Computation Capabilities of Server-Side Trusted Execution Environments

A Comparison of TEEs to Privacy-Preserving Technologies

Research Questions

What are the computational limitations and capabilities of server-side Trusted Execution Environments concerning functionality, efficiency, security, and usability?

How do Trusted Execution Environments compare to Fully Homomorphic Encryption (FHE), Oblivious RAM (ORAM), Structured Encryption (STE), and Secure Multi-Party Computation (MPC)?

1. Introduction

- Despite running vulnerable software that can leak sensitive data-in-use, cloud servers are complex and widely adopted.
- TEEs provide hardware-based isolation for secure computation, with embedded cryptographic primitives. Many implementations exist, with varying trade-offs.
- Some protocols exist (FHE, MPC, ORAM, StE), but are known to be inflexible or inefficient. No prior work has systematically compared TEEs to these cryptographic techniques in a unified framework.

2. Methodology

- Literature review by following the **Backward Snowballing** method, starting from a System of Knowledge work [7].
- Selected relevant technologies and extracted their whitepaper work for a detailed description.
- Enriched literature by querying papers on Scopus regarding the four characteristics, leading to 69 materials.
- Compared common features of technologies with peers.

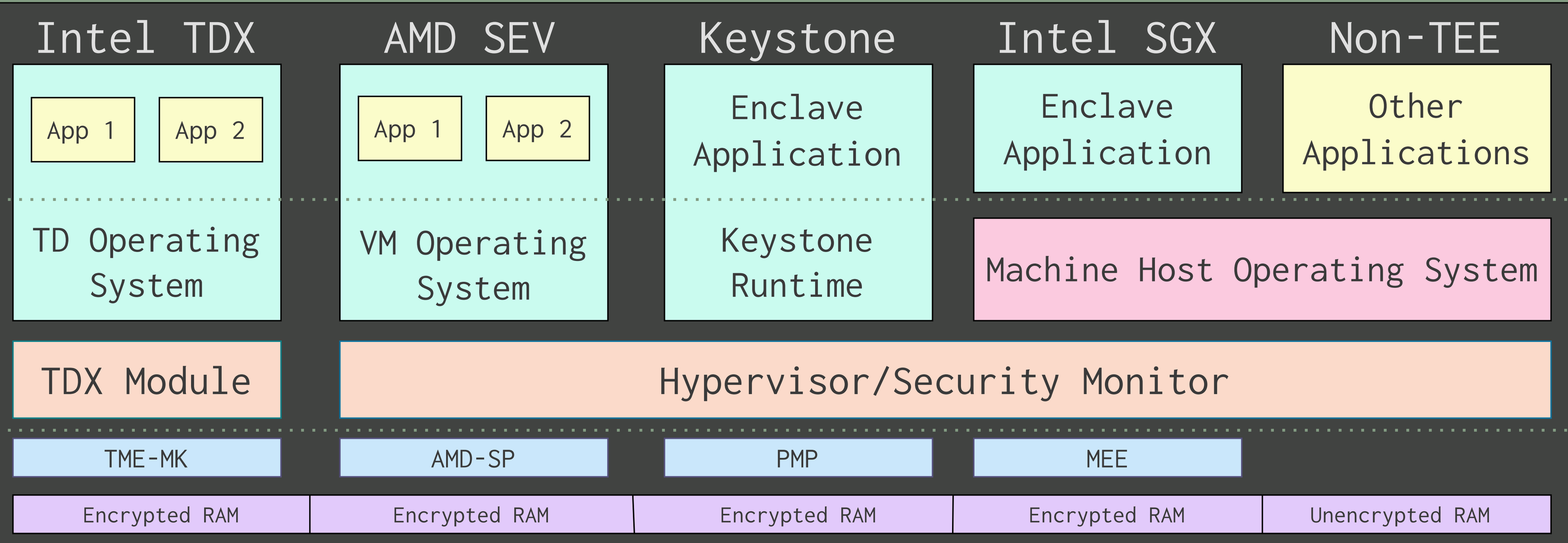
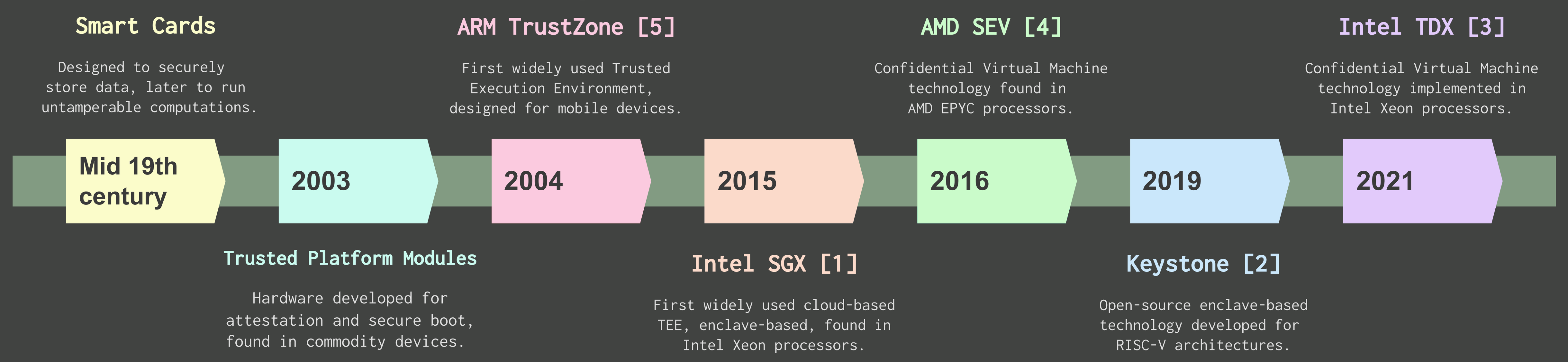


Figure 1: Discussed Trusted Execution Environments Designs

3. Technologies: Past to Present



4. Characteristics

Functionality - How restrictive is the technology, and can it perform these features?
Efficiency - What is the performance overhead compared to the non-isolated option?
Security - How large is the trusted computing base, and how many vulnerabilities were there in the past?
Usability - How practical is the system from the developer's perspective?

	Functionality		Efficiency		Security		Usability	
	Attestation	Sealing	Speed	Integrity Overhead	TCB Size	CVEs	Deployment	Debugging
Intel TDX	✓	✗	Near-native	MACs	Largest	10	Minimal OS mods	On-TD and Off-TD
AMD SEV	✓	✗	Near-native	None, added RMT in SNP	Large	49	No mods	API-based
Intel SGX	✓	✓	Near-native with SGXv2	EPC extras MACs	Small	48	SDK or Gramine	Release and Debug Mode
Key stone	✓	✓	Near-native	Optional in SW or HW	Smallest (flexible)	0*	SDK or RISC binaries	✗

Table 1: Key properties of selected Trusted Execution Environments (TEEs)

	Computation	Parties	Performance	Threat Model	Leakage	Found in	Use Cases
TEE	Any (Code)	Client-Server Attestation	Near-native, except I/O	Malicious, full software	Plaintext CPU RAM patterns	Cloud servers optional	Data analysis Trusted AI
FHE	Any (Circuit)	Client-Server	Expensive KeyGen	IND-CCA2 threat	None	Open-source libraries	Medical data ML training
MPC	Any (Circuit)	Client-Server Distributed	Slow, const** scaling	Semi-honest Malicious	Ideally none	Distributed protocols	Auctions DNA analysis
ORAM	Any query	Client-Server	Slow, log scaling	Semi-honest Malicious	Side-channels	Secure processors	Signal ObliDB
StE	Some queries	Client-Server	Fast, log access	Semi-honest	Volume size RAM patterns	Encrypted databases	MongoDB

Table 2: Comparison criteria of privacy-preserving computation technologies and TEEs

*Issues or the GitHub repository can be found
**At least constant, can be linear

5. Comparison

FHE - Strongest in security, not practical yet for general use cases.
MPC - Best in distributed environments and flexible, with offline setup overhead.
ORAM - Great at hiding access patterns, limited to querying, and can be slow.
STE - Efficient, good in I/O access, but only for querying data.
TEE - Easy to integrate, efficient, but exposed to powerful attacks.

6. Conclusions

- There is no "silver bullet" - properties must be balanced based on use cases.
- CVMs have a better performance and ease of use at the cost of a larger TCB than enclave-based counterparts.
- TEEs outperform the other techniques, but are less secure, shifting the trust to the vendor.
- MPC and FHE ”will inevitably become attractive” [6, p. 138] with stronger hardware.

7. Future Work

- Discuss more properties, such as live migration or physical attacks.
- Benchmarking framework among the five techniques to measure equal uses.
- Joining techniques with TEEs and test efficiency, security, functionality.

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