Maru: Hardware-Assisted Secure Cloud Computing

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Cloud provider does not trust users

Use virtual machines to isolate users from each other and the host

VMs only provide one way protection
Users trust their applications

Users must implicitly trust cloud provider

Existing applications implicitly assume trusted operating system
Users create HW-enforced trusted environment

Supports unprivileged user code

Protects against strong attacker model

Remote attestation

Available on commodity CPUs
New **enclave** processor mode

18 new instructions to manage enclave life cycle

**Enclave memory** only accessible from enclave

Certain instructions disallowed, e.g., syscall

No system calls

Performance overhead

Intel SGX: Hardware-Assisted Security

![Diagram](image)
SGX: System Call Overhead (pwrite)

System calls outside of enclave are expensive
SGX: Memory Access Overhead

Large amount of enclave memory leads to poor performance
SGX Research Challenges

- Untrusted component
- Attack surface
- Performance overhead
- Secure enclave
- Sensitive code and data
- TCB size
I. Complete unmodified applications in enclaves (Systems support?)

II. Privilege Separation (Minimal TCB?)

Systems Support for SGX?
1. SCONE: Secure CONtainer Environment

1. Good performance/security trade-off
   - Small TCB (0.8×–2.1× of native size)
   - Low overhead (0.3×–1.1× of native throughput)

2. Efficient system call support
   - M:N user-level threading
   - Asynchronous syscall execution

3. Transparent interface shielding
   - Encryption of file descriptors
   - TLS support for network sockets
   - Encrypted data stored outside enclave
# 2. Glamdring: Application Partitioning

<table>
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<th>1. Static / Dynamic Analysis</th>
<th>2. Graph partitioning</th>
<th>3. Automated source-to-source code transform</th>
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<tr>
<td>Collect information to obtain valid partitioning</td>
<td>Find partitioning of application</td>
<td>Implement partitioning using Intel SGX SDK</td>
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**Diagram:**
- **Original source code** → **Modified binary (initial tainting)** → **Trace Collection** → **Instrumented binary** → **Graph Partitioning** → **Code Generation**
- **Untrusted app code**
- **Sensitive app code**
3. LibSEAL: Secure Auditing Library

LibSEAL: Secure TLS Auditing Library
- Provide accountability to TLS-enabled application
- Help link integrity violations to origin

Workflow:
1. Securely log communication between client and service
2. Audit against application-specific invariants

Use cases:
- Dropbox: Have files been lost?
- Git: Is the server hiding commits?
- Owncloud: Were there illegitimate modifications to content or layout?
Maru: Security Threats in Data Science

- External attacker
- Malicious insider
- Malicious tenant
- VM
- OS
- Data science job
- Other VM
- Hypervisor
- Hardware
1. **Security model for shielded data science jobs**
   - How to harden shielded jobs? How to deal with vulnerabilities, bugs?
   - What about external dependencies/libraries?

2. **Integration of language runtimes with secure enclaves**
   - How to integrate SGX support for the JVM?
   - What is the right programming model for SGX enclaves?

3. **Unikernel support for secure enclaves**
   - How to support existing legacy binaries?
   - How to build type-safe minimal secure enclaves for data science jobs?

4. **Prototype platform implementation and evaluation**
   - Integration with Apache Flink or other dataflow frameworks

5. **Dataflow attacks and mitigations strategies**
   - What attacks are possible by observing encrypted dataflows?
   - Can we apply techniques for unobservable communication?