A case for Unifying Trusted Execution Environments

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Comparing Trusted Execution Environments

TEE	Client SGX [13]	Scalable SGX [15]	ARM TrustZone [25]	AMD SEV [19]	Intel TDX [5]	Penglai [8]

TABLE I: Non-exhaustive comparison of various TEE implementations. Circles depict full (●), partial (◐) or no support (○).

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Architecture	x86	x86	ARM	x86	x86	RISC-V
Target	Client CPU	Server CPU	Various	Server CPU	Server CPU	Various
Isolation granularity	Process	Process	Process	VM	VM	Process

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Integrity	●	●	◐	○	●	●
Freshness	●	○	○	○	○	●

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Q1: Which TEE hardware should I use?

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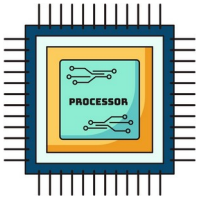
Forest of TEE Frameworks

App

TEE Framework



SGX

TrustZone

SEV-SNP

RISC-V

Forest of TEE Frameworks

App

SGX-LKL

SGX-SDK

NestedSGX

HyperEnclave

Penglai

SCONE

OP-TE

Occlum

Q2: What programming model should I use

Q3: Where will my application run?

SGX

TrustZone

SEV-SNP

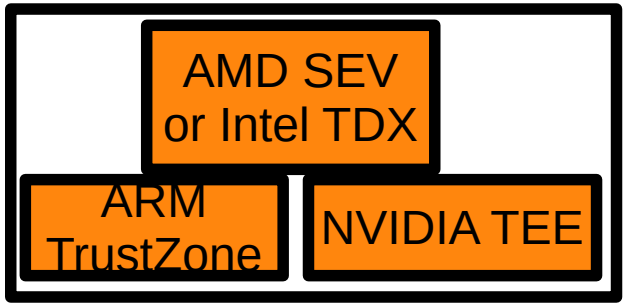
RISC-V

Problem

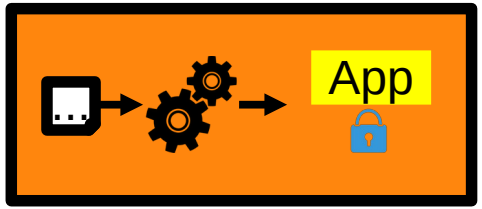
- Current TEE landscape is heterogeneous
  - Implementations offer different security guarantees and architectural features
- TEE frameworks:
  - Constrained to a few specific architectures
  - Miss critical components

Limits TEE applicability and effectiveness in heterogeneous environments

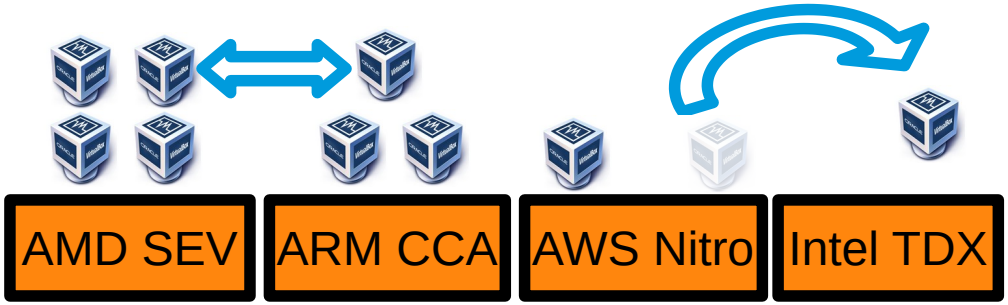
Heterogeneous TEE Platforms are Already Here



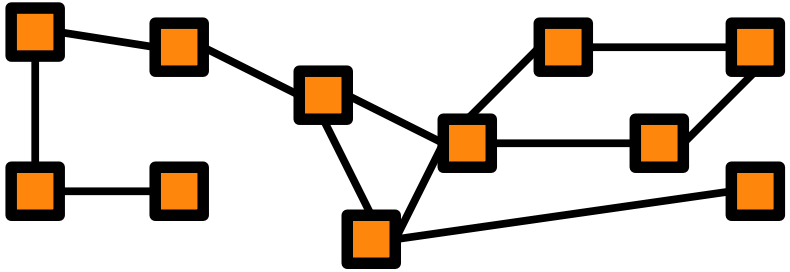
NVIDIA Confidential Computing



Attested Build



Confidential Cloud Computing



P2P Applications (e.g., Blockchain)

Requirements for a Framework to Unify TEEs

- Compatibility with all TEEs
  - Present and Future
- Awareness of each TEE characteristics
  - “Cannot execute this app on this TEE without lowering security”
- Small Trusted Computing Base
  - Smaller TCB => Smaller Attack Surface
- Formal Verification
  - Correctness and security guarantees

FUTEE: Framework for Unifying TEEs

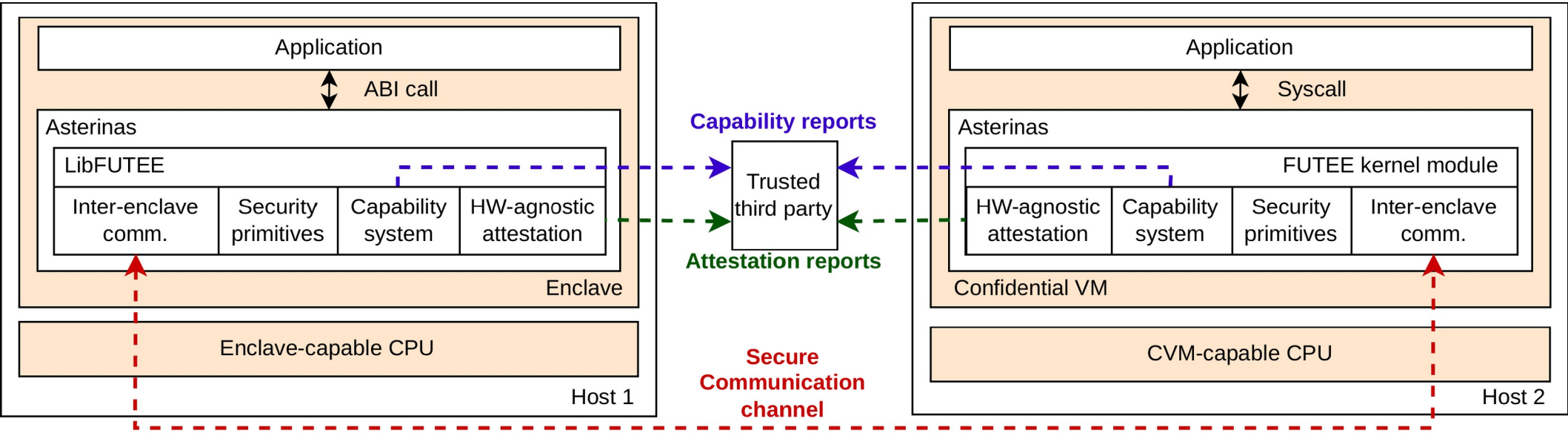
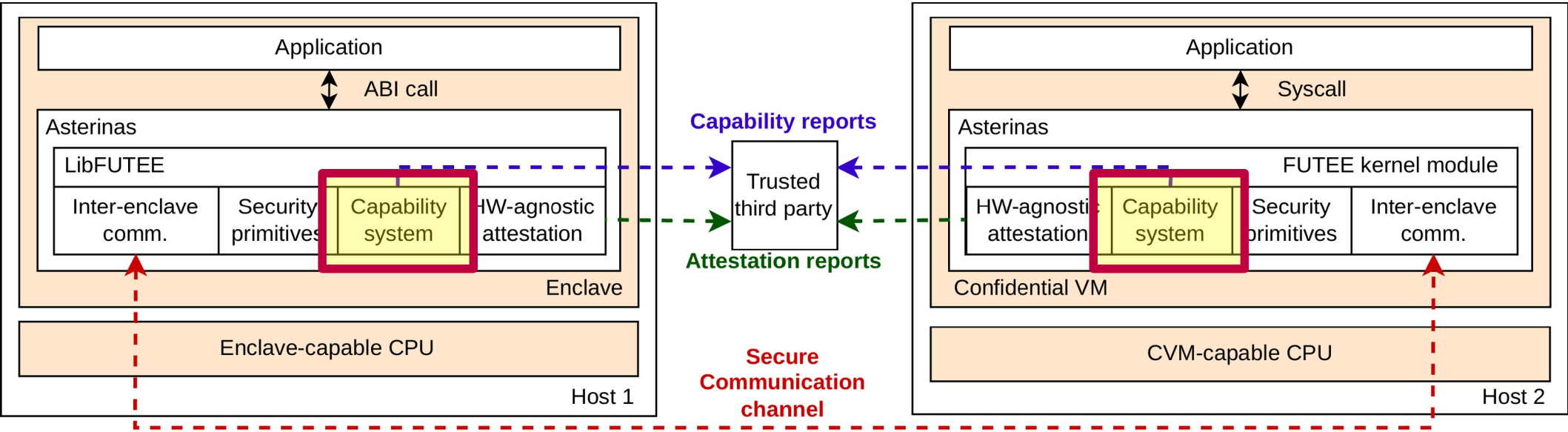


Fig. 1: Two secure applications communicate between each others via FUTEE. Dashed lines represent message exchange.

FUTEE: Framework for Unifying TEEs



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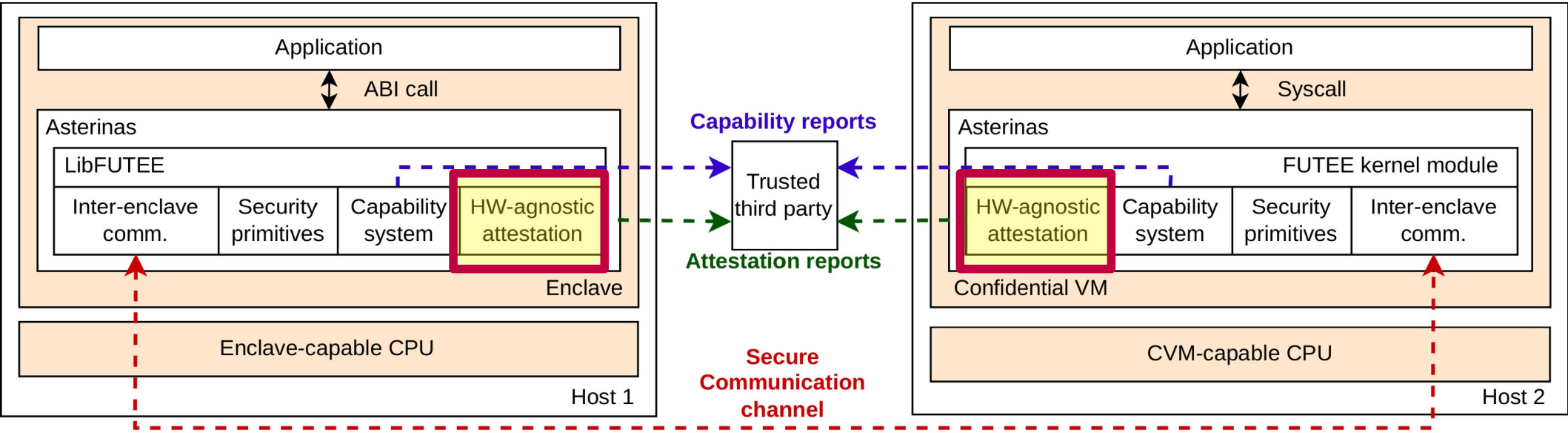

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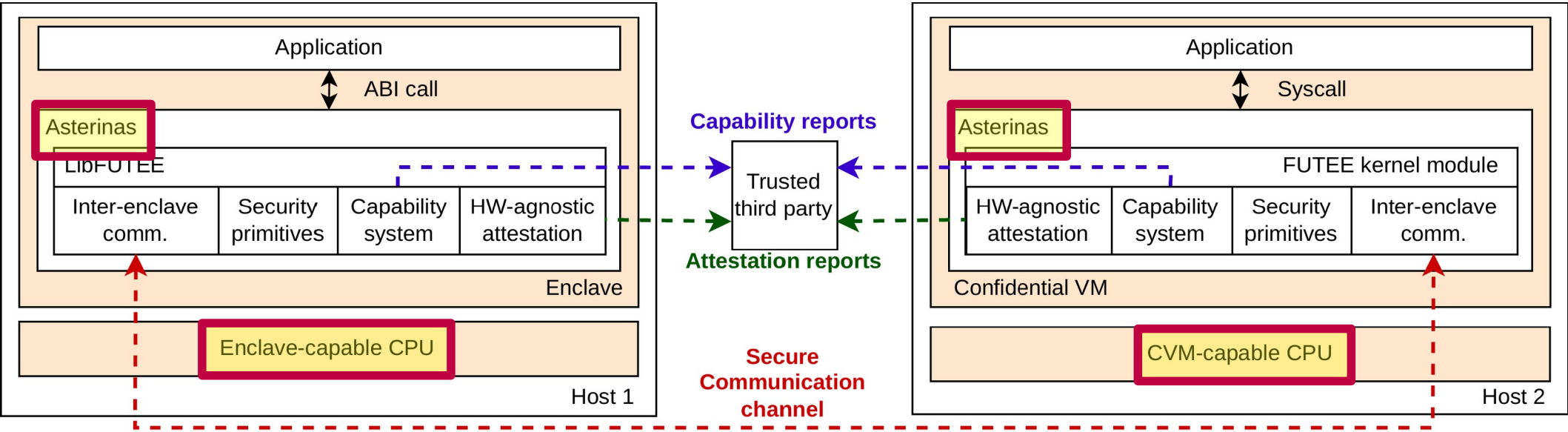

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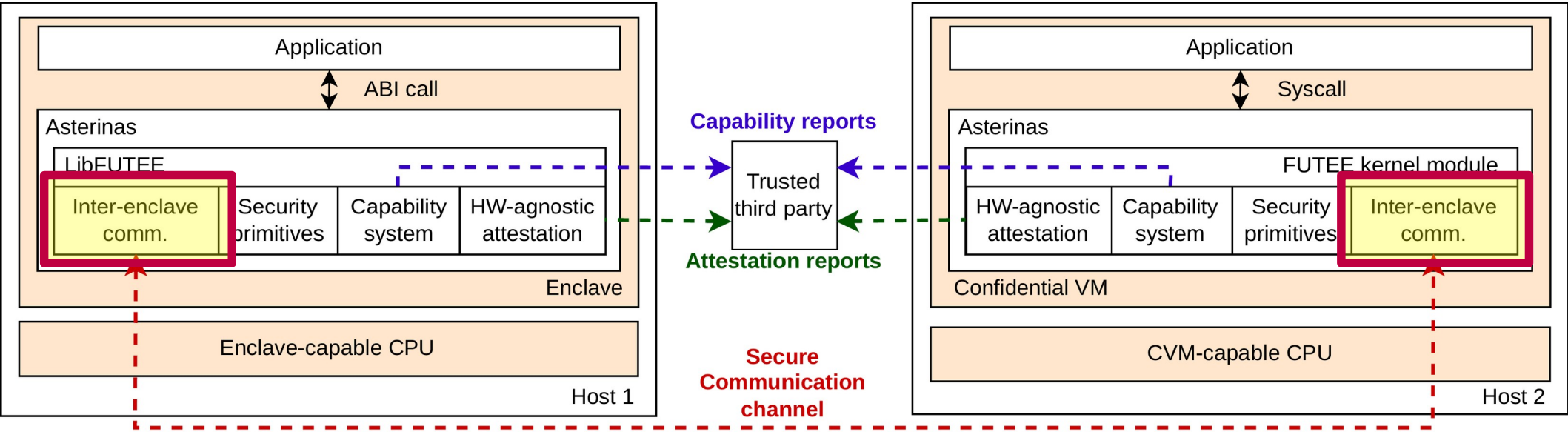

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Capability System

- Augment attestation report with this TEE functionalities
  - “CPUID for TEEs”
  - E.g., secure memory size, monotonic counters
- Is my application running in a TEE?
  - With X and Y guarantees?
- Can I execute my application on a different kind of TEE?

Vendor-Agnostic Attestation

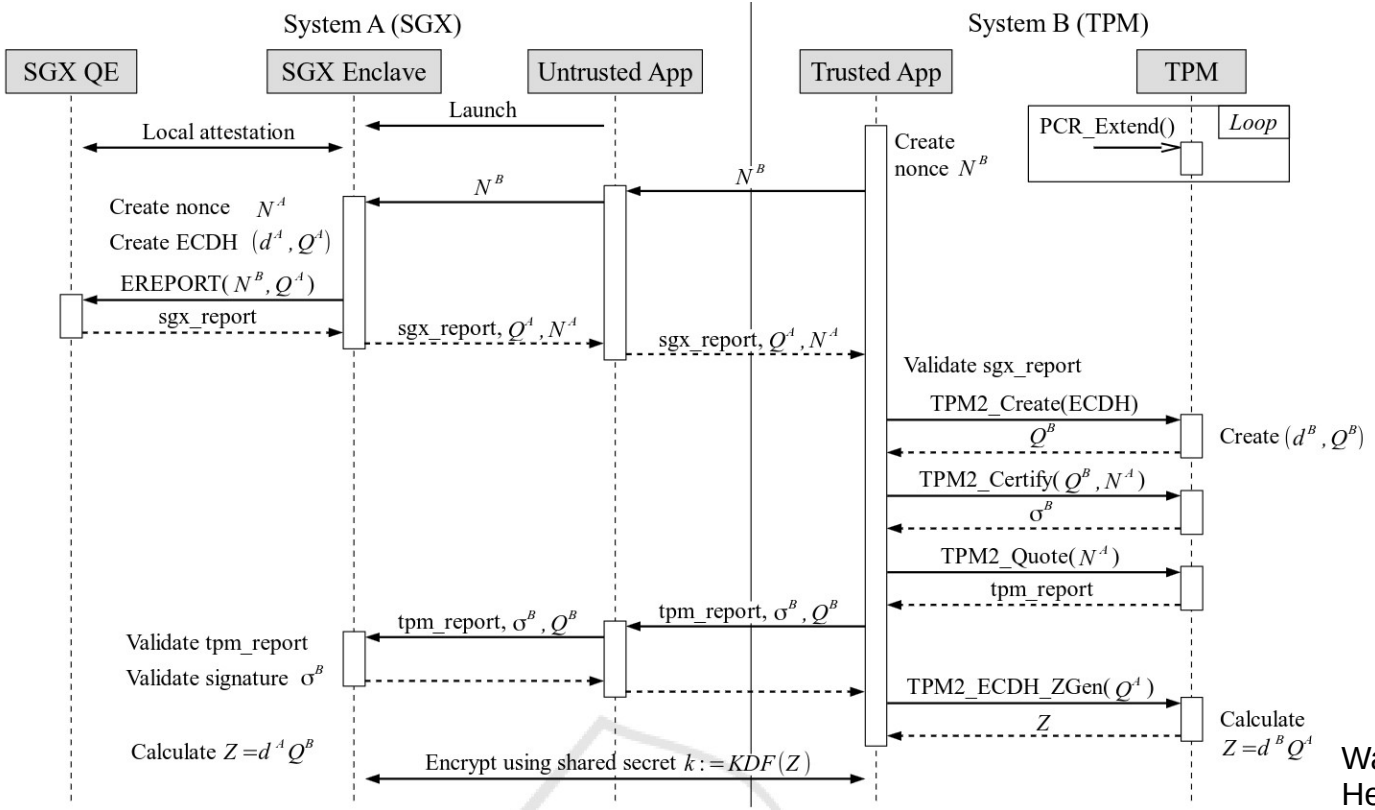


Figure 1: Remote attestation mechanism between SGX enclaves and TPMs.

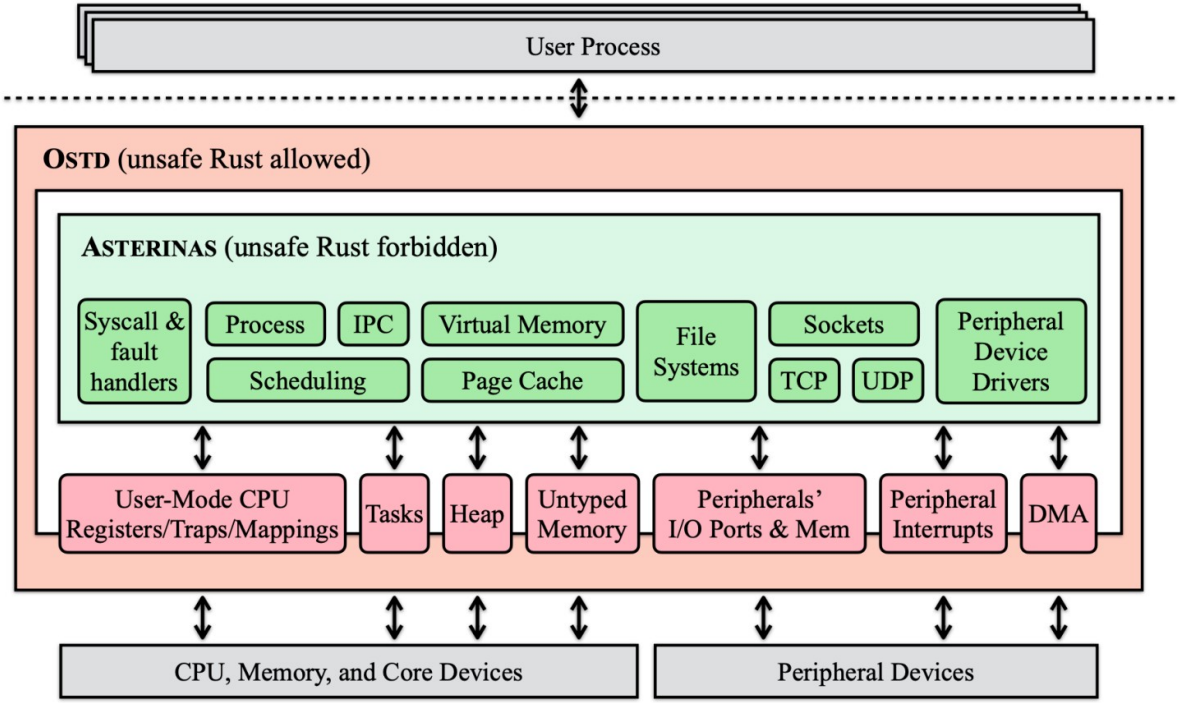
Wagner et al., “Towards Heterogeneous Remote Attestation Protocols”, SECRYPT ‘22

Inter-Enclave Communications

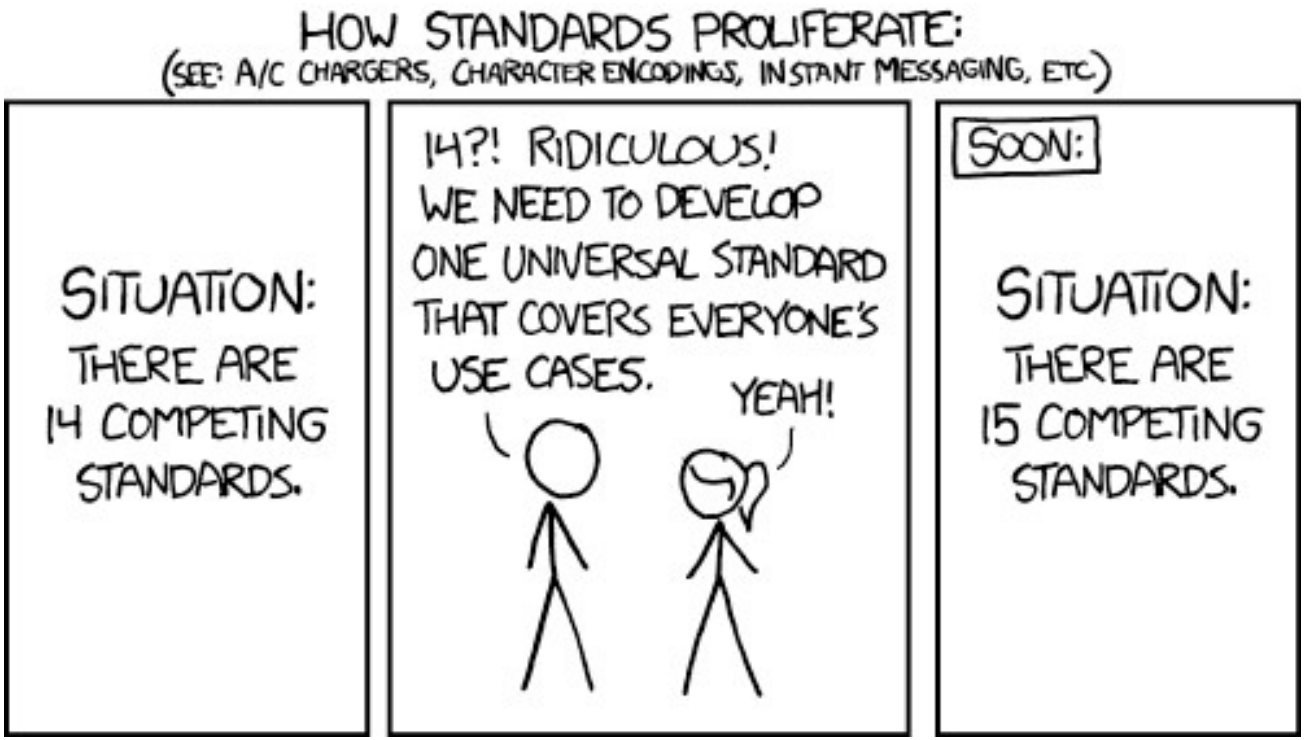
- Generic API
- Different applications need different guarantees
  - Confidentiality, integrity, ...

Framework Implementation Proposal

- Based on Asterinas
  - (Mostly-)Verified OS in Rust
  - TDX support
  - Small TCB



N+1 Framework?



Conclusions

- TEE landscape is heterogeneous
- We need a framework to unify them
  - Without weakening security guarantees
- FUTEE: a Framework to Unify TEEs
  - Capability system
  - TEE-agnostic attestation
  - Inter-TEE communication
  - Leverage Asterinas

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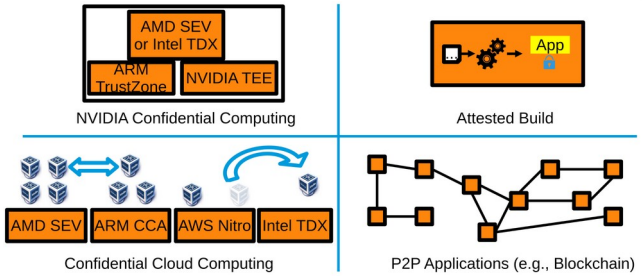

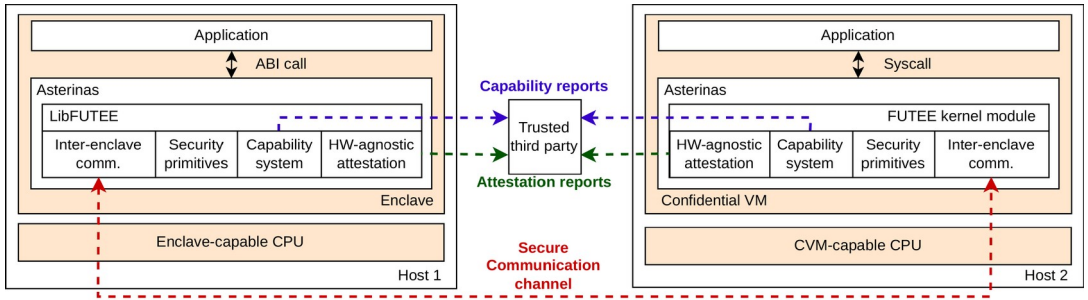

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