MAGE: Mutual Attestation for a Group of Enclaves without Trusted Third Parties

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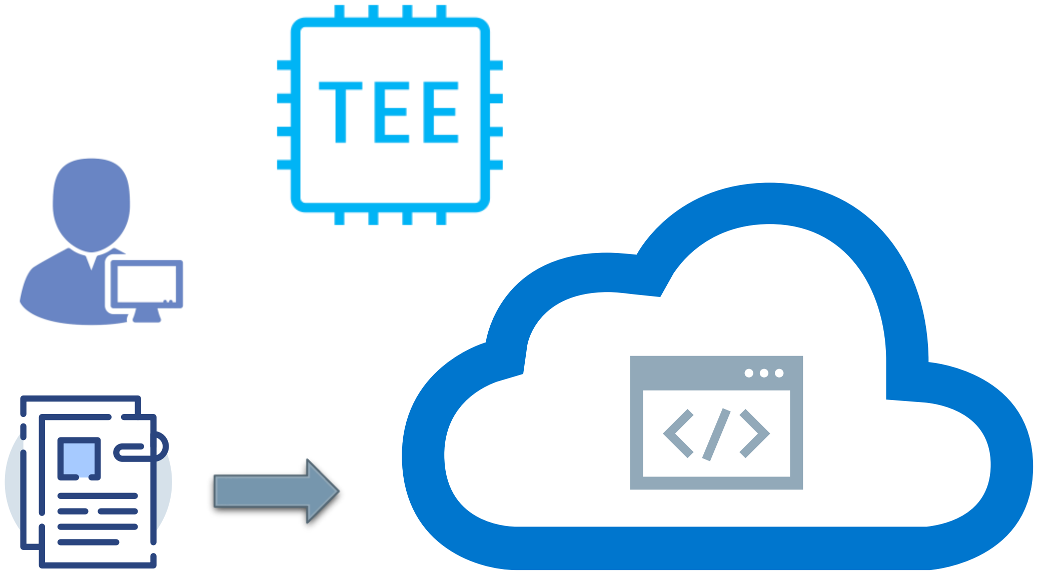
Trusted execution environment (TEE)



intel SGX

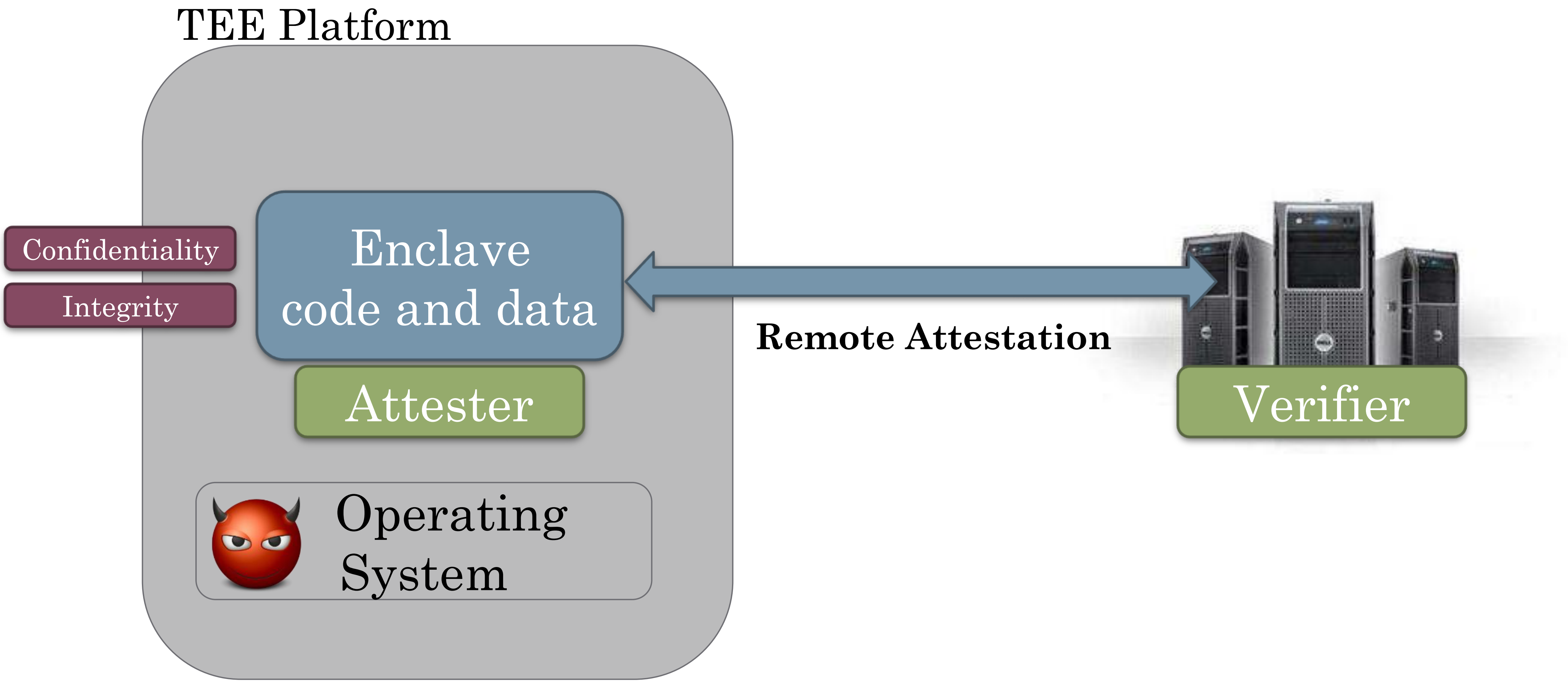
AMD
Secure Encrypted Virtualization

Google Cloud

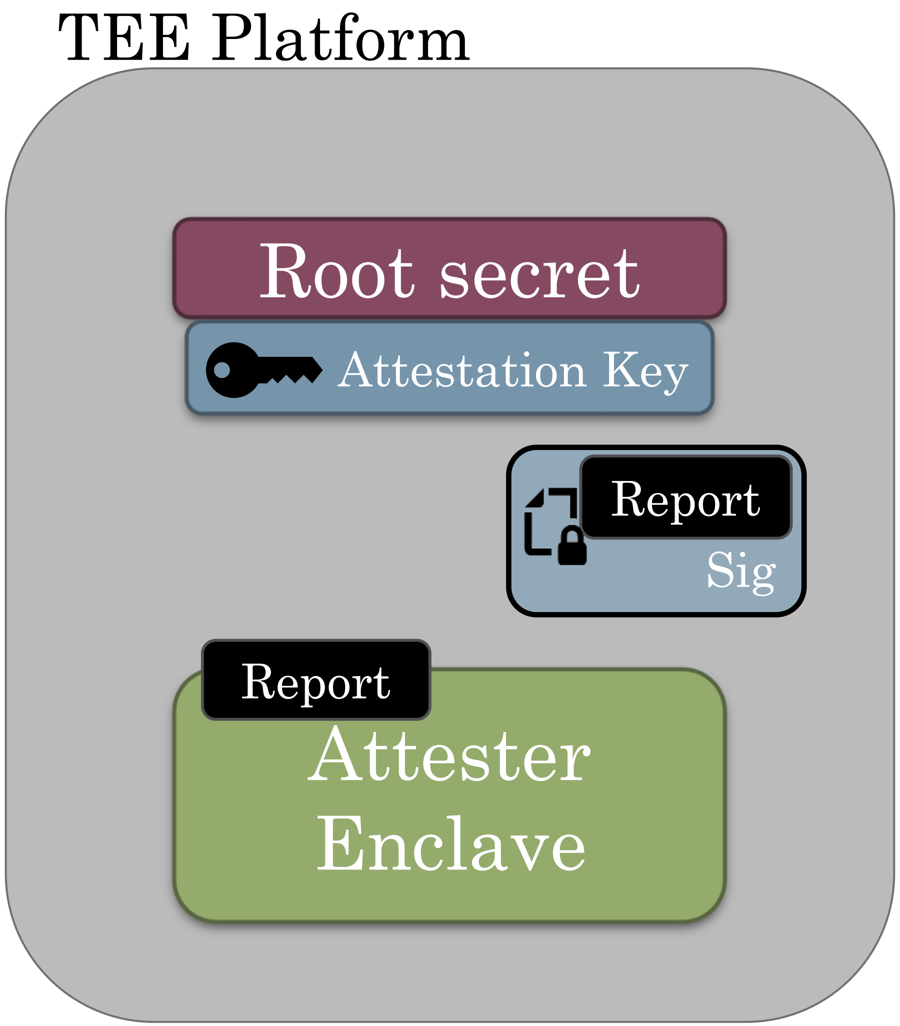
Microsoft Azure

Alibaba Cloud

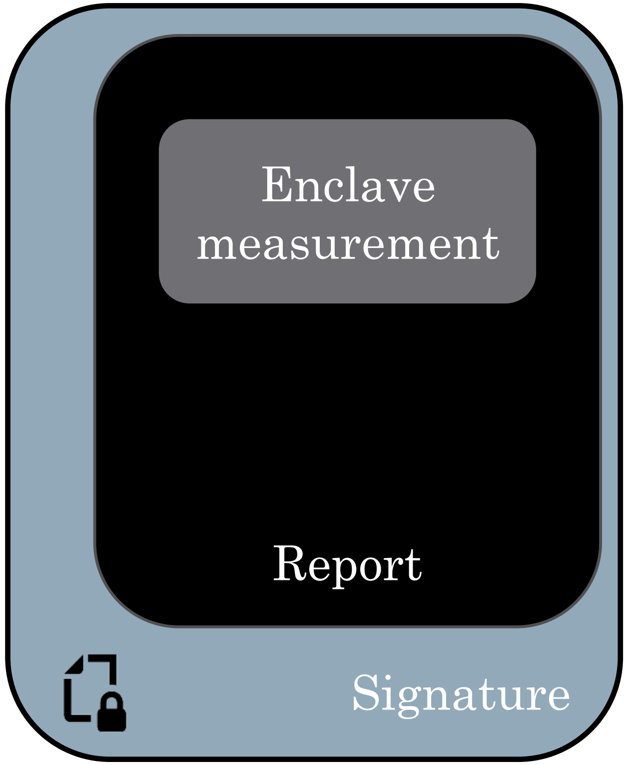
Remote attestation



Q1: Is the attester an enclave?

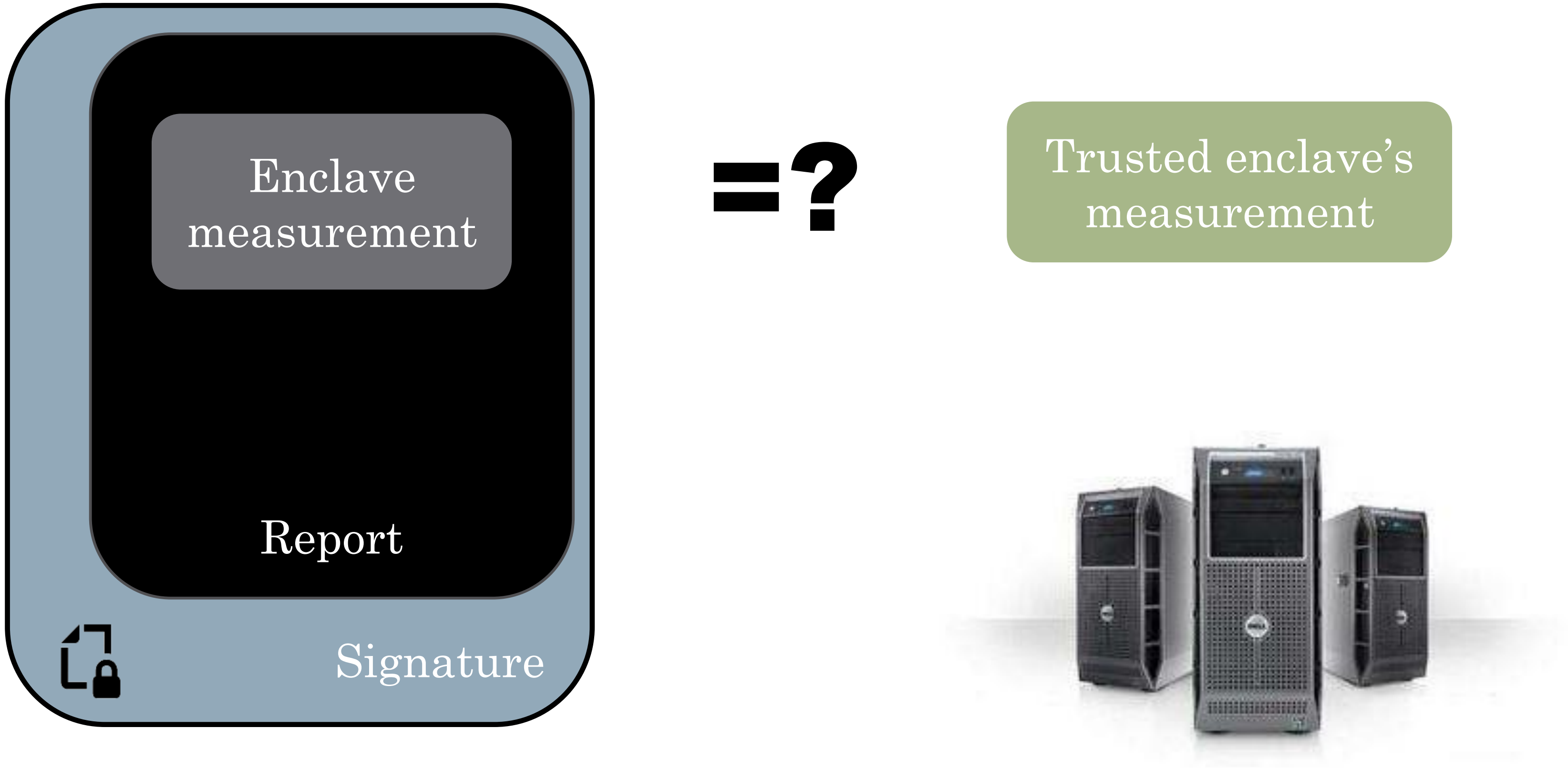


Q2: What is the attester enclave's identity?

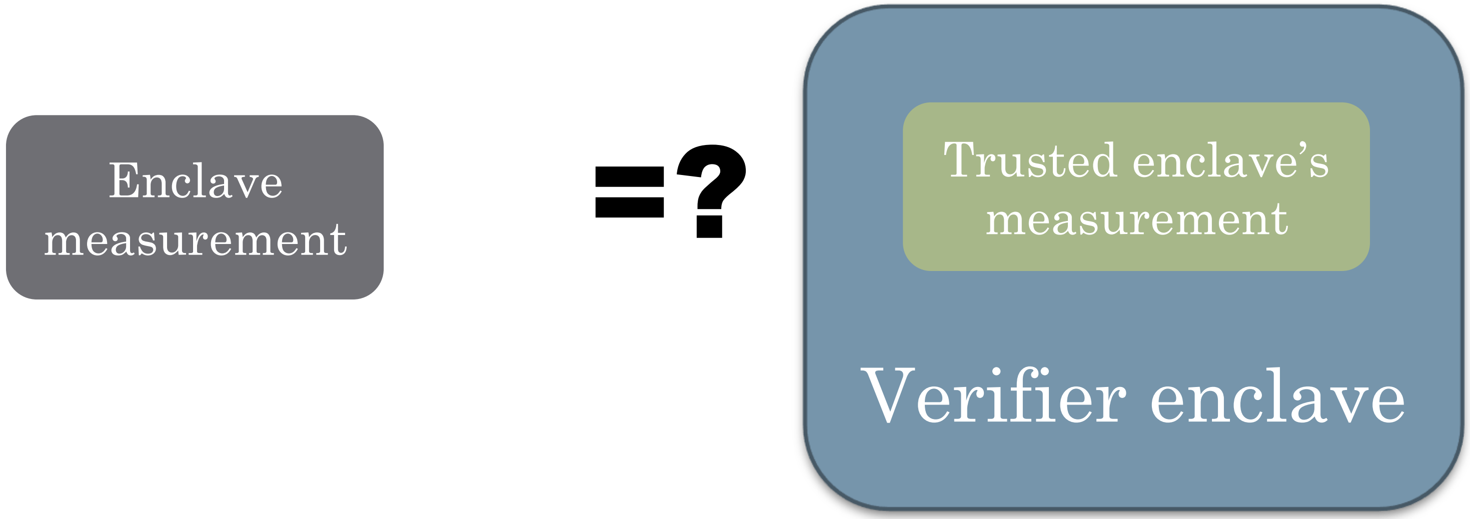


Enclave measurement: the cryptographic hash of the initial code and data of an enclave, as the identity of the enclave.

Q3: Is the identity trusted?

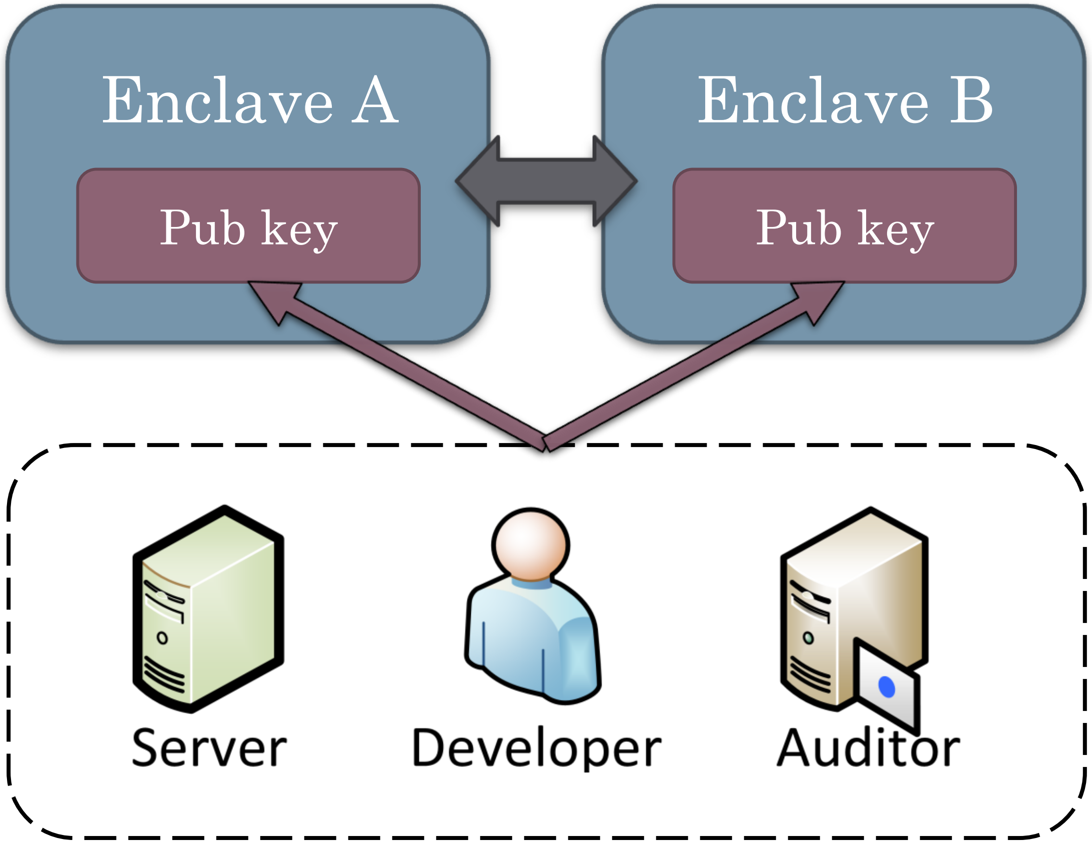


Q3: Is the identity trusted?



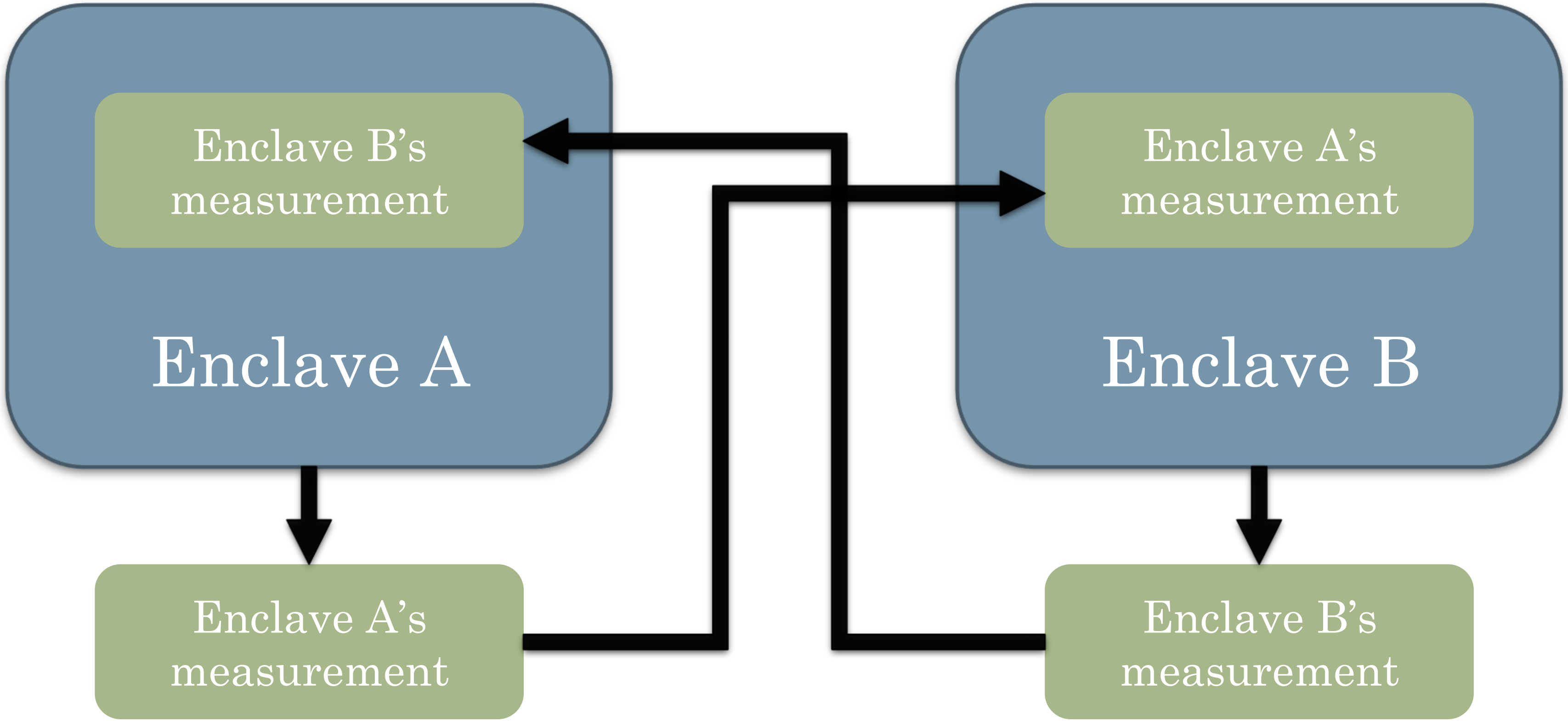
Mutual attestation with TTPs

- Trusting multi-enclave applications via **mutual attestation**
- TTPs increase the TCB and might incur extra costs for running PKIs



Trusted third parties (TTPs)

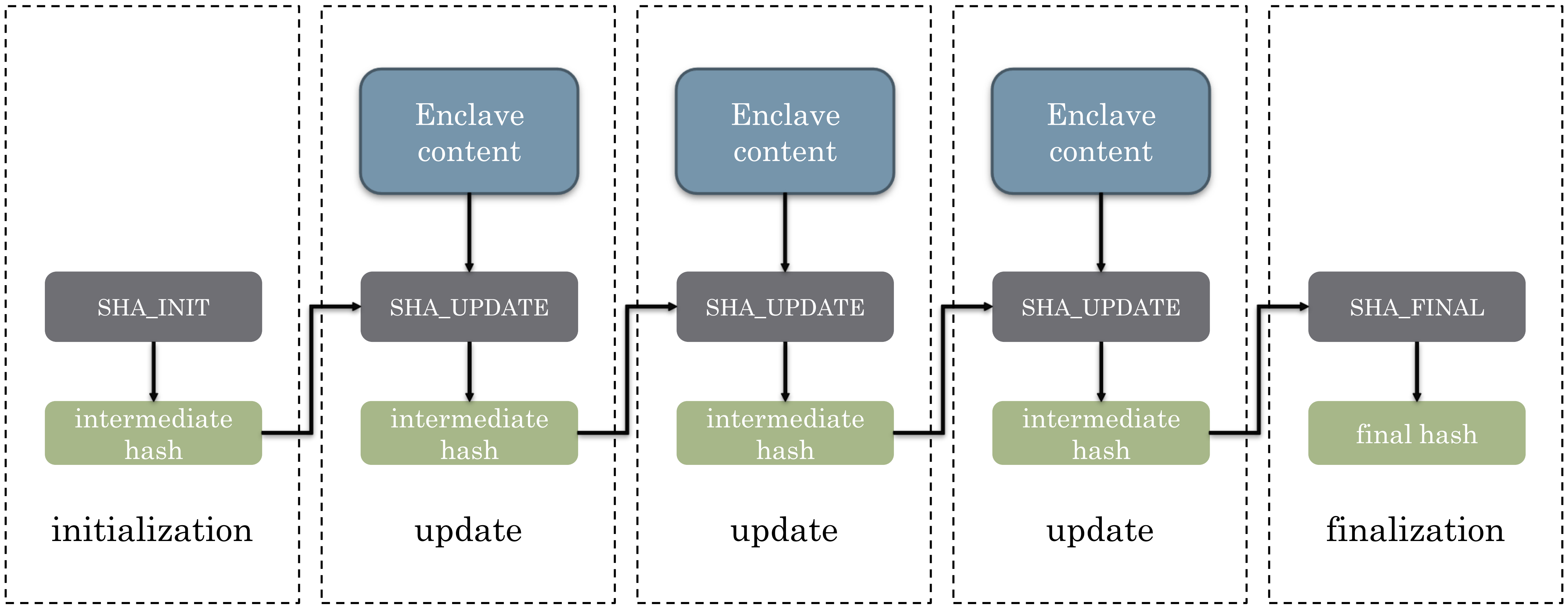
Mutual attestation without TTPs



Circular dependency

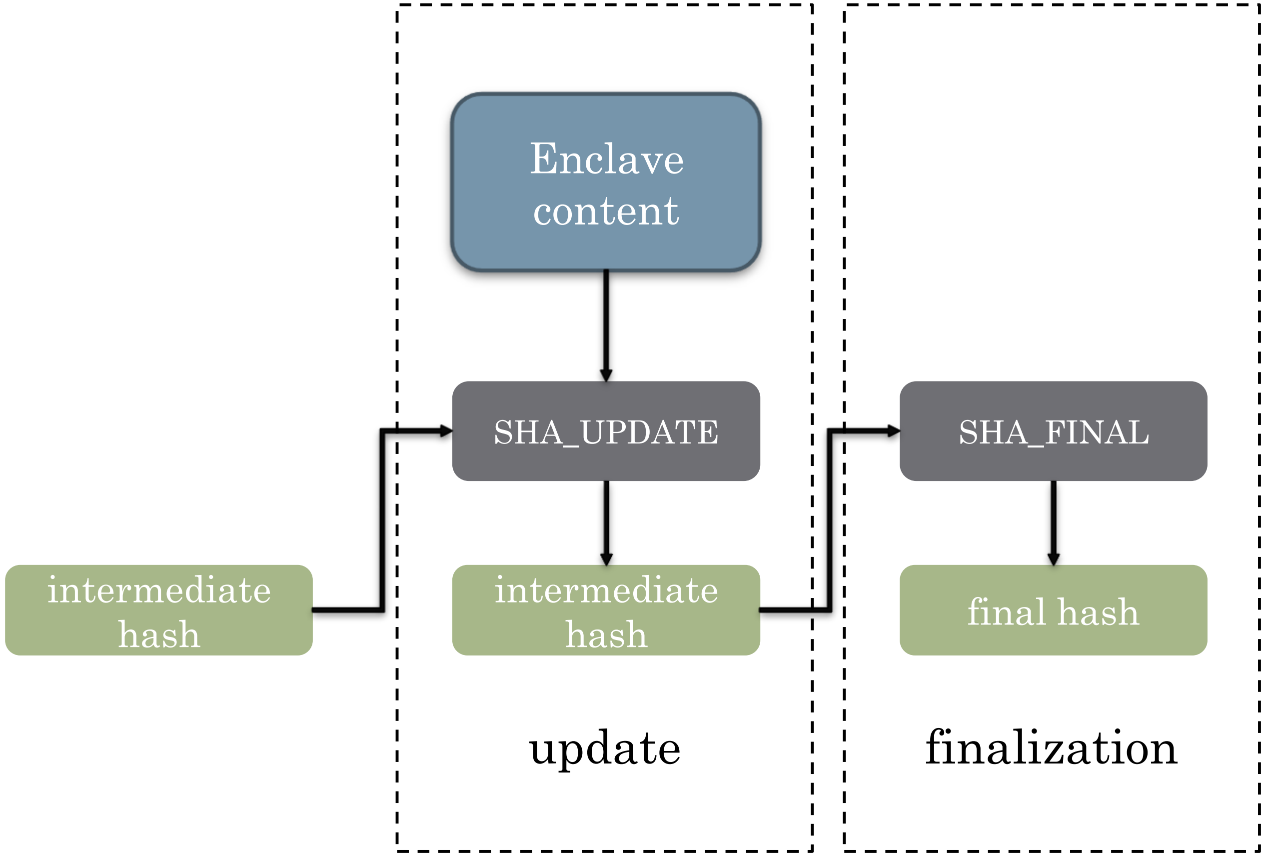
Measurement calculation

The measurement calculation (e.g., SHA-256) is deterministic and sequential



Measurement calculation

Key observation: knowing the intermediate hash and information to perform subsequent measuring operations would be sufficient to derive the final output

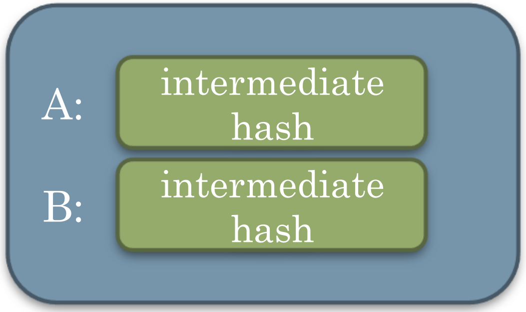


MAGE

During enclave creation

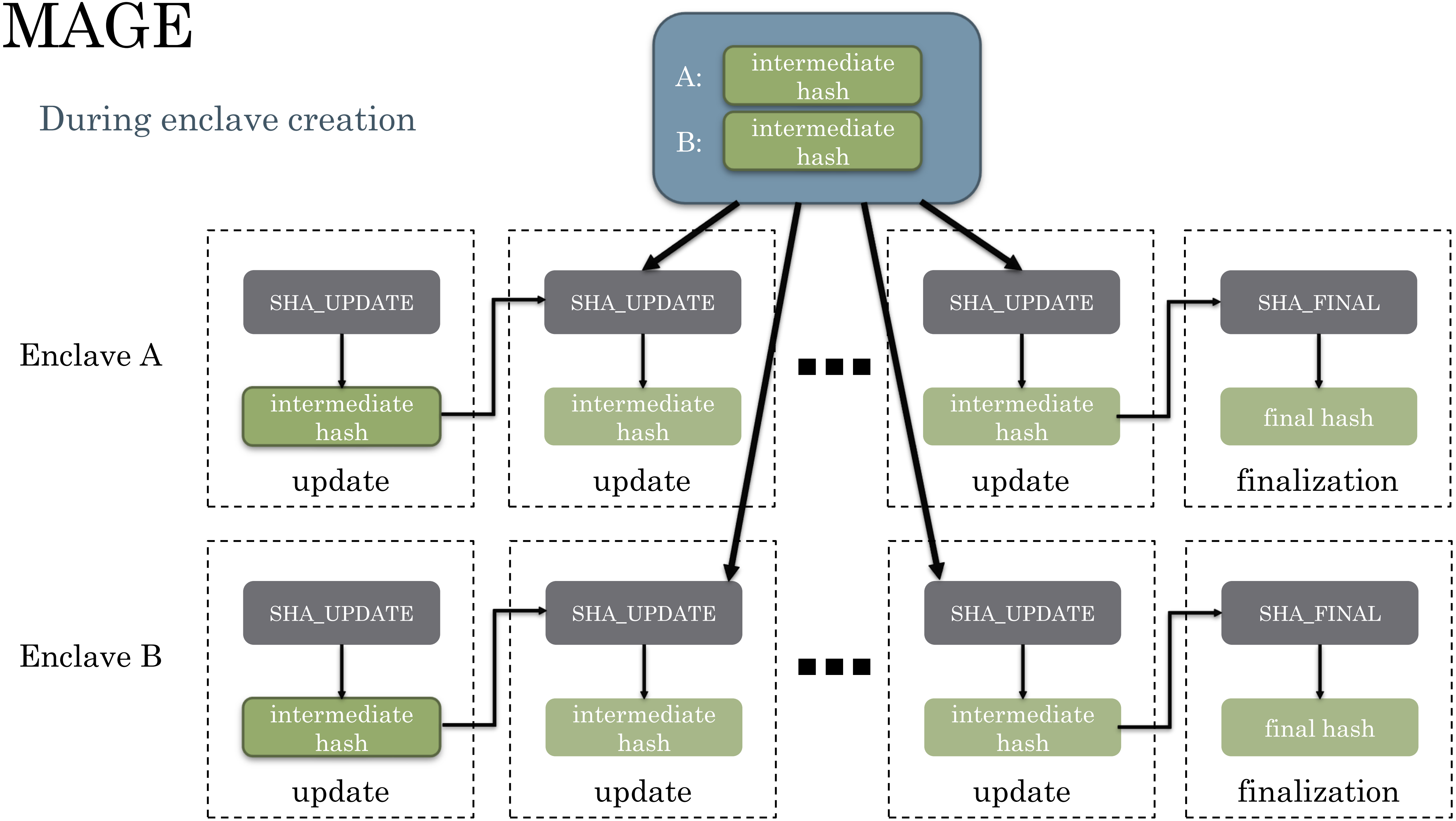
Introduce an **common part**

at the end of each enclave



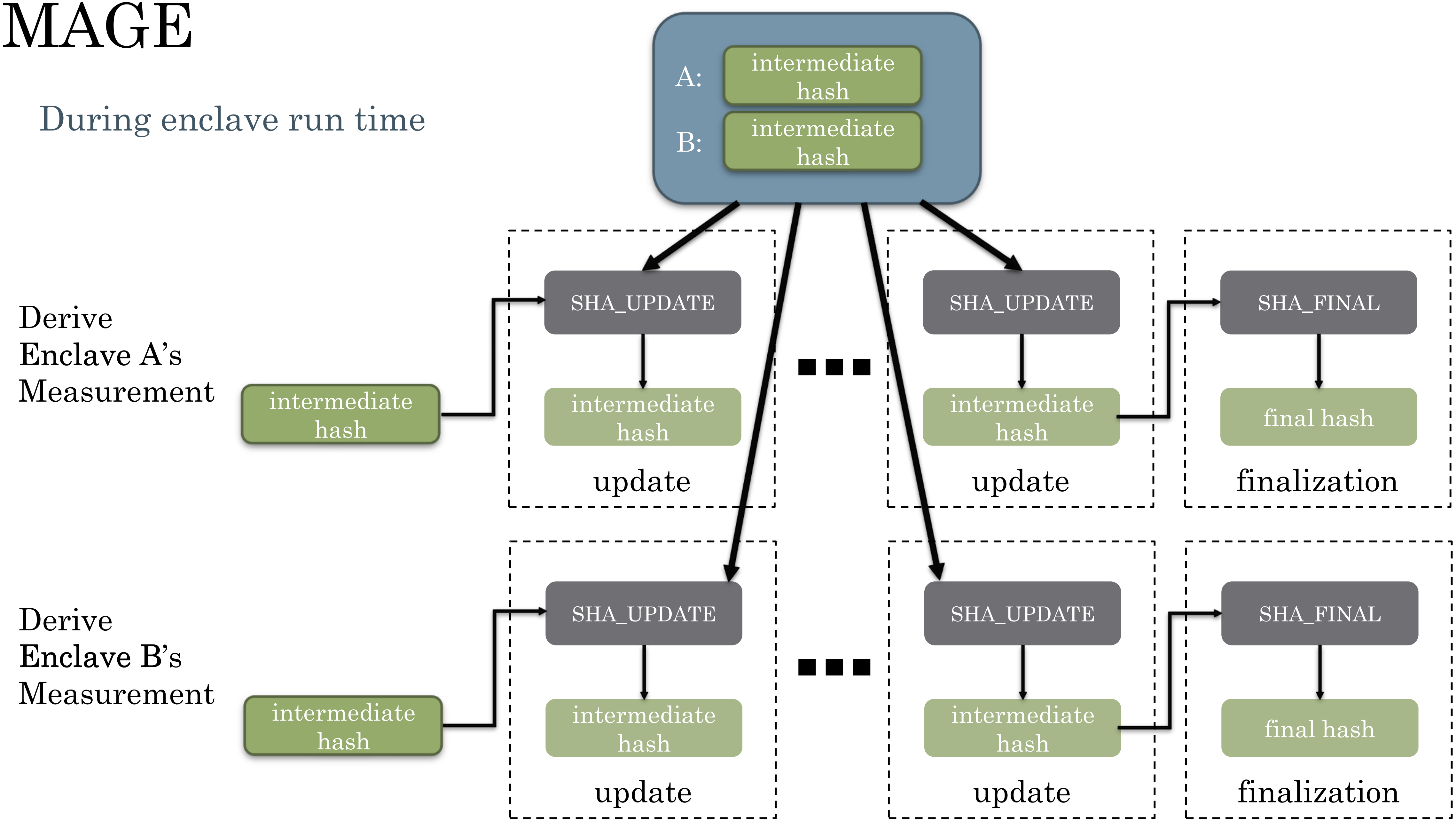
MAGE

During enclave creation



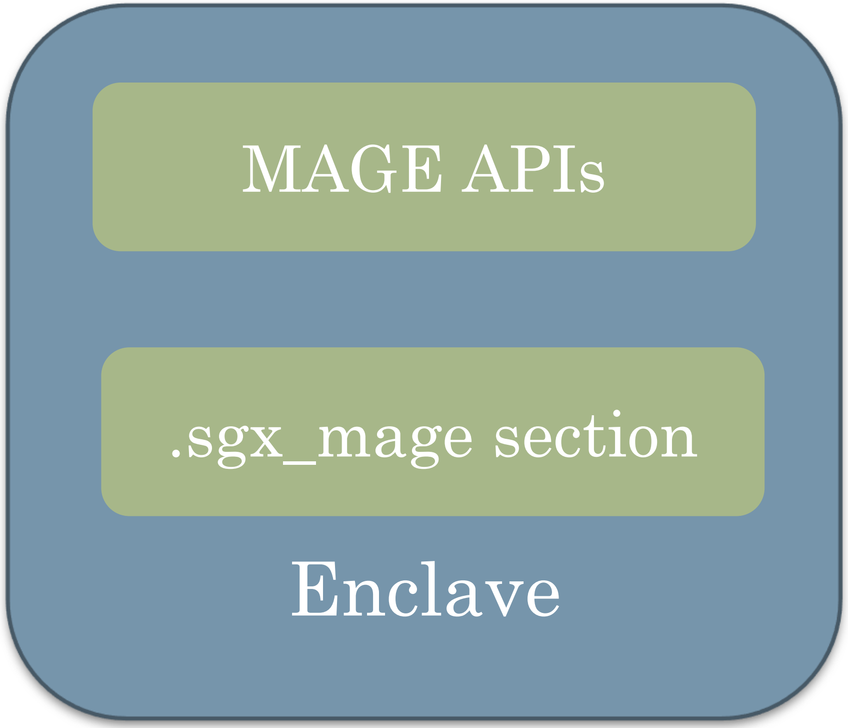
MAGE

During enclave run time



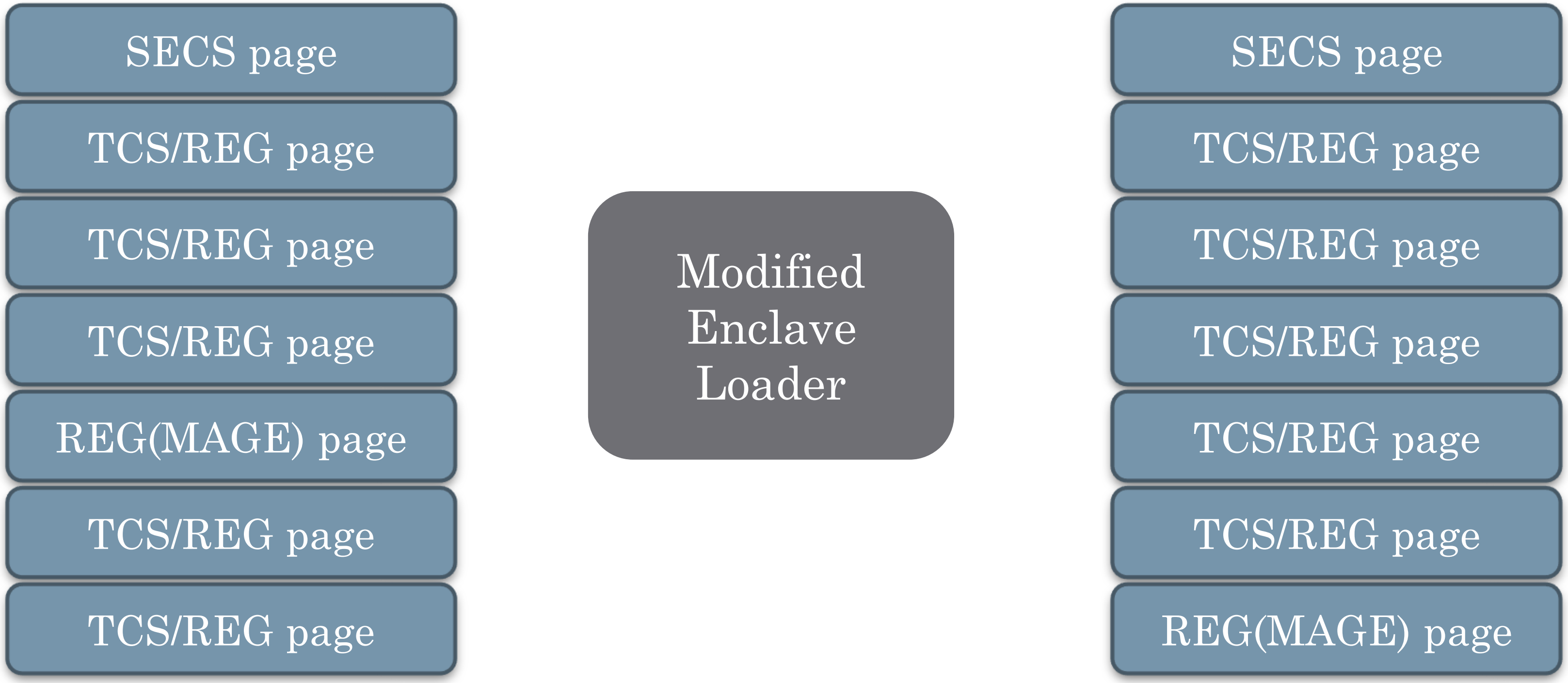
Implementation for Intel SGX

- MAGE library:
  - Reserve a read-only data section, named .sgx_mage
  - Provide APIs for deriving measurements from .sgx_mage



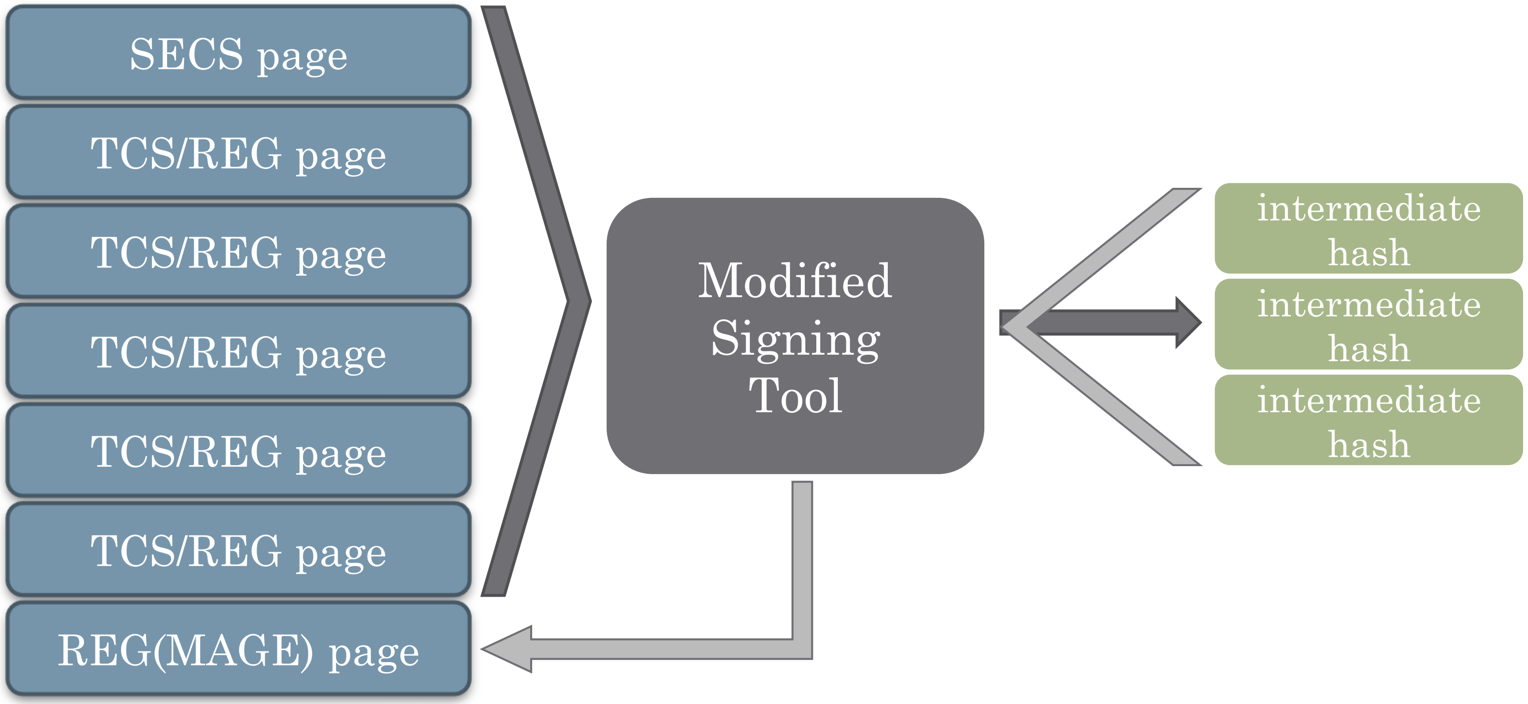
Implementation for Intel SGX

- Modified enclave loader:
  - Load .sgx_mage section after all other enclave code and data



Implementation for Intel SGX

- Modified signing tool:
  - Extract intermediate hashes from enclaves.
  - Insert intermediate hashes into .sgx_mage section



Performance

- Memory overhead
  - Linear with the number of trusted enclaves
  - 48 bytes to store auxiliary information (e.g., intermediate hashes, page metadata) for deriving one enclave measurement
  - One 4KB page could support 85 enclaves

- Measurement derivation efficiency
  - Linear with the size of .sgx_mage section
  - 21.7 microseconds to derive one measurement when .sgx_mage section consists of one page

Discussion

- Alternative designs
  - Extending MAGE with untrusted storage for better scalability.

- Extensions to other TEEs
  - Even between different types of TEEs.

- Supporting enclave updates/private code

Thank You!

GitHub repo https://github.com/donnod/linux-sgx-mage

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