SHIELD: Encrypting Persistent Data of LSM-KVS from Monolithic to Disaggregated Storage

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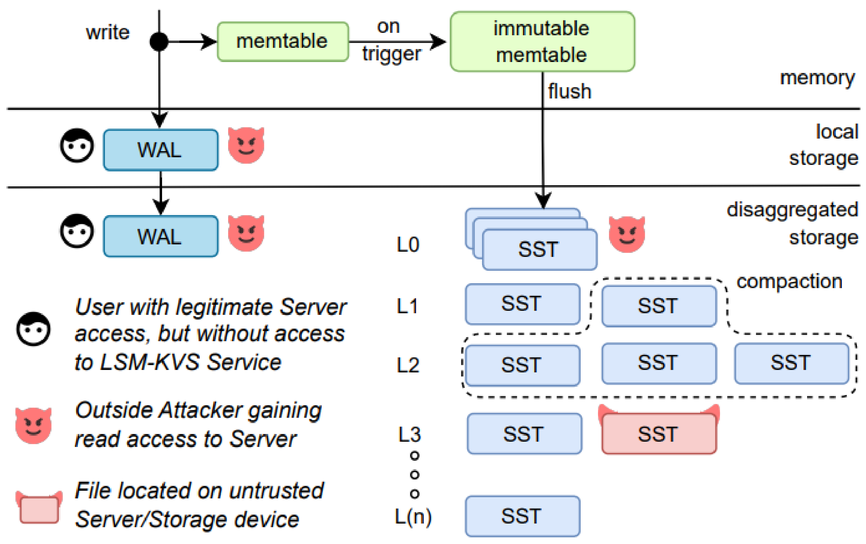
THREAT MODEL

Plaintext LSM-KVS files on multiple servers with untrusted applications and large attack surface.



MOTIVATION

- LSM-KVS in disaggregation has components (compaction, storage, WAL) across servers. **Solution must be flexible to disaggregated setups**.
- Data Encryption Key (DEK) **practices (Unique DEK per file and DEK-rotation) necessary** for robust protection in disaggregation.
- SOTA presents **high overhead (350-3,750%)** from using hardware-based TEEs. It's focus on in-memory protection **misses bottlenecks** (WAL-write), while using a **single DEK**.

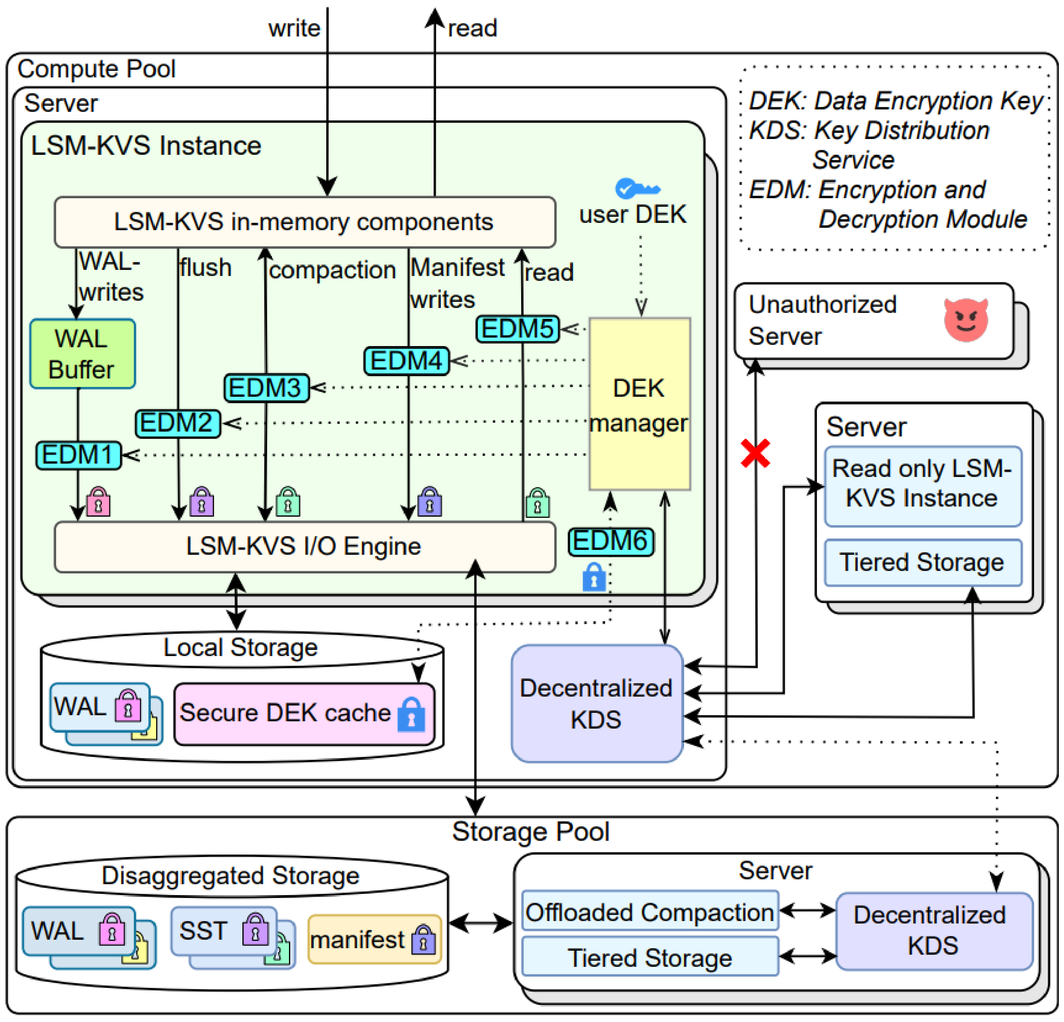
CHALLENGES

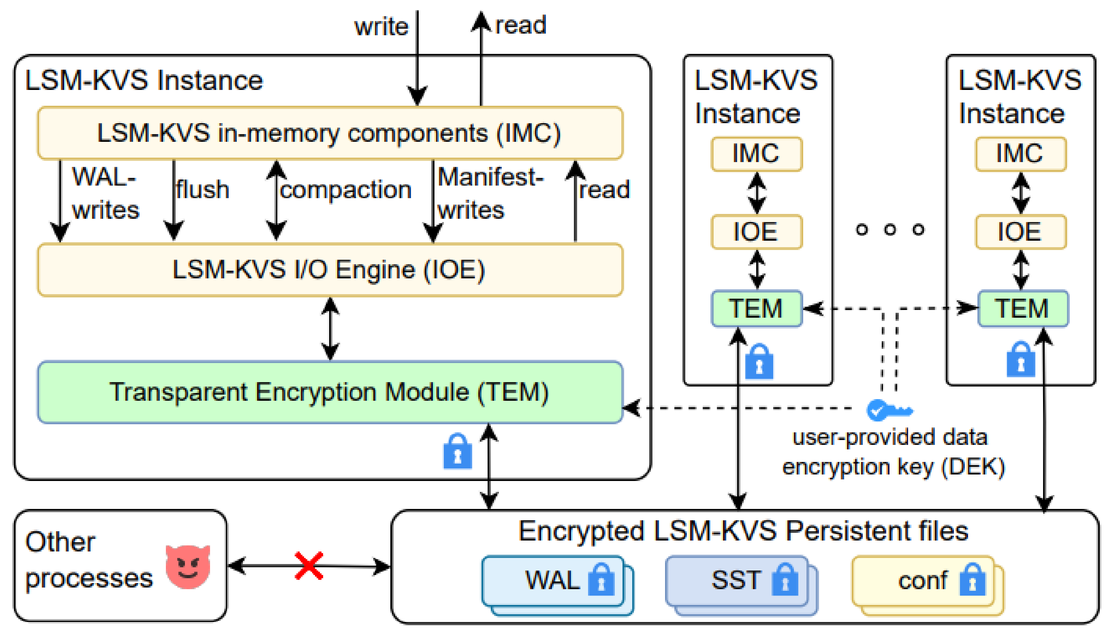
1. **How and where to embed DEK-practices** in LSM-KVS?
2. How to **mitigate the WAL-Write Encryption Bottleneck**?
3. How to **co-ordinate DEK/LSM-file relationship** for flexible setups?

ENCFS (DISTRIBUTED) & SHIELD (DISAGGREGATED STORAGE)

EncFS (For Monolith and Distributed):

- **Intercept IO to/from FS** to enable transparent encryption in LSM-KVS.
- Simple solution but **DEK leak can compromise all data**.
- For **servers completely in your control**. Can be killed on-demand.

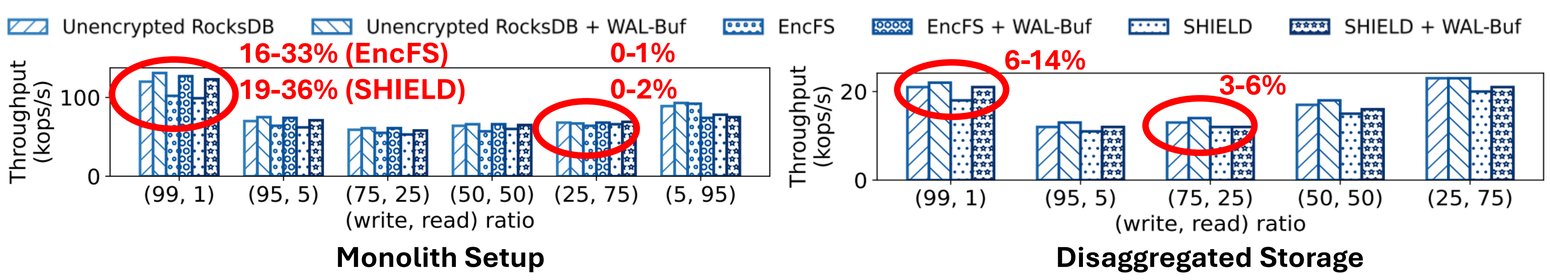




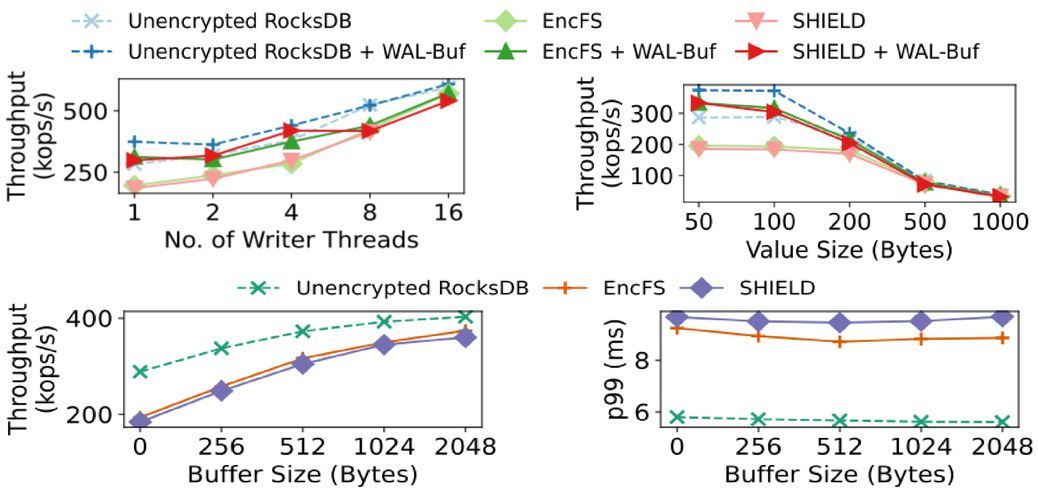
SHIELD (For Disaggregated):

- SST encrypted **after LSM block chunking**. And integration into **Compaction path for DEK-rotation**.
- **Size-configurable WAL-buffer** to mitigate WAL-bottleneck
- Decentralized key distribution service (e.g., SSToolkit, Kerberos) for DEK provision the **utilizes unique DEK identifiers**.
- **Local DEK-cache** secured with user-selected password for other LSM instances to use, avoiding network round-trips.
- **DEK-identifiers stored in LSM-KVS files' metadata**. Authorized servers avoid lookup tables, requesting DEK from KDS for passive and flexible DEK sharing.

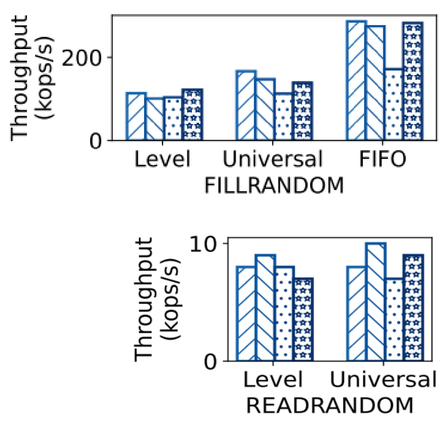
EVALUATION RESULTS



Converging Trend for EncFS & SHIELD



Compatible with different Compaction Styles



DISCUSSION

- We use 128-bit AES in CTR mode for encryption. **SHIELD is compatible with other encryption algorithms**.
- The solution comes with 0-36% overhead. **Encryption has a cost.** SHIELD aims to avoid the penalty and reduce round trips.
- We promise updates for **3 RocksDB major revisions** for the SHIELD codebase.

FUTURE WORK

- What's the deal with TEEs? SOTA suffers high penalties, **can TEE-penalty be avoided?** Exploration needed.
- SHIELD focuses of DS. **Disaggregated Memory with CXL or RDMA devices** will be intriguing future work.

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