Trusted Hardware

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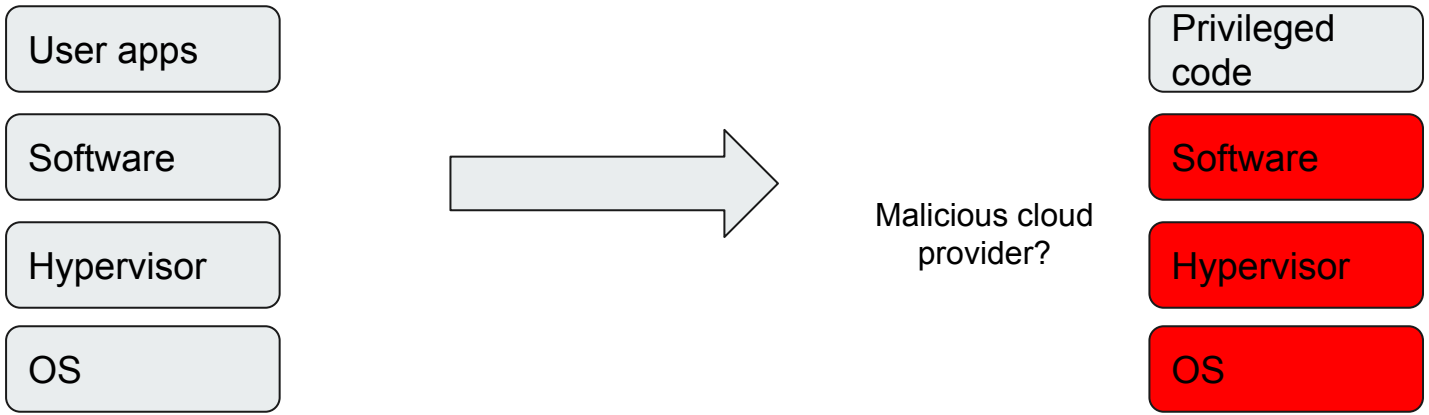
Move to a Cloud-based model

User apps
Software
Hypervisor
OS

PaaS
Cloud Provider manages the stack

User apps
Software
Hypervisor
OS

Move to a Cloud-based model



Can you trust the cloud?

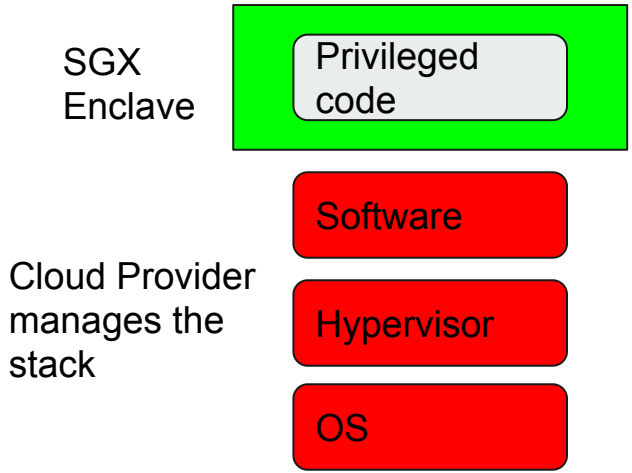
- Huge Trusted Computing Base (TCB)
- Cloud Provider’s software
- Management stack
- Sysadmins

What do we want?

Shielded Execution using SGX

Confidentiality: The execution state is unobservable to the rest of the system.

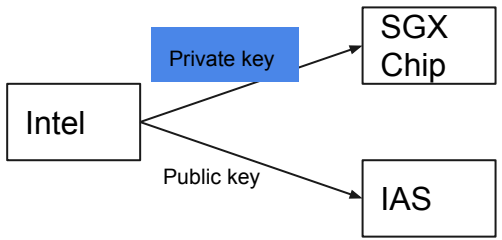
Integrity: If the program completes, its output is the same as a correct execution on a reference platform

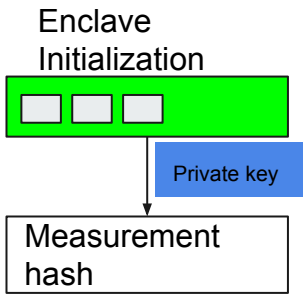


Is shielded execution sufficient?

Remote attestation

- **Goal:** Allow cryptographic verification that specific software has been loaded within an enclave
  - While an enclave is initialized, its contents is cryptographically hashed by the CPU forming the enclave's ***measurement***
- Generated using a key burnt on the SGX chip
  - Root of trust: Intel
  - Intel attestation service (IAS) for verification

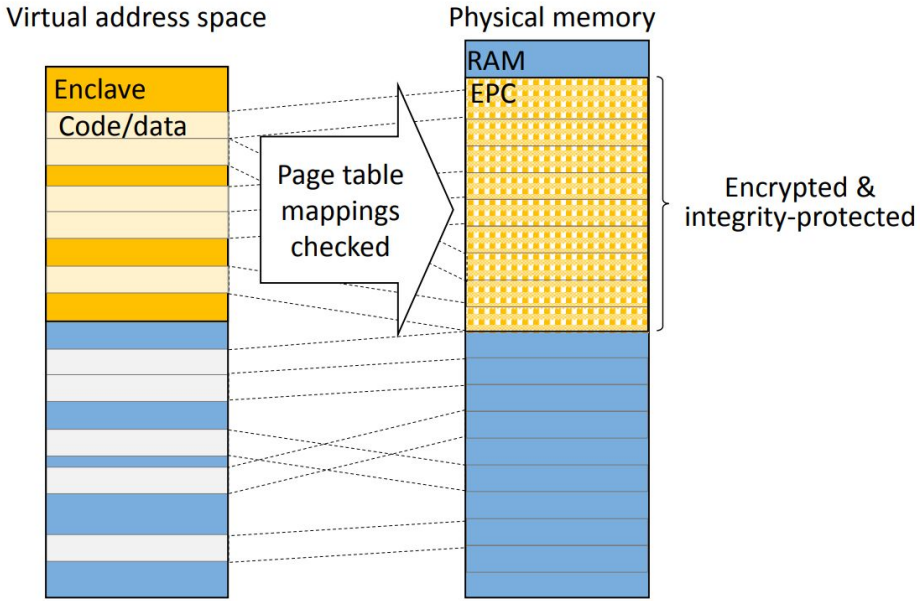




How does SGX achieve this?

Memory protection

- **EPC** (Enclave Page Cache)
  - A separate region in physical memory
  - All enclave pages reside here
  - Hardware tracks meta info corresponding to each page
  - Virtualized



Memory protection

- EPC (Enclave Page Cache): A separate region in physical memory
  - Encrypted and integrity-protected before writing to the main memory

- Same page table as the underlying OS
  - **Access checks** are performed to ensure any other application (not even other enclaves) can access an enclave's data

Execution lifecycle (high-level)

- Loading stage: Performed by untrusted code
  - Enclave is initialized by copying code/data into **EPC Pages**
  - At the end of which, contents are hashed to compute enclave's **measurement hash**
- Enclave mode:
  - Special instructions to create an enclave, add pages to enclave and exit an enclave
  - Similar to switching from user to kernel mode
  - Secure mechanisms to handle interrupts (or) page faults to protect from OS exception handlers

Before SGX?

Trusted Platform Module (TPM)

- Attestation-based
- Can be used with commodity systems
- **Weak security**
  - Much bigger TCB than SGX: Measurement hash covers **all** the OS modules and device drivers
  - Very hard to keep an up-to-date list of the hashes
  - Many more attacks....

How to port legacy applications into SGX?

Developing applications in SGX

- Untrusting OS: Makes it harder
- Any function call (or) syscall made outside the enclave are not guaranteed to return
- Even if data returns, enclave cannot trust the data returned

Haven

- Haven design goals:
  - Mutual distrust b/w guest and host
  - Run legacy apps inside SGX without any modifications
- Application interacts only with LibOS
  - Assumes libOS is carefully implemented
- Shield module interacts with the untrusted host OS

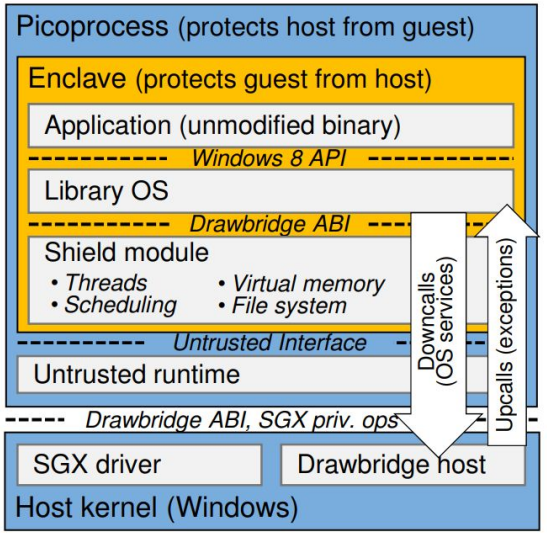


Figure 2: Haven components and interfaces

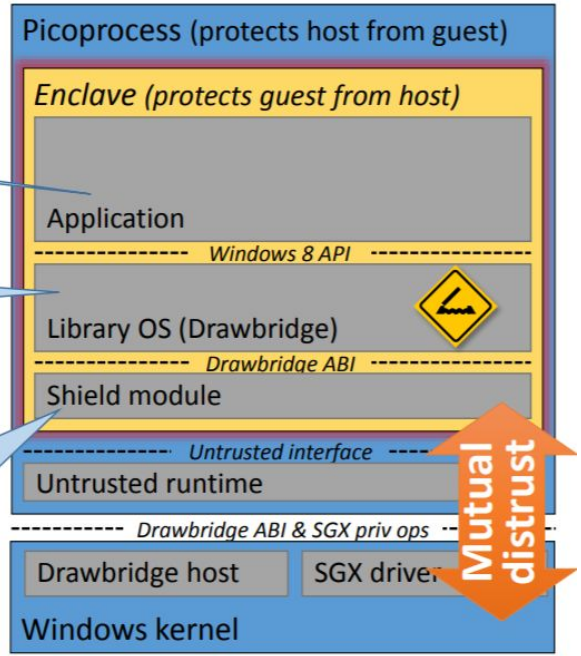
How Haven handles Iago attacks

Iago attacks: “Malicious kernel attempts to subvert an isolated application by exploiting its assumption of correct OS behaviour, for example when using the results of system calls”

LibOS: Implement entire OS as part of the *Trusted Computing Base*. Limits the interaction of enclave app with the actual OS, thus reducing the attack surface.

Haven

- Unmodified binaries
- Subset of Windows, enlightened to run in-process
- Shields LibOS from Iago attacks
- Includes typical kernel functionality
  - Scheduling, VM, file system
- Untrusted interface with host



LibOS and Exokernels

Both bring OS level functionalities to the user space, but for what reasons?

- Efficiency in Exokernel: “Move OS functionality to the user space to grant more flexibility”
- Security in Haven’s LibOS: “Move OS functionality into the enclave to reduce attack space”

Haven Performance

- 35% - 65% slowdown
- Depends on the exact use case
-

Haven influencing SGX

Haven influencing SGX design

- Dynamic memory allocation
  - SGX does not allow addition of enclave pages after the creation of enclave
- Exception Handling
  - SGX does not allow handling of all exceptions
- Some other limitations

Fixed in v2.0

SGX: What's new?

- Latest v2.3
  - Trusted randomness, other crypto operations
  - File abstractions inside an enclave
- Baidu's Rust SGX SDK
  - Dockerized
  - Runs a simulated version on machines without SGX chip as well

Is SGX secure?

- Sophisticated side channel attacks
- Foreshadow - Usenix'18
    - Speculative execution

Trusted hardware makes the attacker's job costly

Discussion

Haven

- Exokernel connection to Haven
- Impact of Haven and why it's not more widely used?

SGX

- Does trusted hardware solve the problem of security in the cloud?
- Can SGX still be useful in face of side channel attacks?

Thank you!

References:

1. Haven, Slides
2. Intel SGX explained