Secure I/O
IBM® LinuxONE
Trusted computing base

Confidential Workload
Guest OS

Hypervisor KVM
Host OS

Secure Execution Image

Security hashes

Keys

Initramfs

Kernel

Parameters

Machine public key certified by CA

Client private key

IBM® LinuxONE

Ultravisor

Machine private key
Only available in hardware

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Connecting an EP11 cryptography co-processor to an IBM Secure Execution Guest

**Goal**
Ensure that KVM/Host cannot get any key material

**Bind**
- Binds an EP11 exclusively to a SE-guest

**Associate**
- Create a session
  - **Secret** defines session
  - All key material is session bound
    → Only usable in this session
  - Sessions can be continued later

**Association Secret**
- Encrypted secret, created on another trusted machine
- Secrets are managed by UV per SE guest instance
### TDISP State Machine

- One state machine per TDI
- State transitions
  - TDISP command from the host
  - Device or function reset
  - Error condition

<table>
<thead>
<tr>
<th>State</th>
<th>Device Config Changes?</th>
<th>DMA/MMIO</th>
<th>Device hold confidential data?</th>
<th>Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>UNLOCKED</td>
<td>Yes</td>
<td>Yes - Not Confidential</td>
<td>No</td>
<td>Legacy</td>
</tr>
<tr>
<td>LOCKED</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Verification by TVM</td>
</tr>
<tr>
<td>RUN</td>
<td>No</td>
<td>Yes - Confidential</td>
<td>Yes</td>
<td>TDI in use by guest</td>
</tr>
<tr>
<td>ERROR</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Fatal Error - Confidential data wiped</td>
</tr>
</tbody>
</table>
CoVE-IO
RISC-V Secure I/O

Jiewen Yao (Intel) / Samuel Ortiz (Rivos)
RISC-V AP-TEE-IO TG
CoVE-IO

- **Confidential Virtual machine Extensions for I/O**
- Extension of the [RISC-V Confidential Computing ISA](#) (a.k.a. CoVE)
CoVE-IO ABI and Flows

- connect() → bind() → start()
- TSM owns the SPDM session
  - And manages TDISP and the IDE keys
- TSM manages DMA & MMIO mappings
- Host VMM owns the physical device
  - Host initiates the SPDM session establishment
  - VMM → TSM: covh_connect_device()
- Host VMM binds the device interface
  - VMM → TSM: covh_bind_interface()
- Guest verifies the bound interface
- Guest starts the interface
  - Guest → TSM: covh_start_interface()
SEV-TIO: Trusted I/O for SEV-SNP Guests

Jeremy Powell & Tom Lendacky
SEV-SNP – Untrusted Devices

- MMIO Cannot Map to Private Memory
- DMA to Private Memory Blocked
SEV-TIO – Trusted Devices

**MMIO Can Map to Private Memory**

**Shared Memory**

**Private Memory**

**MMIO**

**RMP**

**Guest**

**DMA directly to Private Memory**

**Shared Memory**

**Bounce Buffer**

**Private Memory**

**Buffer**

**RMP**

**Guest**

**Guest uses data in Private Memory**

**DMA to Private Memory Allowed**
Diagram is only an example.

Guest & TDI lifecycle has many open design decisions.
Protecting PCIe Traffic

- Secure Protocol and Data Model (SPDM)
  - Protocol connecting device to ASP
  - Encrypted and integrity protected
  - Control path for configuring trusted device
- PCIe Integrity and Data Encryption (IDE)
  - Confidentiality and authenticity between PCIe ports
  - Keyed by ASP using SPDM
  - PCIe traffic protected at transaction layer
Enabling Secured MMIO

- Private MMIO ranges
  - Located in private guest memory
  - ASP verifies configuration (system physical $\leftrightarrow$ device mapping)
  - Configures RMP for secure MMIO

- Guest MMIO access
  - Existing RMP checks prevent remapping attacks
  - MMIO access is routed to appropriate device through the device’s IDE stream
Enabling Secured DMA

- Secure Device Table (SDT)
  - Additional RID-indexed table
  - Associates the RID with the guest
  - ASP programs on behalf of guest
- Access control on DMA
  - Hardware routes and tags traffic per SDT entries
  - IOMMU performs RMP checks like CPU MMU
  - Guest manages DMA targets like any other private guest memory (i.e., using PVALIDATE instruction)
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Framing Questions

• What if there was a standard Platform Secure I/O interface definition?
  o How much deviation would upstream tolerate from that standard?
• Given there is no standard and multiple vendor interface proposals in flight what is Linux's role in mitigating differentiation?
• Given the fundamental complexity of Secure I/O where do we start as a community?
Towards a Linux Secure I/O Interface

Definition

• Guiding principles:
  o Find the coarsest grained (externalizes the least amount of complexity to Linux) and minimal set of verbs to transition a device-instance into and out of Secure I/O operation. Advocate for vendors to move their interfaces to that standard.
  o Start with the most ruthlessly simple implementation, but no simpler, and incrementally evolve to address more use cases.
Apply the Principles

- SPDM, IDE, and TDISP protocol abstracted behind TSM
- Common TSM verbs: Connect, Bind, Unbind, Disconnect, Info (Certs, Measurements, Report)
- Linux GHCx for common guest to host operations
- Dispatcher(s) to help limited TSM execution environments offload protocol handling complexity