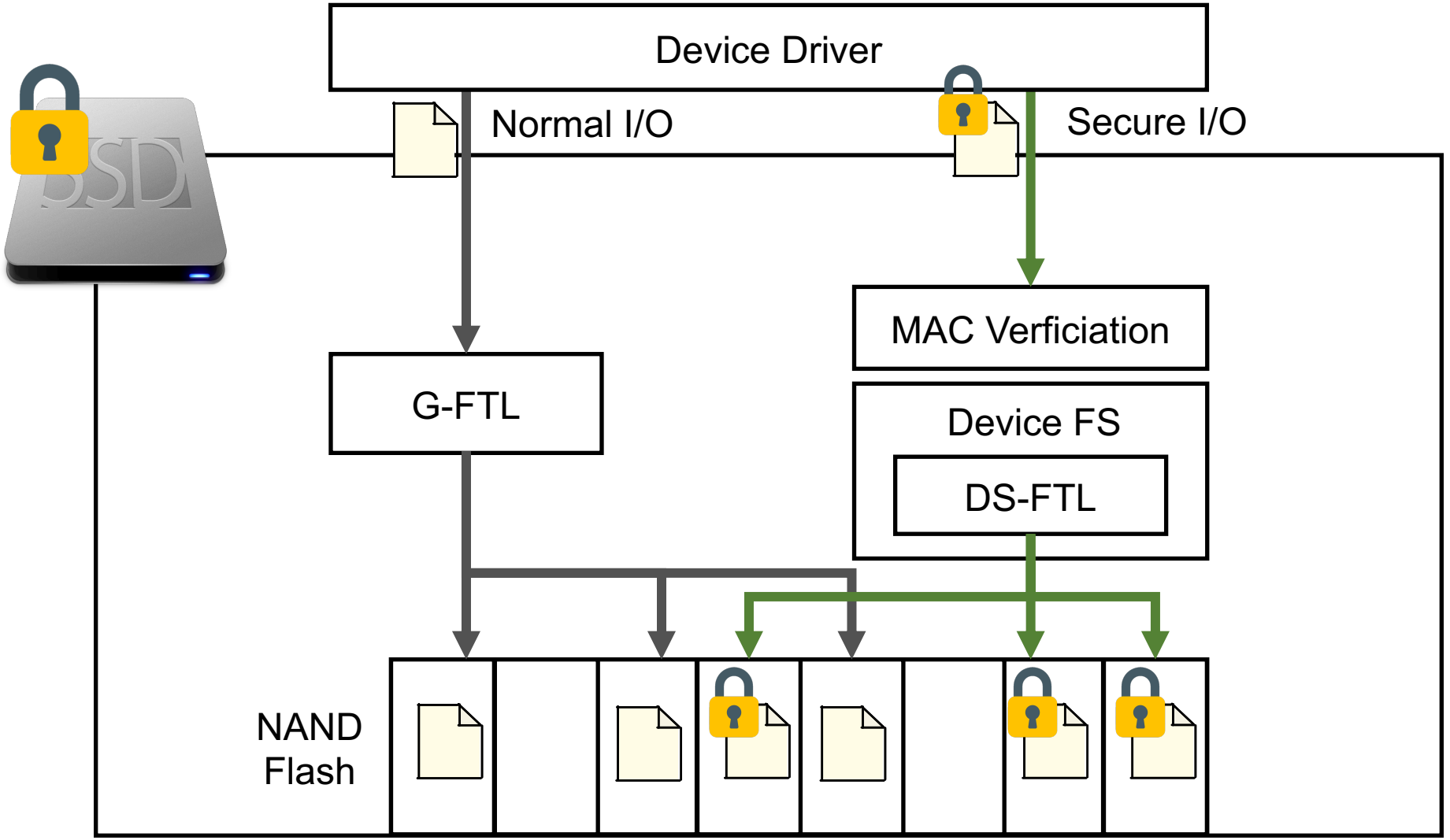


Design & Implementation: ***DSFS***

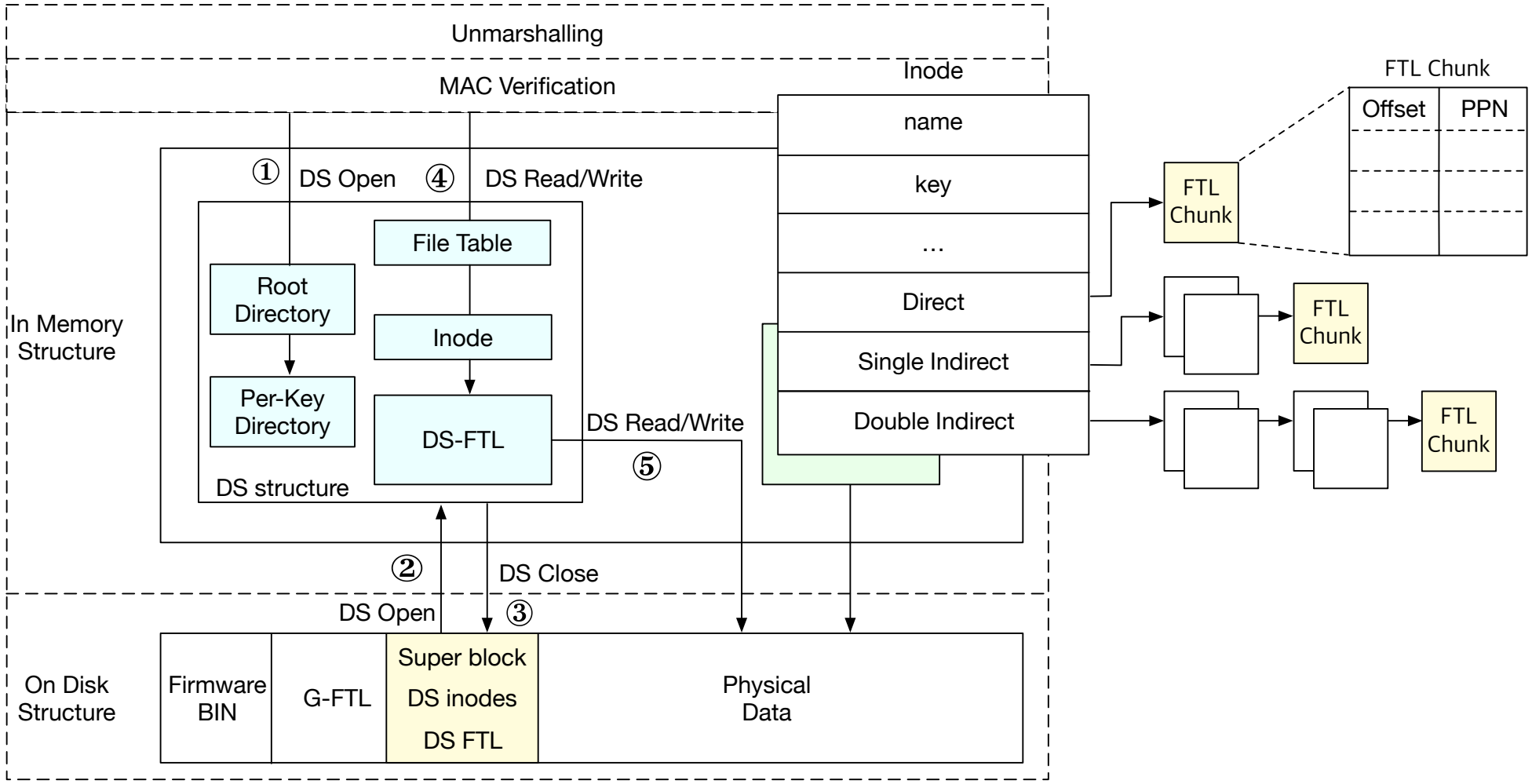


Integrity of the file is guaranteed from the point when the application flushes the file.

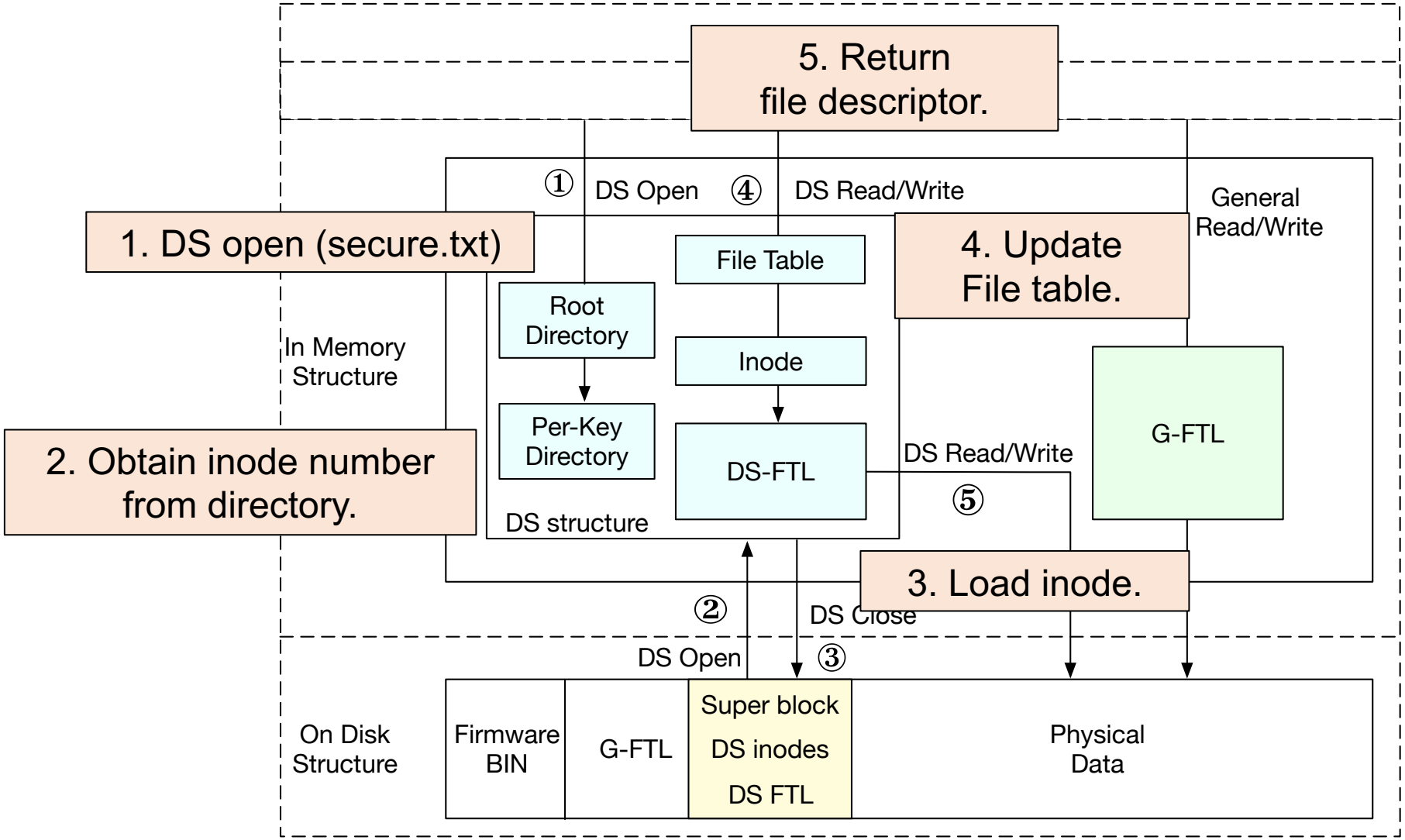
Design & Implementation: ***DSSSD***



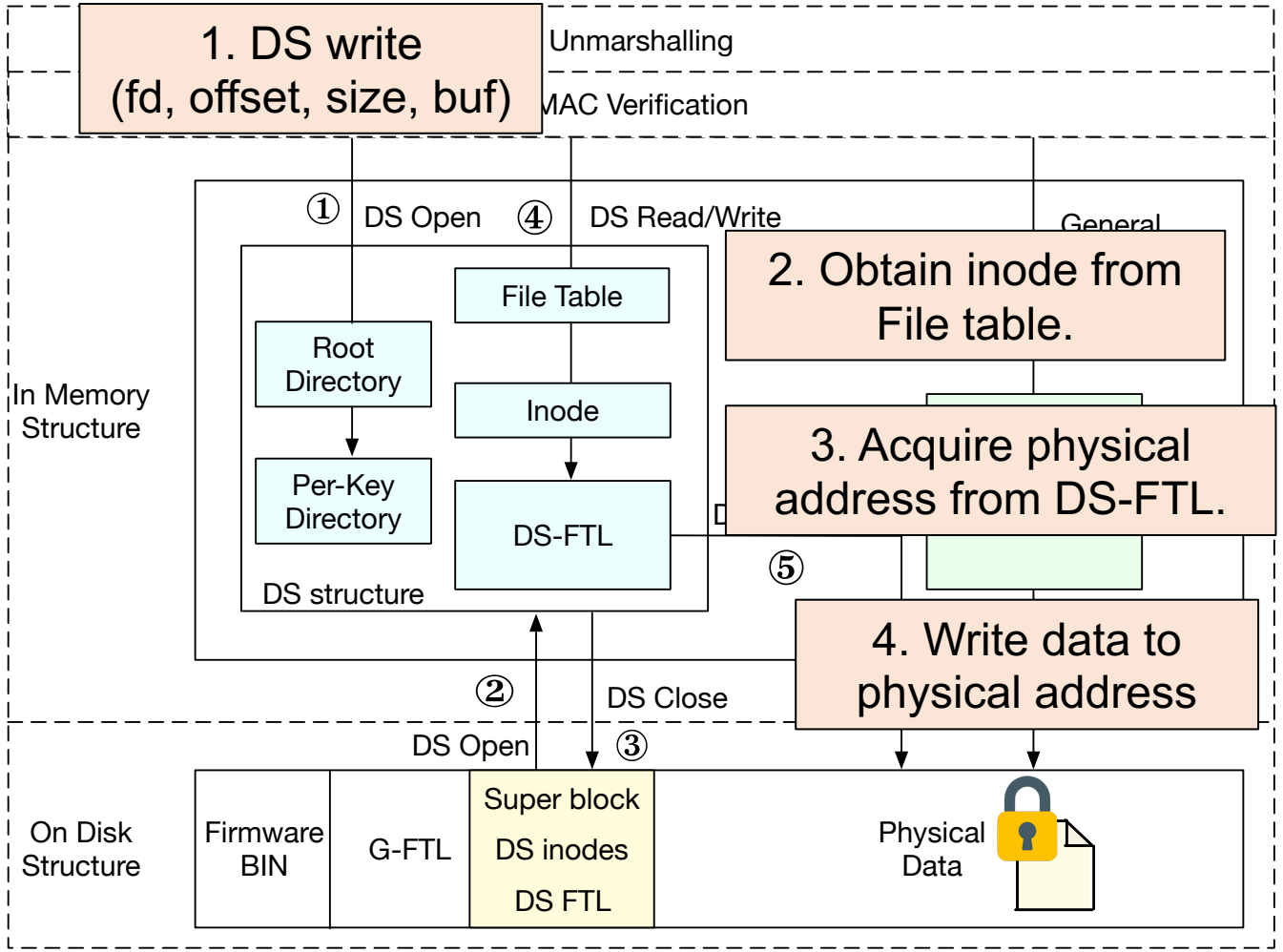
Design & Implementation: ***DSSSD***



DSSSD : secure file open flow



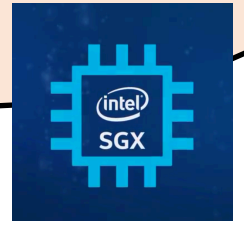
DSSSD : secure file write flow



Evaluation: Prototype implementation

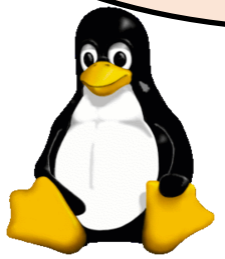
SSD: 2661 Loc
Kernel: 243 Loc
SGX SDK: 791 Loc

DSFS, DSAE

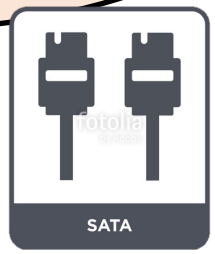


Intel SGX

Two-way Authentication Module

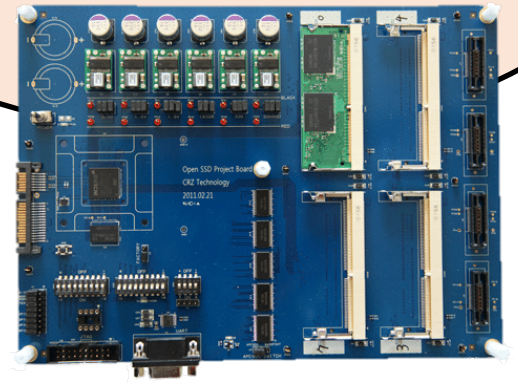


Linux 4.10.16



SATA Interface

DSSSD



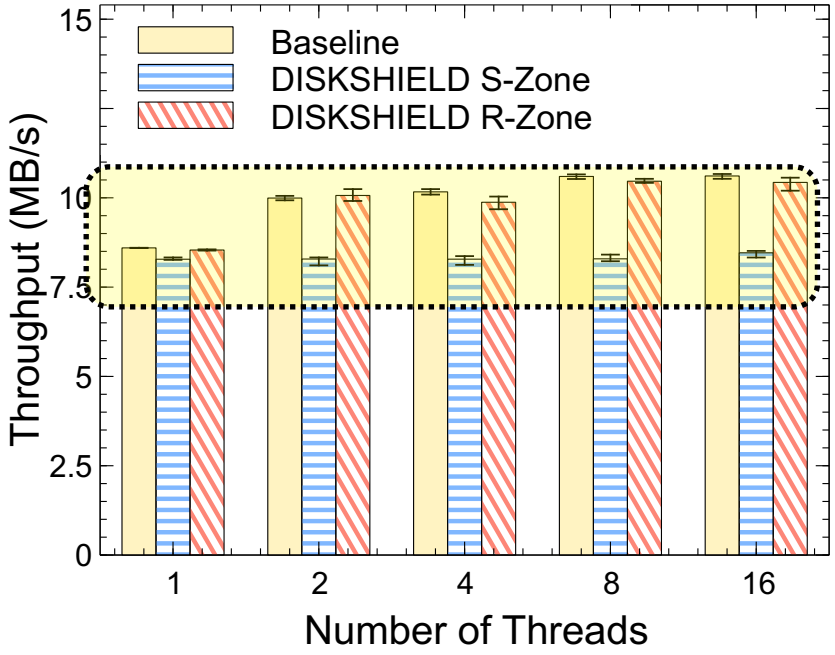
Open SSD Jasmine

Evaluation

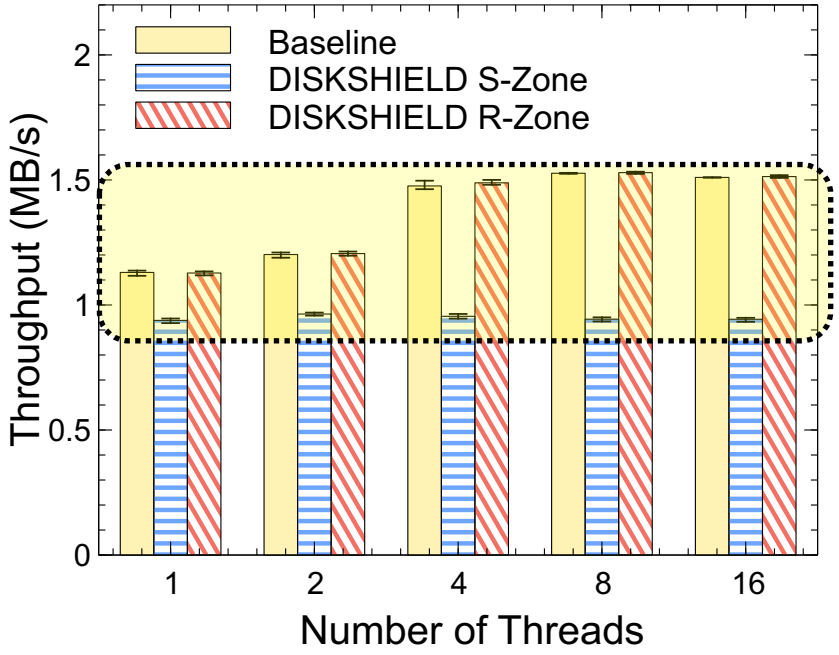
Baseline, R-zone: Normal I/O
S-zone: Secure I/O

Baseline : IPFS + EXT4 + Normal SSD
R-zone : IPFS + EXT4 + DSSSD (normal)
S-zone : DSFS + DSSSD (secure)

1. Baseline and R-zone throughput are the same
- **There is no normal I/O overhead of DSSSD.**



Big file Read



Big file Write

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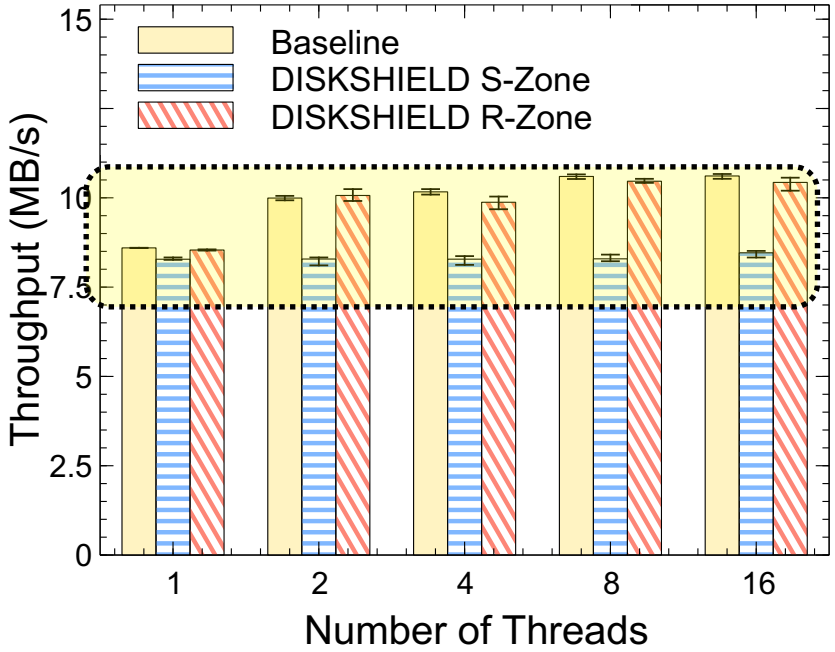

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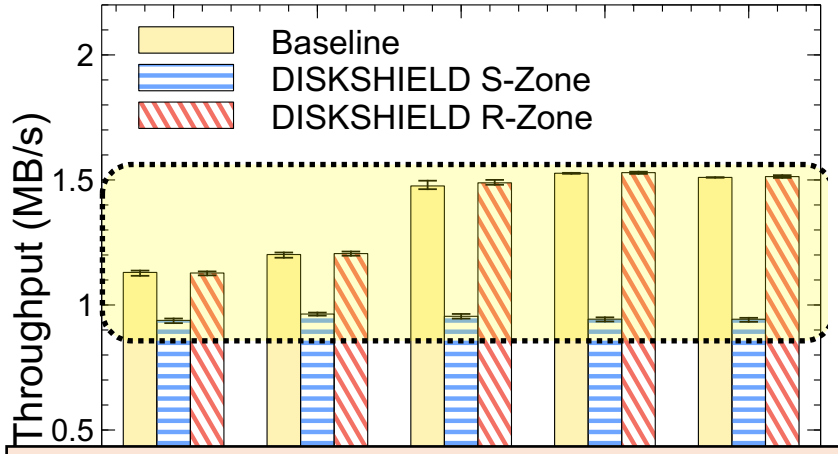

1. Baseline and R-zone thr
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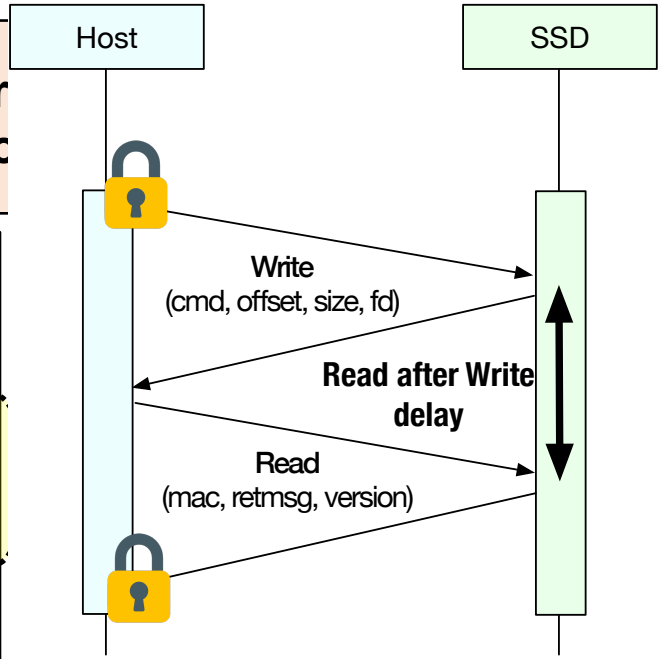
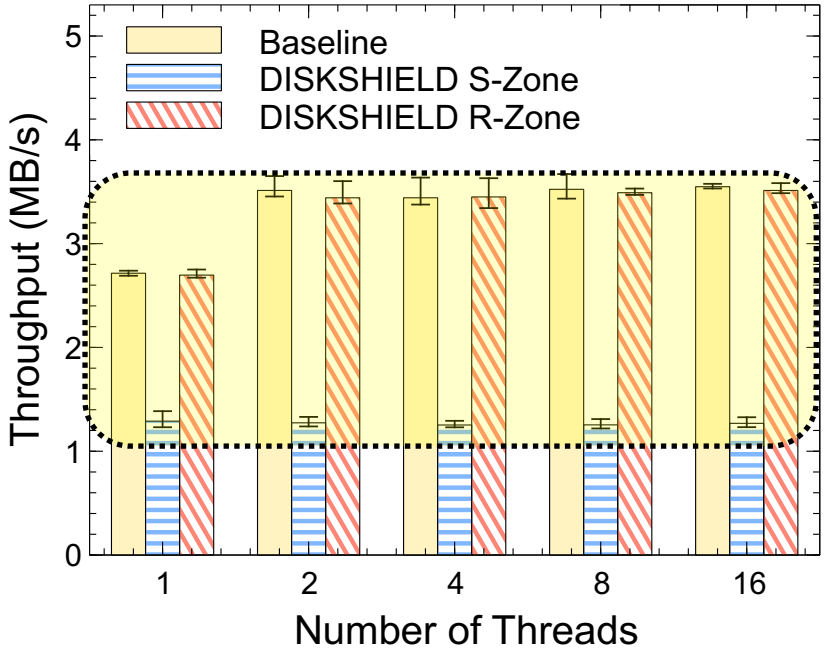


2. In S-zone, throughput was 17% lower than baseline.
- **Two-way authentication module overhead**

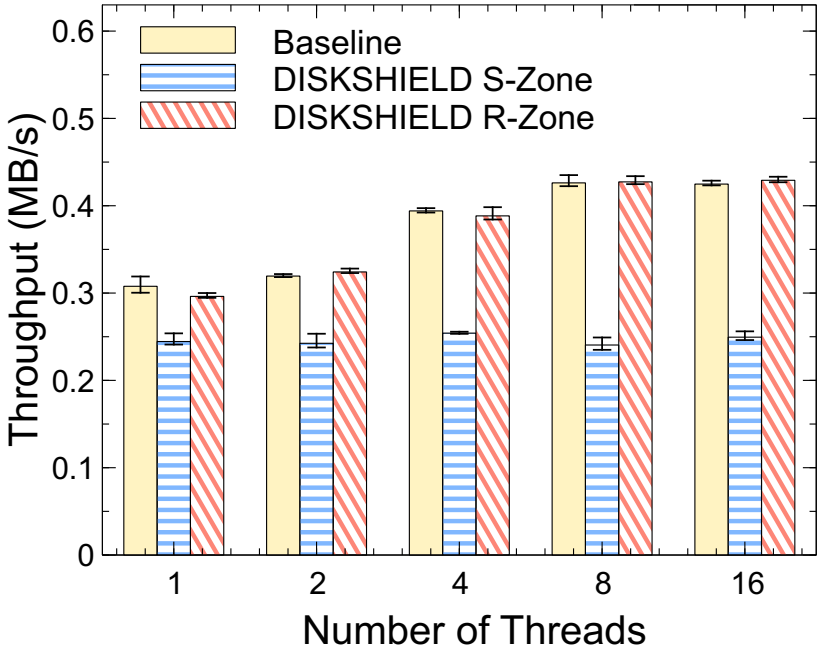
3. S-zone is not scalable even if the number of threads increases.
- **Corase-grained lock of two-way authentication module**

Evaluation

1. S-Zone's read throughput drops by more than 50%.
- Overhead to load/store multiple inodes in DSSSD
  - DSSSD loads only one inode. -> No cache effect!
  - It should prefetch multiple inodes at once like EXT4 filesystem.



Small file Read



Small file Write

Conclusion

- DISKSHIELD guarantees file integrity from privileged data tampering attacks.
  - Defense of all attack surfaces: Persistent data attack, Fresh data attack, metadata attack
- DISKSHILED runs in local environment without additional disk.
  - It can be implemented only by firmware update to existing SSD without hardware cost.

DISKSHIELD: A Data Tamper-Resistant Storage for Intel SGX

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