Mitigating I/O Vulnerabilities In Trusted Execution Environments

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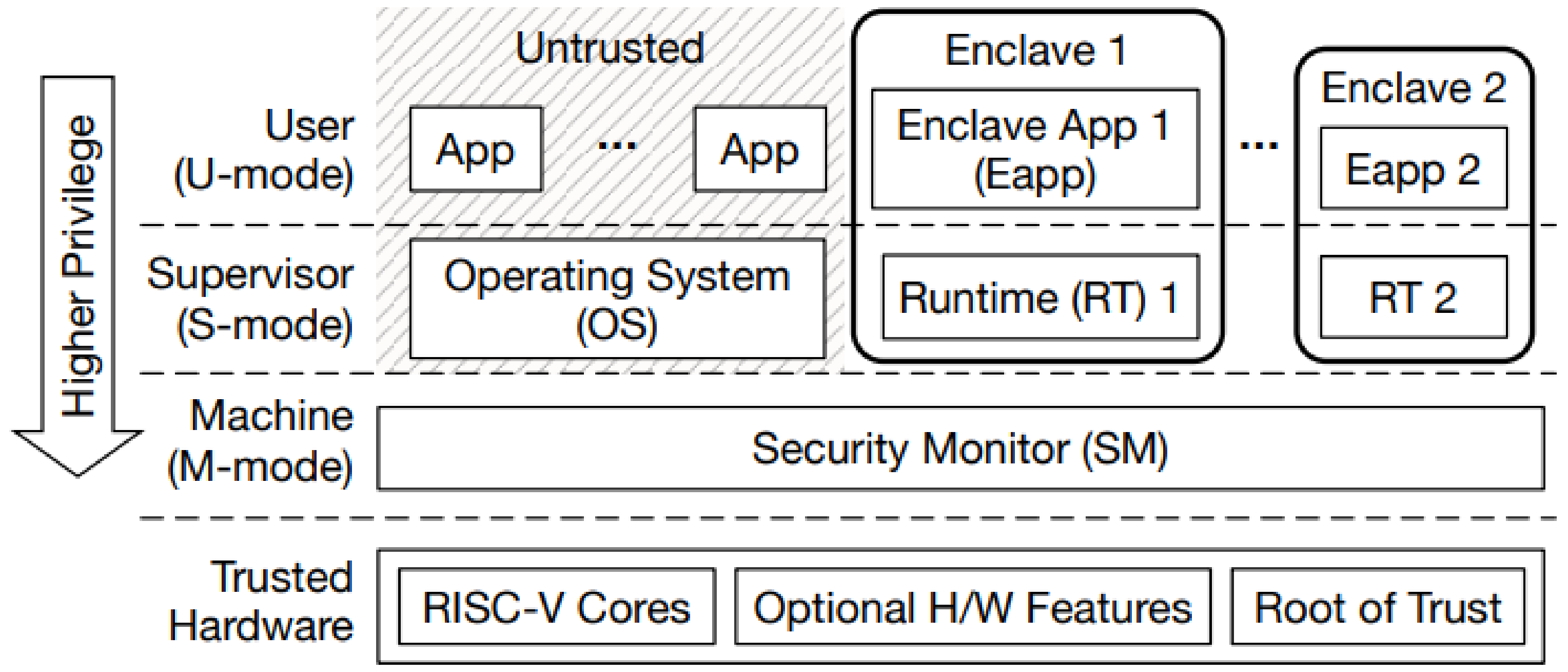
Introduction

Trusted Execution Environments (TEEs) protect sensitive code and data from untrusted systems. While existing TEEs like Intel SGX are closed and rigid, **Keystone** offers a flexible, open-source TEE for **RISC-V**, enabling customizable enclave designs. However, I/O pathways remain a potential attack surface. This project investigates Keystone's I/O vulnerabilities and explores strategies for securing enclave interactions.

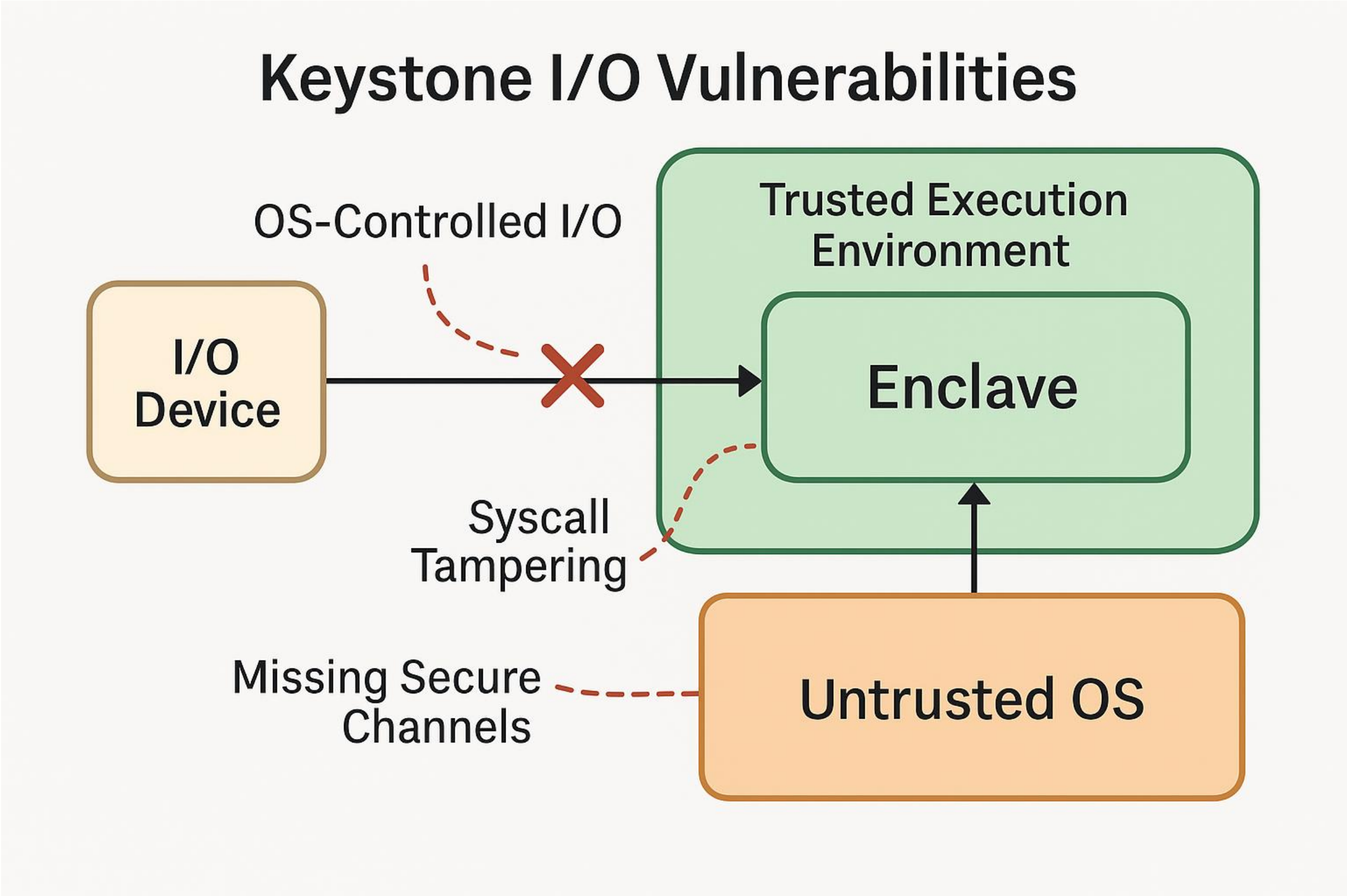


Acknowledgements

- D. Lee, M. Yun, R. Xu, S. Arora, I. Lebedev, R. Xu, and S. Devadas, "Keystone: An Open Framework for Architecting Trusted Execution Environments," https://doi.org/10.48550/arXiv.1907.10119
- QEMU - https://www.qemu.org/

Research Methods

- Deploying **Keystone** with **FireMarshal** and **Chipyard** on **AWS EC2** using RISC-V toolchain and FireSim.
- Building and testing Keystone with **QEMU (Quick EMUlator)** using Buildroot and custom defconfigs.
- Conducted literature review on **TEE models**, Keystone internals, and enclave benchmarks.
- Plan to explore **enclave memory** and **I/O isolation** through **PMP** and **edge call mechanisms**.
- Plan to analyze **attestation flow**, secure boot procedures, and syscall security within the security monitor.


Keystone I/O Vulnerabilities

Progress/Achievements So Far

- •Built toolchains and dependencies using Buildroot.
- •Successfully compiled host-binutils and toolchain after cleaning stale builds.
- •Patched CMakeLists to support keystone-sdk configuration.
- •Managed PATH, environment, and overlay issues during image build.

Existing Vulnerabilities

- **OS-Controlled I/O** – Data paths to I/O devices remain exposed to OS tampering and snooping.
- **Syscall Tampering** – I/O syscalls can be intercepted or altered by a malicious OS.
- **Missing Secure Channels** – TEEs lack built-in secure I/O, relying on vulnerable custom implementations.

Future Plans

- Fix g++ linker to finalize SDK build, validate enclaves on QEMU, and benchmark performance/security.
- Integrate FireSim for profiling and analyze I/O vulnerabilities with architectural fixes.
- Resolving QEMU and cross-compilation issues (GLIBC, pkg-config) due to outdated model.