Software Guard Extensions (Intel® SGX) Attestation and Sealing

HASP - 2013

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Outline

- The challenge
- Attestation
- Sealing
- Tying it all together

The Challenge – Provisioning Secrets to the Enclave

- An enclave blob is in the clear before instantiation
  - Sections of code and data could be encrypted, but their decryption key can't be pre-installed
- Secrets must come from outside the enclave
  - Keys
  - Passwords
  - Sensitive data
- The enclave must be able to convince a 3rd party that it's trustworthy and can be provisioned with the secrets
- Subsequent runs should be able to use the secrets that have already been provisioned

Enclave Lifecycle

Launch

- An enclave is built and launched

Attestation

- The enclave proves its identity to a remote party

Provisioning

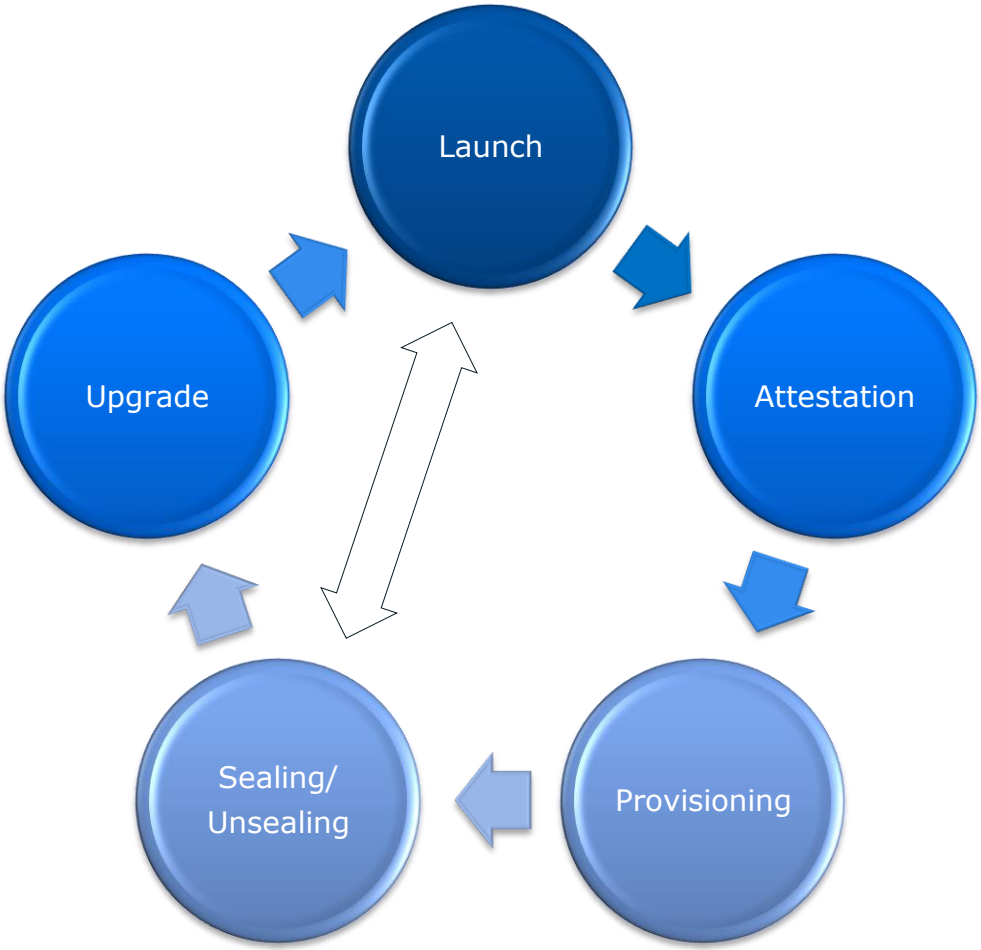
- The enclave receives secrets from the remote party

Sealing/Unsealing

- The enclave securely exports secrets for future use

Upgrade

- From time to time updates to enclave software are installed



Trustworthiness

- A service provider must vet the enclave's Trusted Computing Base (TCB) before it should trust it and provide secrets to it
  - The enclave's software
  - The CPU's hardware & firmware
- Intel® SGX provides the means for an enclave to securely prove to a 3rd party:
  - What software is running inside the enclave
  - Which execution environment the enclave is running at
  - Which Sealing Identity will be used by the enclave
  - What's the CPU's security level

EREPORT & EGETKEY

- EREPORT
  - Generates a REPORT that is signed by a cryptographic MAC using a REPORT KEY
  - The REPORT includes:
    - MRENCLAVE – software TCB
    - MAC – hardware & firmware TCB
    - User Data – aux trusted information (e.g. ephemeral session key)
- EGETKEY
  - Provides an enclave with a persistent key
    - REPORT KEY for attestation verification
    - SEAL KEY for sealing
      - Enclave Identity sealing key
      - Sealing Identity sealing key

Attestation

Attestation – Software TCB

- When building an enclave, Intel® SGX creates a log of all the build activities
  - Content: Code, Data, Stack, Heap
  - Location of each page within the enclave
  - Security flags being used
- MRENCLAVE ("Enclave Identity") is a 256-bit digest of the log
  - Represents the enclave's software TCB

- A software TCB verifier should:
  - Securely obtain the enclave's software TCB
  - Securely obtain the expected enclave's software TCB
  - Compare the two values

Local Attestation

- "Local attestation": The process by which one enclave attests its TCB to another enclave on the same platform
- Using Intel® SGX's *EREPORT* and *EGETKEY* instructions
  - EREPORT generates a cryptographic REPORT that binds MRENCLAVE to the target enclave's REPORT KEY
  - EGETKEY provides the REPORT KEY to verify the REPORT

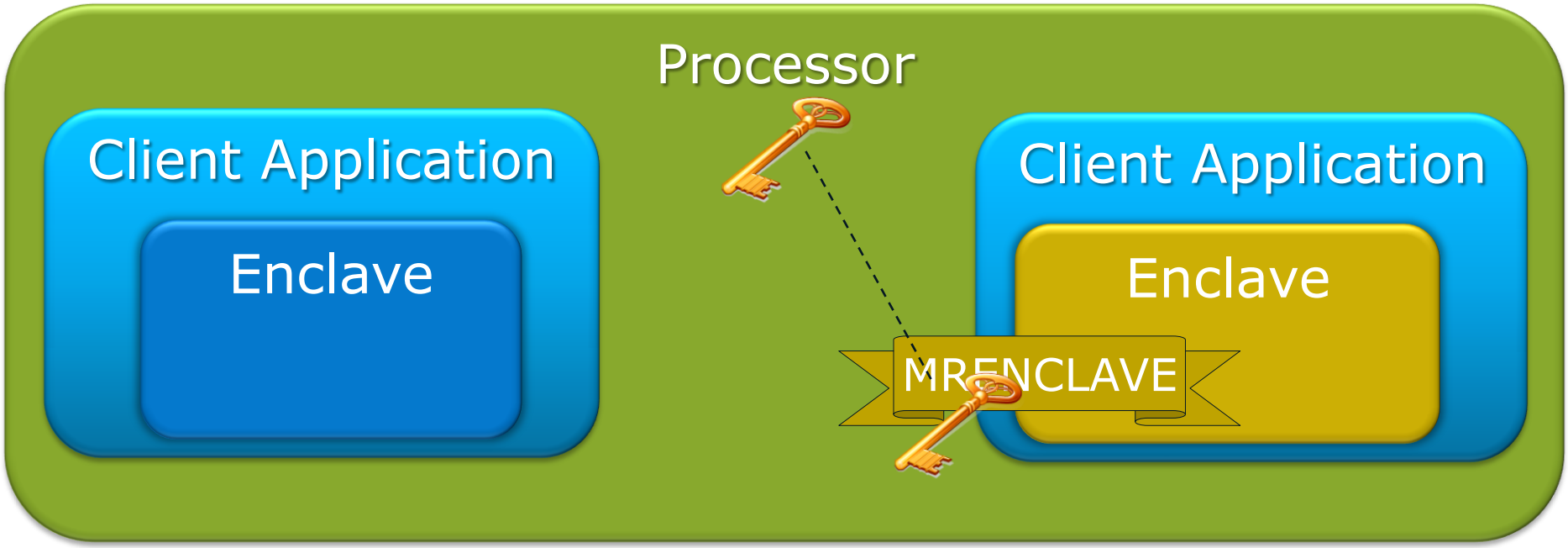
TCB component	Attestation
CPU hardware & firmware	Symmetric - CPU REPORT KEY
Software	MRENCLAVE

Remote Attestation

- "Remote attestation": The process by which one enclave attests its TCB to another entity outside of the platform
- Intel® SGX Extends Local attestation by allowing a Quoting Enclave (QE) to use Intel® EPID to create a QUOTE out of a REPORT
  - Intel® EPID is a group signature scheme

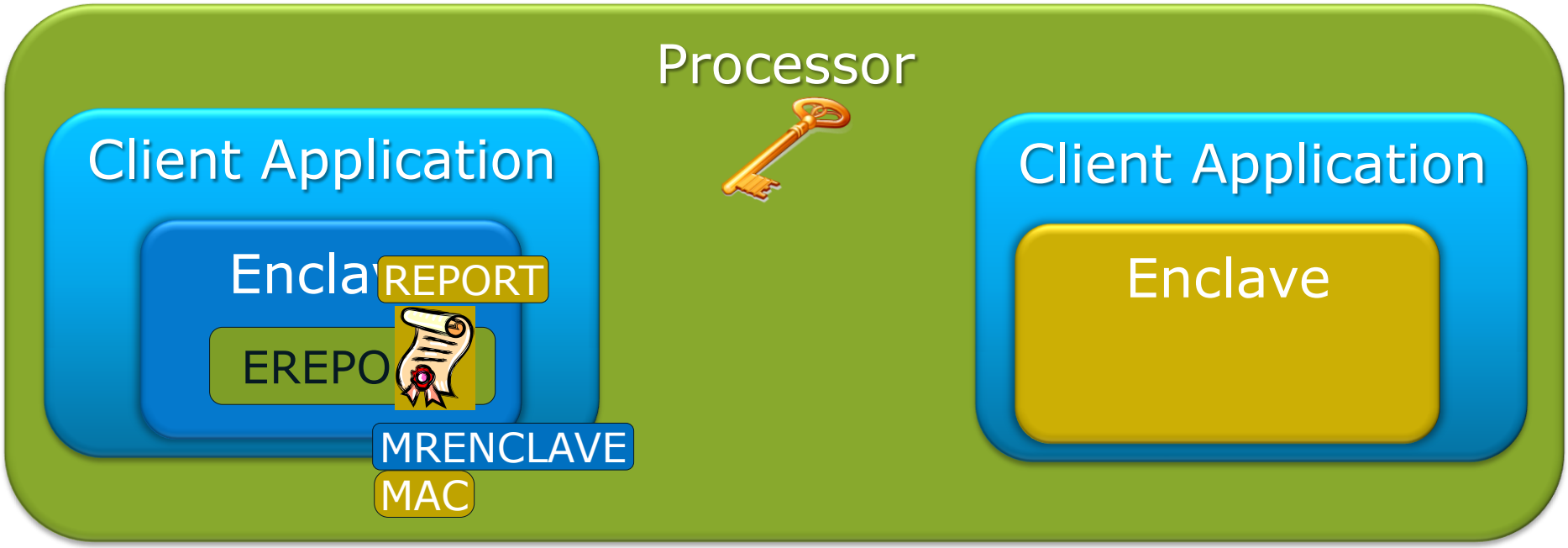
TCB component	Attestation
CPU hardware & firmware	Asymmetric - Intel® EPID
Software	MRENCLAVE

Local Attestation - Flow



1. Verifying enclave sends its MRENCLAVE to reporting enclave
2. Reporting enclave creates a cryptographic REPORT that includes its MRENCLAVE and sends to verifier
3. Verifying enclave obtains its REPORT key and verifies the authenticity of the REPORT

Local Attestation - Flow



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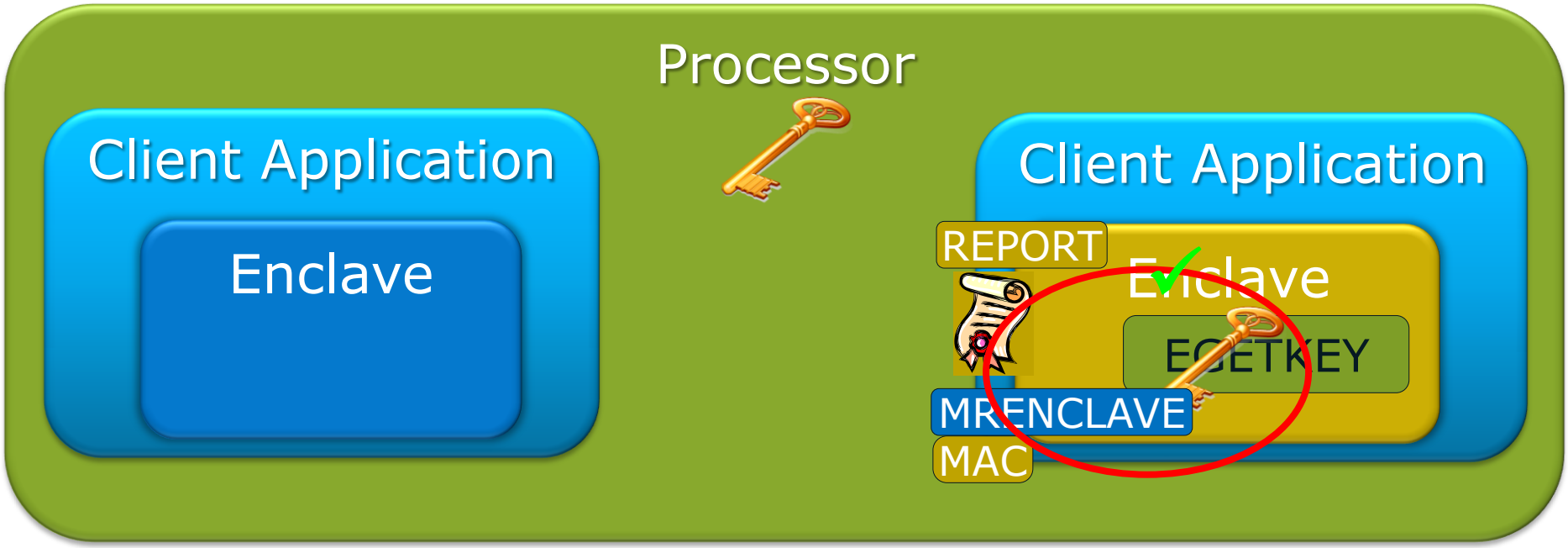

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Remote Attestation - Flow

1. Verifying enclave becomes the Quoting Enclave.
2. After verifying the REPORT the, QE signs the REPORT with the EPID private key and converts it into a QUOTE
3. Remote platform verifies the QUOTE with the EPID public key and verifies MRENCLAVE against the expected value

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Sealing

Sealing Authority

- Every enclave has an Enclave Certificate (SIGSTRUCT) which is signed by a Sealing Authority
  - Typically the enclave writer
  - SIGSTRUCT includes:
    - Enclave's Identity (represented by MRENCLAVE)
    - Sealing Authority's public key (represented by MRSIGNER)
- *EINIT* verifies the signature over SIGSTRUCT prior to enclave initialization

Sealing

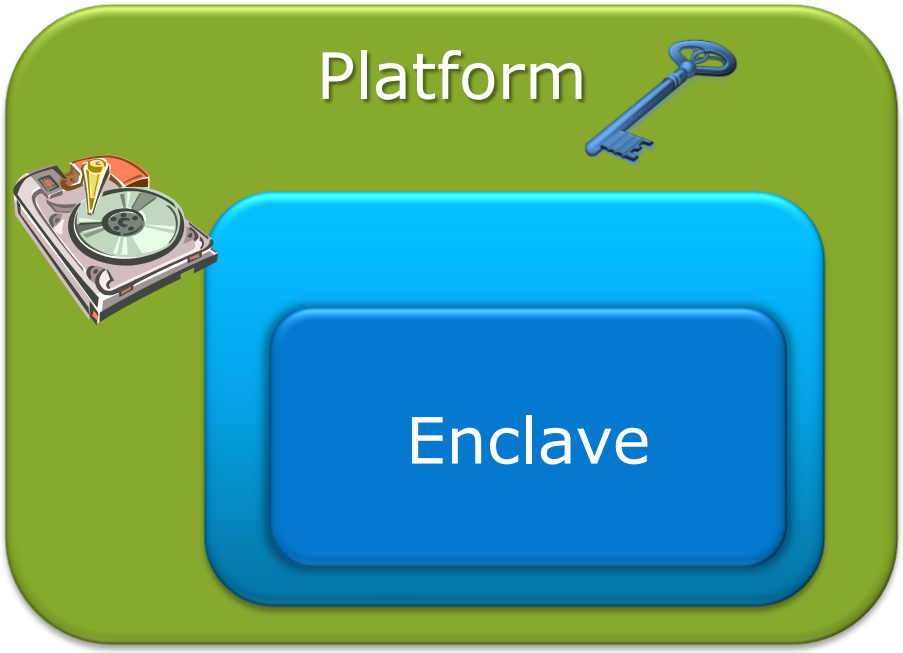
- "Sealing": Cryptographically protecting data when it leaves the enclave.
  - Totally under software's control
  - Many policies possible
- "Sealing Identity" of an enclave is a combination of:
  - Sealing Authority
  - Product ID
    - Typically the applications Product ID
  - Security Version Number (SVN)
    - Product's security level
    - Incremented by the authority as security vulnerabilities get fixed

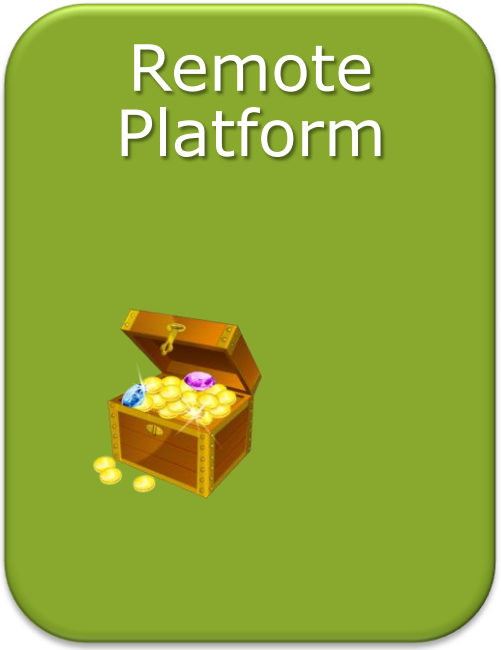
Intel® SGX provides the way to obtain persistent keys

Sealing Policies

- Sealing to Enclave Identity
  - EGETKEY bases the key on the value of the enclave's MRENCLAVE
  - Ensures that only this specific software instance will be able to regenerate the same SEAL KEY
- Sealing to Sealing Identity
  - EGETKEY bases the key on the value of the Sealing Identity
  - Ensures that the same SEAL KEY can only be regenerated by:
    - The same Sealing Authority
    - The same Product ID
    - An SVN >= Current SVN

Sealing - Flow





1. Secret provided to the Enclave
2. Enclave calls EGETKEY and obtains a SEAL KEY
3. Enclave wraps the secret with the SEAL KEY and stores the blob on disk

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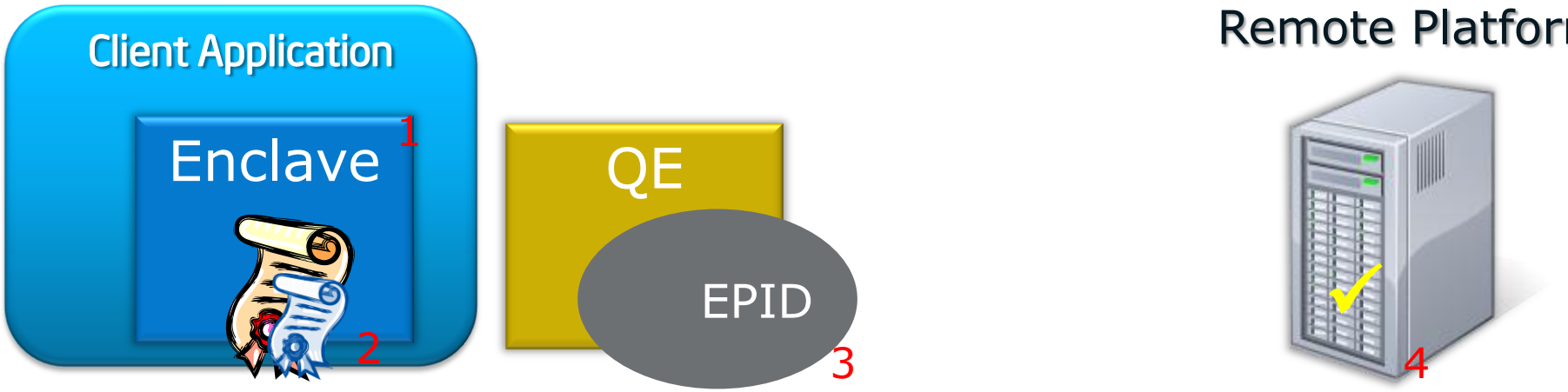
Example: Secure Transaction



1. Enclave built & measured against ISV's signed certificate
2. Enclave calls *EREPORT* to obtain a REPORT that includes enclave specific data (ephemeral key)
3. REPORT & user data sent to Quoting Enclave who signs the REPORT with an EPID private key
4. QUOTE sent to server & verified
5. Ephemeral key used to create a trusted channel between enclave and remote server
6. Secret provisioned to enclave
7. Enclave calls *EGETKEY* to obtain the SEAL KEY
8. Secret is encrypted using SEAL KEY & stored for future use

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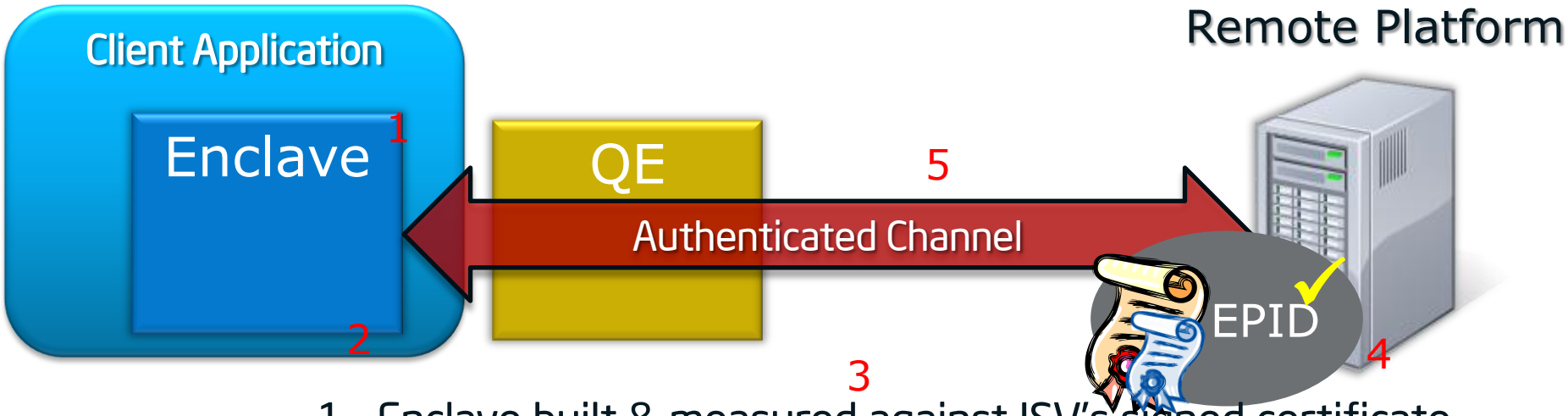

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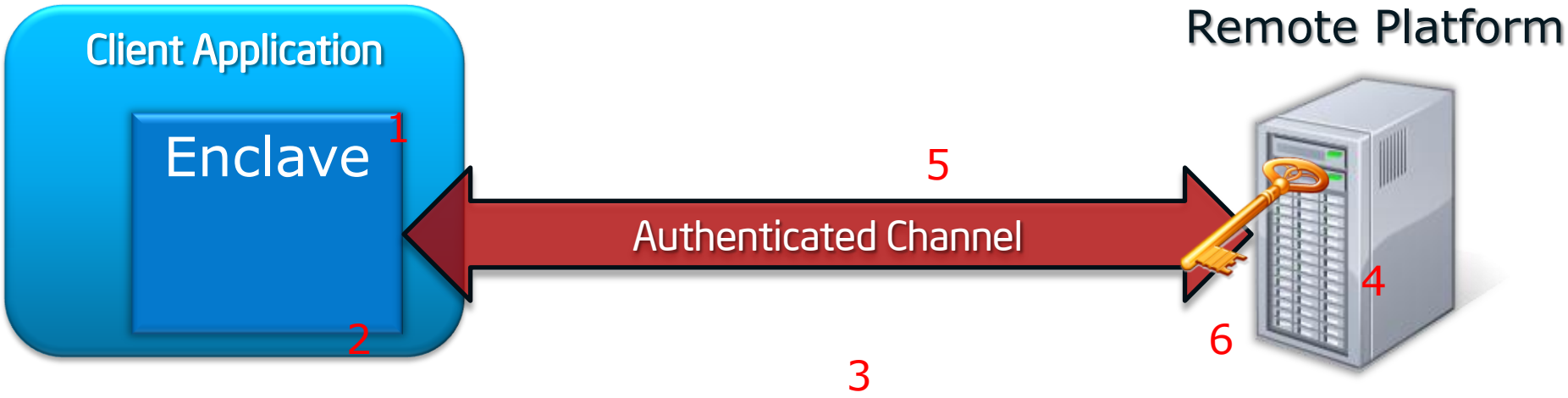

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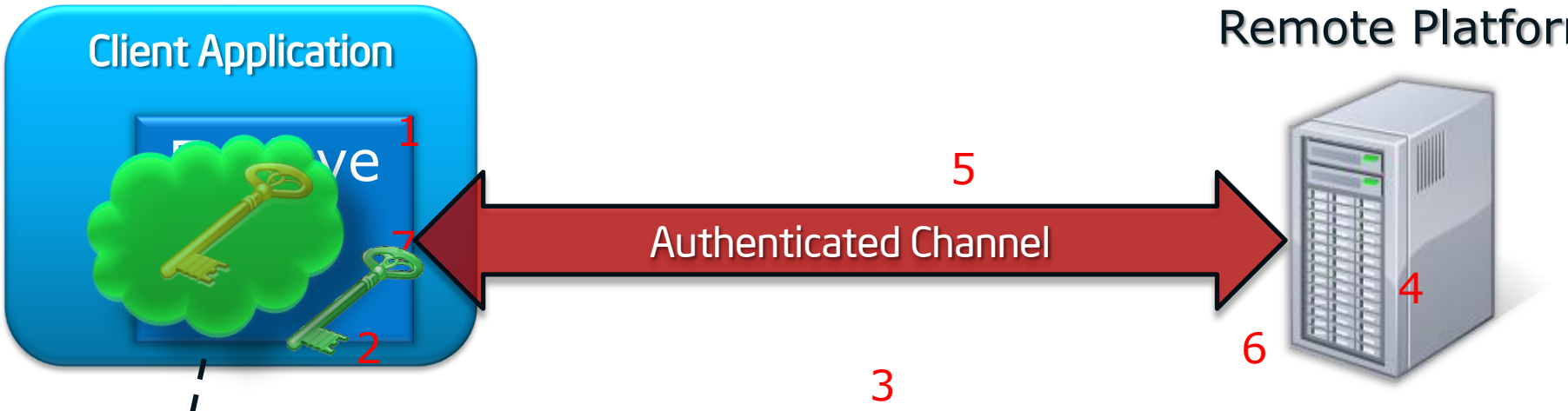

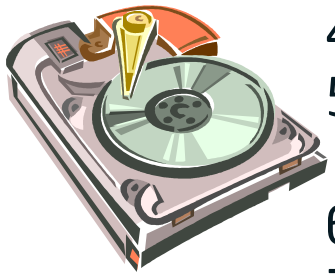

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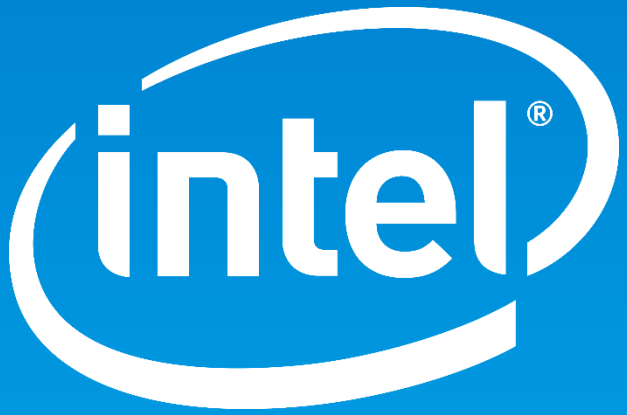
Summary

- Intel® SGX's *EREPORT* and *EGETKEY* instructions provide unique attestation and sealing capabilities to protected software containers (a.k.a enclaves)
- Attestation
  - Local attestation between 2 entities running on the same platform
  - Remote attestation between an entity running in an enclave and a remote 3rd party entity
- Sealing
  - A sealing key that is unique to a software's instance
  - A sealing key that is shared between different versions of the same software as long as they have equal or better Security Version Numbers
    - For offline migration of data to newer versions of the application

Thank You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