Exploring I/O Support for Virtualization-Based Trusted Execution Environment

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Sep. 2022 / KVM Forum 2022
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Agenda

- Background
- Current direct I/O support for TEE VM (TVM)
  - Working model and challenges
- TDISP support for TVM
  - PCIe* TEE Device Interface Security Protocol (TDISP) Overview
  - Intel® Trust Domain Extensions (TDX) with TEE-IO (TDISP) support
- Summary
Virtualization techniques are used to provide an increased security guarantee for Trusted Execution Environment (TEE) such as TEE Virtual Machine (TVM).

Confidential computing inside TVM requires I/O support:
- Assistances or accelerations provided by external devices.

Focus on direct IO support discussion in this presentation.
Current direct I/O solution for TVMs – Overview

- Devices are not allowed to read / write the TVM’s confidential memory
- No protection for data inside shared memory which can be accessed by VMM
- Data path between Host and Device is not trusted
  - IOMMU is not in the TCB
  - Physical Link is not protected
Current direct I/O solution for TVMs – Working Model

- TVM Data can be consumed by either device (case 1) or peer (case 2)
- Secured data channel must be established to improve data confidentiality and integrity
Current direct I/O solution for TVMs – Challenges

- Additional cryptographic protections required for TVM data
- Performance overhead as extra steps needed for encrypt copy-out & decrypt copy-in to/from shared memory
Include device into TVM’s TCB?

- Is there any mechanism to allow TVM to include the target device into the TVM’s TCB?
TDISP Overview

- PCIe* TEE Device Interface Security Protocol (TDISP) defines an architecture of trusted I/O virtualization (TEE-IO)
  - Establishment a trust relationship between a TVM and a TDISP-compliant device
  - Help secure the data-path interconnect between the host and device
  - Support TDISP-compliant device assignment and removal life cycle in a trusted manner
TDISP Overview

- TDISP builds upon the foundation provided by:
  - DMTF* Security Protocol and Data Model (SPDM)
  - PCIe* Component Measurement and Authentication (CMA)
  - PCIe* Integrity and Data Encryption (IDE)
  - PCIe* Data Object Exchange (DOE)
• **TDI: TEE Device Interface**
  - Unit of device assignment
  - Can be an entire device, a non-IOV function, a PF or a VF

• **DSM: Device Security Manager**
  - Enforce security isolation for TDIs
  - Authentication of device identities and measurement reporting
  - IDE encryption keys configuration
  - TDI management
    - (UNLOCKED, LOCKED, RUN and ERROR)
  - Access control
  - Security mechanisms to isolate TVM data
TDISP – Architecture Overview

- **TSM: TEE Security Manager**
  - Enforce security isolation for TVMs
  - Manage security states of TDIs
  - Security mechanisms and access controls
  - Establish and manage IDE Keys for the host

- **Trusted MMIO/DMA**
  - T bit in TLP IDE prefix
  - Used by device and host translation agent to provide access control

*TDISP Host/Device Reference Architecture [From PCIe* TDISP spec]*
Intel® TDX with TEE-IO support – Overview

1) TDISP-complaint device
   - Implement TDIs and DSM

2) IDE support

3) Trusted MMIO / DMA
   - Access control based on T bit

4) Intel® TDX Module + TPA
   - Function as TSM
   - TPA (TDX provision agent) is an architectural TD, helps TDX module with SPDM support

[Diagram of Intel® TDX with TEE-IO architecture]

[Text: Intel® TDX with TEE-IO architecture [From: Software enabling for Intel® TDX in support of TEE-I/O]]
1) **VFIO: Expose TDI to TD**
   - Identify TEE-IO capability of the device
   - Additional TDISP initialization / cleanup

2) **PCI TDISP support**
   - TDI state management
   - Request SPDM and IDE support for TDISP use case
   - Bind a TDI(s) to the target TVM

3) **Trusted MMIO/DMA support**
   - KVM: manage trusted MMIO via Secure EPT
   - IOMMU: New TDX mode for trusted address translation, and reuse Secure EPT as IO page table
4) PCI TDISP support (inside TD)
   - TDI enumeration
   - TDI attestation
   - TDI acceptance
   - Extensions to kernel APIs to support trust MMIO and DMA use case
Summary

- IO support is important for confidential computing inside TVM. Current direct I/O solution has limitations and performance overhead as device can’t access TVM’s private memory.

- TDISP defines an architecture of trusted I/O virtualization. New architecture allows TDI to be accepted into the TVM’s TCB.

- Intel® TDX with TEE-IO is designed to implement the TDISP architecture. Besides platform and Intel® TDX module extensions, software changes to Linux / KVM are required, including common support for TDISP and specific implementation for Intel® TDX.

* Intel® TDX with TEE-IO is trying to reduce the performance overhead but actual performance results may vary.
Reference

- PCIe* TDISP: [https://members.pcisig.com/wg/PCI-SIG/document/18268](https://members.pcisig.com/wg/PCI-SIG/document/18268)
- PCIe* CMA: [https://members.pcisig.com/wg/PCI-SIG/document/14236](https://members.pcisig.com/wg/PCI-SIG/document/14236)
- DMTF* SPDM: [https://www.dmtf.org/dsp/DSP0274 v1.2+ &](https://www.dmtf.org/dsp/DSP0274) [https://www.dmtf.org/dsp/DSP0277](https://www.dmtf.org/dsp/DSP0277)
- PCIe* IDE: [https://members.pcisig.com/wg/PCI-SIG/document/16599](https://members.pcisig.com/wg/PCI-SIG/document/16599)
- PCIe* DOE: [https://members.pcisig.com/wg/PCI-SIG/document/14143](https://members.pcisig.com/wg/PCI-SIG/document/14143)