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STANlite – a database engine for secure data processing at rack-scale level

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Intro

Data processing in cloud databases – commonly used practice

- Leakage of security sensitive information
- Compromising of data processing

Mechanisms of prevention:

- Own trusted infrastructure
- Secure processors
- Homomorphic encryption

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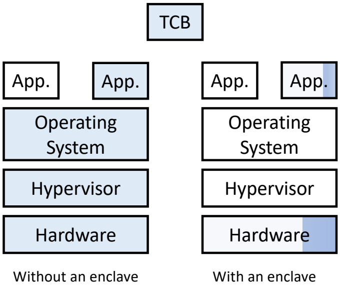
Intel Software Guard eXtensions (SGX)

- Trusted execution in untrusted environments

Trusted execution in untrusted environments

SGX Enclaves – new system entities:

- Located in User space
- Physical pages are encrypted
- Cannot be accessed by devices or software



Trusted Computing Base

Trusted execution in untrusted environments

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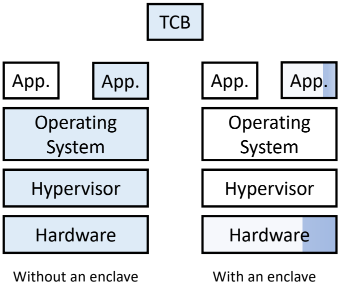

Trusted Computing Base

⇒ Trusted execution on commodity hardware

Programming of enclaves

Challenges:

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  - At least in 50 times slower than a system call [1, 2]

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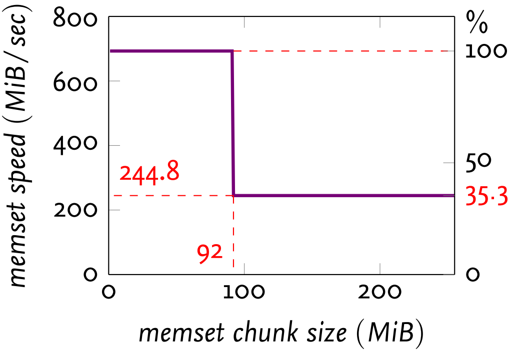
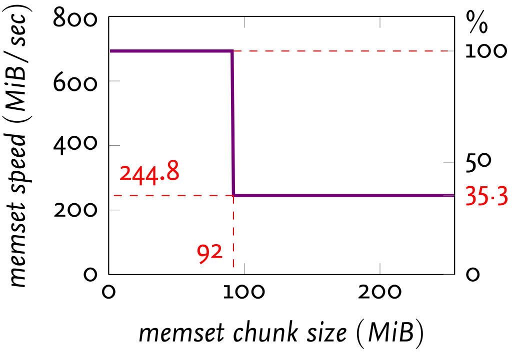
- Paging

Enclave Page Cache (EPC) limit



EPC limit



- ~92 MiB are available
- Heavyweight paging
  - Involves a kernel
  - Threads should exit
  - Encryption/decryption
  - Integrity protection

STANlite

STANlite: a secure database for data processing in clouds

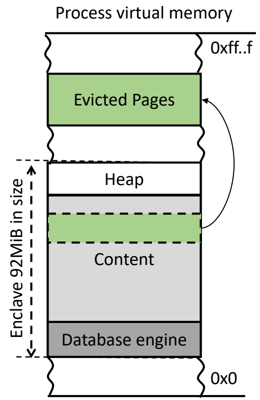
- Built on top of SGX Enclaves
- Processes large volumes of data without paging
- ECall-free high-performance communications over Remote Direct Memory Access (RDMA)

Agenda

- **Implementation of key components**
- **Evaluation**
- **Related works**
- **Conclusion**

STANlite

- Enclaved software can access untrusted memory
- The database can manage own pages
  - Swap in and swap out on request
  - Keep frequently used content inside
  - Evict rarely used content in encrypted form
- Fix memory layout to prevent the heavyweight paging



⇒ Special Virtual Memory Engine (VME)

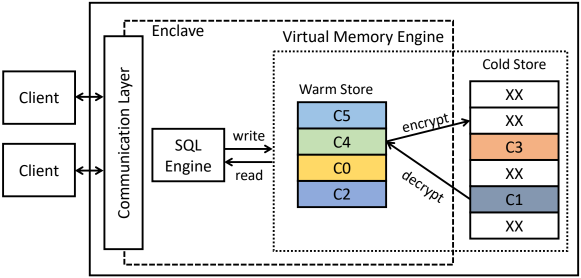
Architecture

VME components:

- Warm Store
- Cold Store
- Least Recently Used list

Swapping:

- Encryption/Decryption
- Hash sums for rollback attacks prevention



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The basis

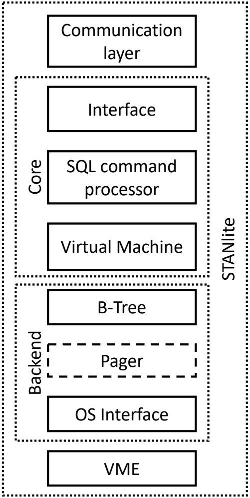
SQLite as SQL engine:

- Low footprint
- Read/Write semantic

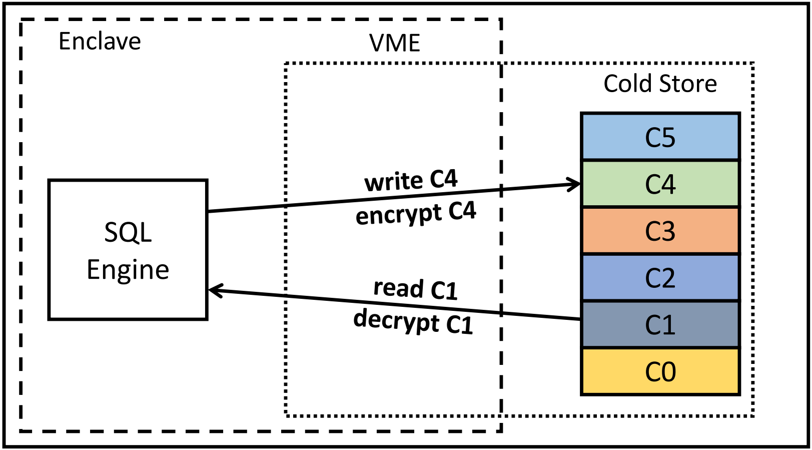
VME Integration:

- OS Interface
- Disabled Pager

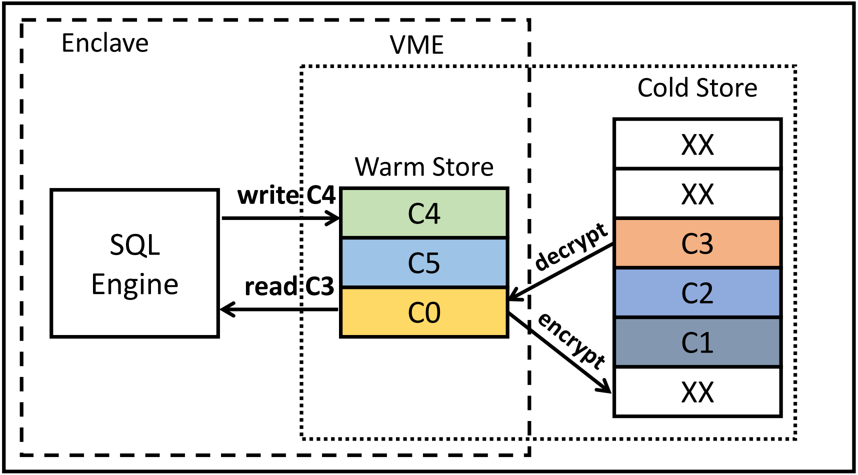
Three VME modes



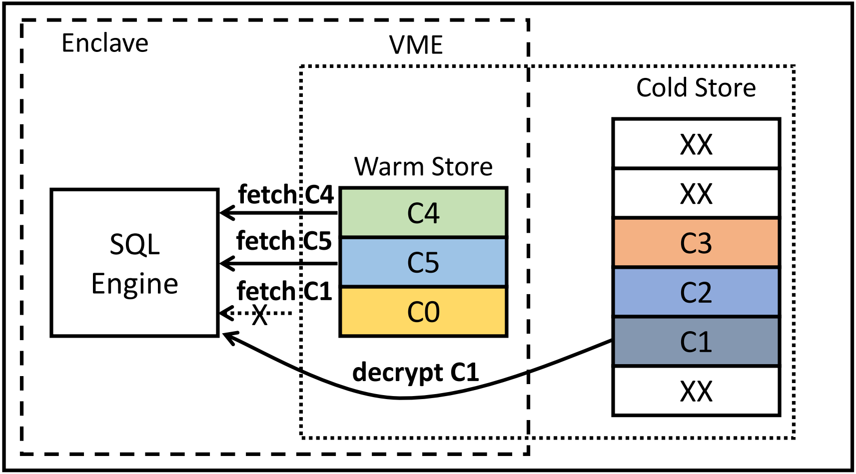
VME mode: Integrity and Confidentiality (Integrity)



VME mode: +Cache (Caching)



VME mode: +Fetch (Fetching)



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Evaluation

Goals:

- Compare virtual memory engines in synthetic tests
- Real-life performance

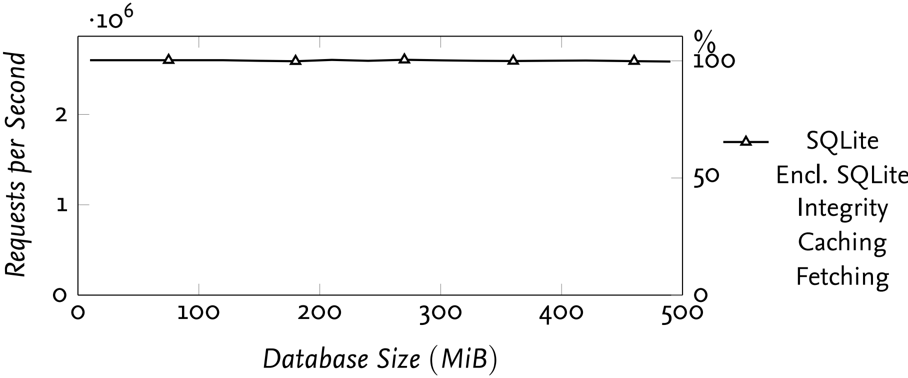
Benchmarks:

- Microbenchmark: a database with random access
- Speedtest1 benchmark: compares different request types
- TPC-C benchmark: real-life load

Setups:

- VME modes: Integrity, Caching, Fetching
- Baselines: Enclaved vanilla SQLite, Non-enclaved vanilla SQLite

Microbenchmark

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CREATE TABLE stest(ID INTEGER PRIMARY KEY AUTOINCREMENT NOT NULL, BODY CHAR;
INSERT INTO stest (BODY) VALUES('<...>'))
SELECT * FROM stest ORDER BY RANDOM() LIMIT 1
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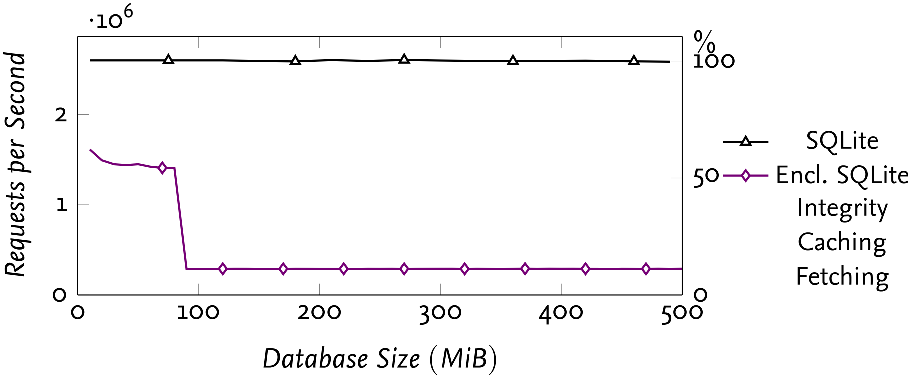
Microbenchmark

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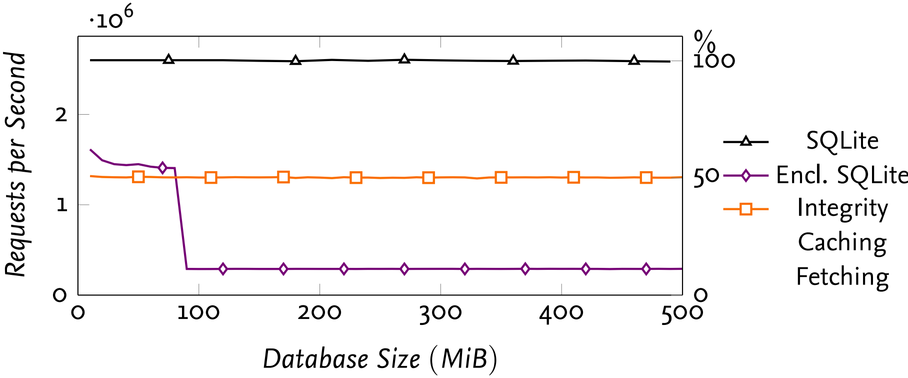


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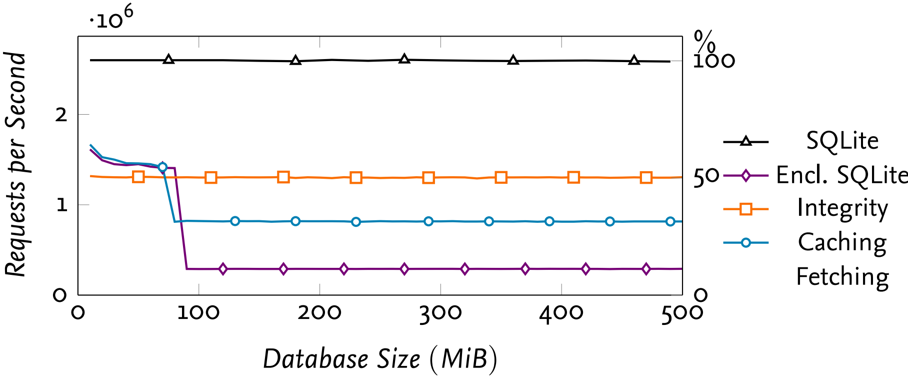


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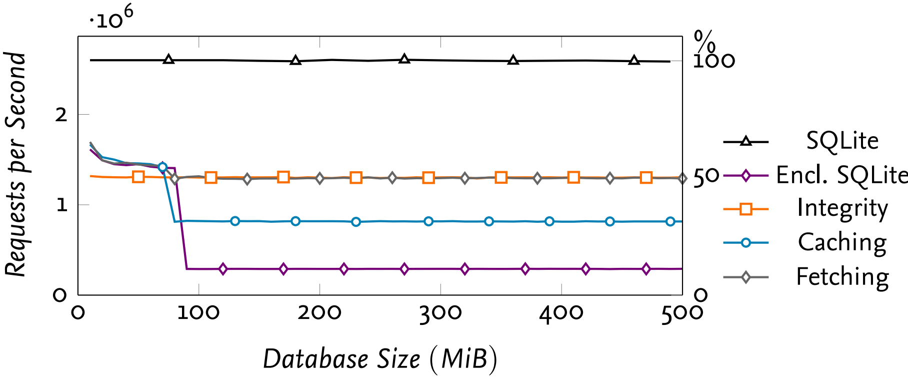


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Speedtest1

VMEs show better performance (1.52×–2×) for:

- `SELECT`, `UPDATE`, `DELETE`, `4-way JOINs`, `subquery`, `ANALYZE`

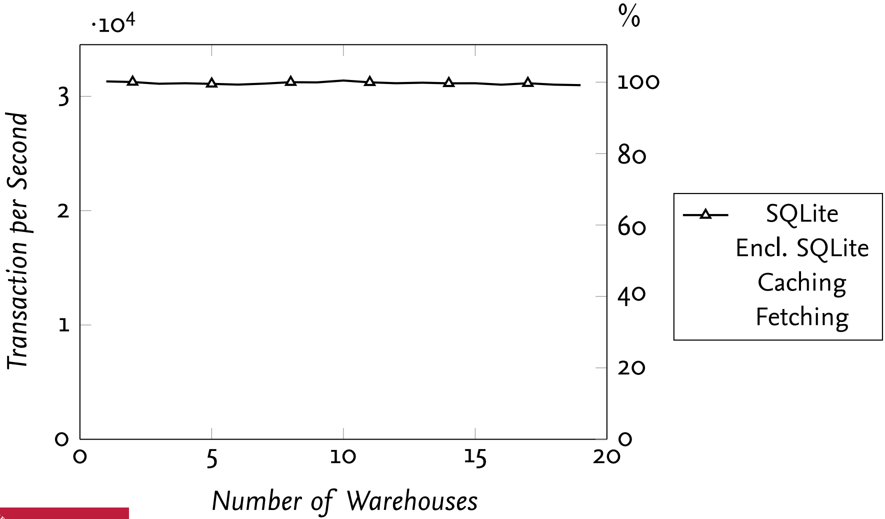
Enclaved SQLite shows better performance (1%–27%) for:

- `INDEX`, `DELETE with refill`, `refill`
- consumes heap memory

Warm Cache improves performance (up to 2×):

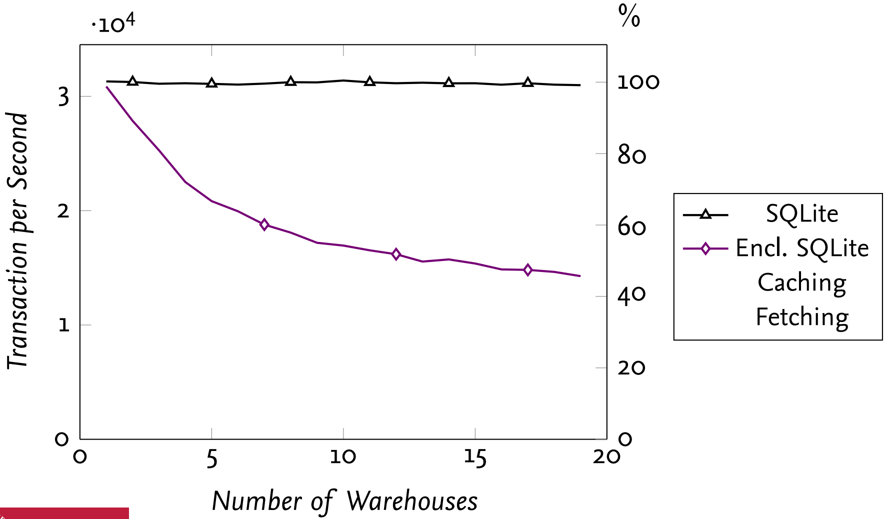
- Integrity check, refill

TPC-C



·10^4
%
Transaction per Second
3
2
1
0
100
80
60
40
20
0
0
5
10
15
20
Number of Warehouses
SQLite
Encl. SQLite
Caching
Fetching

TPC-C



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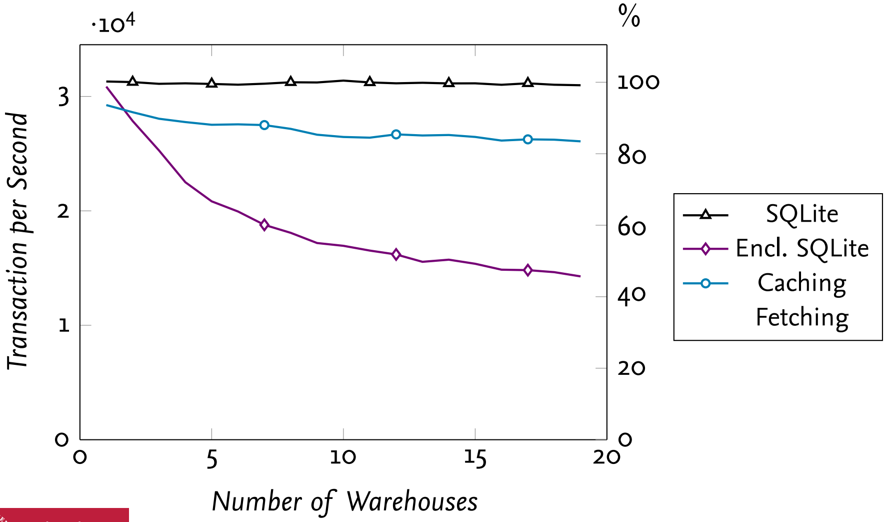
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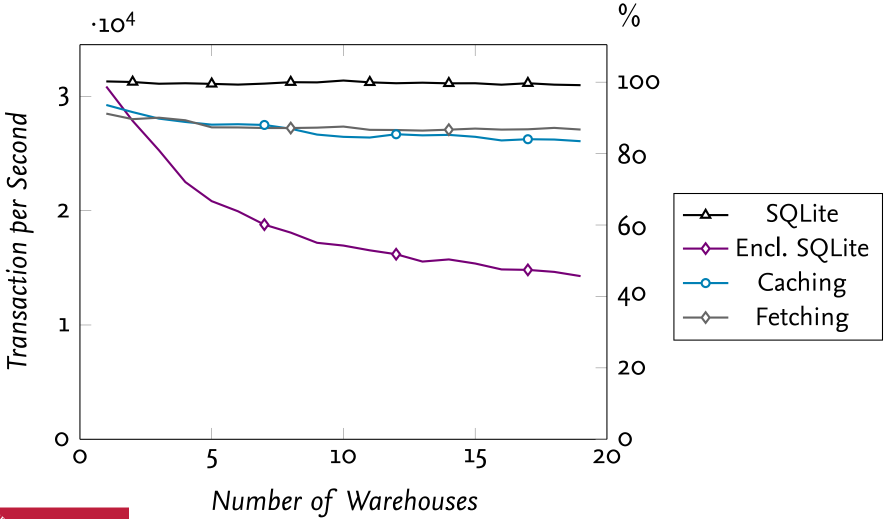

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Related work

- Eleos – Paging for C++-based programs
  - Different memory types
  - Multiple VME modes
- Panoply, Graphene-SGX, SCONE – environments for legacy applications
  - Increase Trusted Computing Base and memory consumption
- Glamdring – code partitioning
  - We virtualise storage memory

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Conclusion

Intel SGX

- Trusted execution in untrusted environment
- Challenges: EPC limit, ECalls

STANlite

- Enclaved in-memory database
- Virtual memory engine
- RDMA-based communication layer

Evaluation

- Microbenchmark: 4.44×
- *Speedtest1*: 1.79×
- TPC-C (2GiB): 2.44×

References

- M. Orenbach, P. Lifshits, M. Minkin, and M. Silberstein, "Eleos: ExitLess OS Services for SGX Enclaves," in *EuroSys*, 2017, pp. 238–253.
- O. Weisse, V. Bertacco, and T. Austin, "Regaining Lost Cycles with HotCalls: A Fast Interface for SGX Secure Enclaves," in *Proceedings of the 44th Annual International Symposium on Computer Architecture*, 2017, pp. 81–93.