SEV-SNP: DEVELOPMENT STATUS UPDATE

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KVM FORUM – 2022
SEV-SNP SECURITY FEATURES

• Introduced with “Zen 3”

• Previously had:
  • SEV, “Secure Encrypted Virtualization”
    • Guest data confidentiality via encrypted guest memory
  • SEV-ES, “Secure Encrypted Virtualization – Encrypted State”
    • Additional guest data confidentiality via encrypted vCPU register state

• SEV-SNP, builds on SEV/SEV-ES to also provide:
  • Guest data integrity
    • Secure Nested Paging
  • Control-flow security (optional)
    • CPUID Security
    • Interrupt Security
    • Secure TSC

• More details later
SEV-SNP SECURITY FEATURES: UPSTREAM STATUS

- Guest kernel support upstream
- Guest OVMF support upstream
- Hypervisor support posted (v6)

<table>
<thead>
<tr>
<th>FEATURE</th>
<th>GUEST SUPPORT</th>
<th>HYPERVISOR SUPPORT</th>
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<tbody>
<tr>
<td>Secure Nested Paging</td>
<td>kernel v5.19</td>
<td>v6 posted</td>
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NESTED PAGING

- Guest page table maps GVA -> GPA
- Nested page table maps GPA -> HPA
- For SEV/SEV-ES: C-bit in guest page table determines whether access is encrypted (bit 47 or 51)
- Guest controls C-bit, only ciphertext is stored in memory: provides data confidentiality
- Host controls NPT/memory: things like remap/replay attacks or silently corrupting guest memory still possible
**SECURE NESTED PAGING**

- Guest page table maps GVA -> GPA
- Nested page table maps GPA -> HPA
- Reverse-map table maps HPA -> GPA
- Also provides additional integrity checks on memory accesses by host/guests
- Provides additional* protection against things like remap/replay/corruption attacks
- How?

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<th>NPT A</th>
<th>RMP Table</th>
<th>Host Memory</th>
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REVERSE-MAP TABLE FORMAT

- **Assigned:**
  - 0 -> host-owned, shared
  - 1 -> guest-owned, private (encrypted*)
- **ASID:** what guest owns it
- **GPA:** what guest GPA it backs
- **Validated:** whether guest has PVALIDATED/accepted it yet
  - C-bit=1, but not validated? -> #VC
- Host can modify/set most fields via RMPUPDATE instruction (necessary for guest page-state changes), but only guest can set the validated bit (via PVALIDATE). Important for integrity.
KVM SUPPORT: SECURE NESTED PAGING

- Host setup_INITIALIZATION OF RMP TABLE
- Guest instance setup_INITIALIZATION
  - pinning pages (KVM_MEMORY_ENCRYPT_REG_REGION)
  - update RMP entries for guest boot (KVM ioctl) / runtime (GHCB request)
- RMP Fault-handling
  - Host #PF (kernel/userspace)
  - Guest #NPF
RMP FAULT-HANDLING (HOST, #PF)

- RMP check violations result in #PF for host threads (error bit 31)
- Page overlap checks
  - 2M host mapping cannot overlap with a private page when writing
  - True for kernel/userspace mappings
  - Kernel direct mappings need handling too (2M and 4K)
- R/W permission checks
  - Cannot write to private pages
  - userspace write -> SIGBUS to kill process
  - kernel write -> crash (buggy/malicious kernel)
  - reads allowed (ciphertext)
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**RMP FAULT-HANDLING (KVM MMU, #NPF)**

- RMP check violations result in #NPF for guest vcpu threads (error bit 31)
- Page size mismatch checks
  - KVM may optimistically map a 2M private range using huge page/RMP entry
  - Guest can optimistically PVALIDATE 2M ranges to match this
  - If 4K pvalidate: #NPF with RMP/SIZEM bits set
    - split NPT mapping
    - PSMASH 2M RMP entry
- C-bit mismatch checks
  - if C=1: RMP entry should be private
  - if C=0: RMP entry should be shared
  - Otherwise: #NPF with RMP/ENC bits set
    - Implicit page state change, update RMP entry to match
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  - Guest #NPF
- Fairly minor changes since v5, however:
  - New proposal: UPM (Unmapped Private Memory), private FD-backed memory
UNMAPPED PRIVATE MEMORY

- Proposed kernel infrastructure to back confidential guests with pages that are not mappable/accessible by userspace
- Generally synonymous with Chao Peng’s private memslot patchset:
  - “KVM: mm: fd-based approach for supporting KVM guest private memory”
- Proposed by a number of developers for various reasons, but the most prevalent driver is TDX support, where writes to private guest memory by userspace result in #MC
- Also being evaluated for use with SEV-SNP, pKVM, and possibly others
**UPM - PRIVATE MEMSLOTS**

- Currently both shared/private memory are backed by normal memslots
  - private memory can be mapped into userspace just like normal memory
  - malloc() / mmap() →
- Adds new private memslot struct
  - Provides both shared/private memory
  - private memory allocated separately via memfd
  - memfd uses MFD_INACCESSIBLE
    - Not readable/writable
    - Can’t be mmap()’d into userspace
- KVM MMU uses an xarray to determine whether to map guest memory from shared/private pool
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#NPF: GPA->HPA lookup (private memslot)
UPM – IMPLICIT CONVERSIONS

- KVM MMU uses an xarray to determine whether to map guest memory from shared/private pool
  - xarray controlled purely by userspace
    - KVM_MEM_ENCRYPT_REG_REGION
    - KVM_MEM_ENCRYPT_UNREG_REGION
- Implicit conversion
  - if C-bit does not match xarray state:
    - KVM_EXIT_MEMORY_FAULT
    - alloc/dealloc private/shared memory
    - VMM converts using REG/UNREG ioctl
- Explicit conversion
  - GHCB page-state change request forwarded to userspace
    - KVM_EXIT_VMGEXIT
    - alloc/dealloc private/shared memory
    - VMM converts using REG/UNREG ioctl

#NPF: GPA->HPA lookup/conversion
(private memslot)

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<th>Private?</th>
<th>VMM A (shared)</th>
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<th>VMM A (private)</th>
<th>Mem FD</th>
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KVM_MEM_encrypt_REG_REGION
KVM_EXIT_MEMORY_FAULT
allocate/deallocate
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VMM Page Table

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VMM A (shared)

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KVM_EXIT_VMEXIT

KVM_MEM_ENCRIPT_REG_REGION

allocate/deallocate
UPM: PROS/CONS

- Pros:
  - Shared infrastructure for managing private guest pages
    - Cross-platform: SNP / TDX, potentially cross-architecture
  - Less chance of guest disruption/exploitation from accessing private memory in userspace
  - Lazy-pinning support

- Cons:
  - More management complexity in VMMs:
    - Allocating/de-allocating private memory
      - Potential for 2X memory usage
        - Lazily-deallocate for performance?
        - Immediately deallocate to reduce memory usage?
    - Handling of new private memslot structure
    - Memory pinning/affinity considerations
  - Performance
    - More exits to userspace, more context switches
KVM SUPPORT: SNP + UPM

- v6 SNP hypervisor patchset uses non-UPM implementation (likely v7 as well)
- Separate tree adds UPM support on top of v6:
  - VMGEXITS for GHCB page-state changes forwarded to userspace
  - Uses UPM to manage memory pinning instead of existing SEV approach
  - KVM_CAP_UPM flag to switch between modes
- Will maintain separate trees until UPM stable/upstream
- Continue to work with community to upstream either solution
FUTURE DEVELOPMENT WORK

- Interrupt Security
- Secure VM Service Modules (SVSM)
  - VMPL0 OS implementation
  - Interrupt security
  - Live migration acceleration
  - vTPM
  - Upcoming talk by Tom Lendacky
- Secure TSC support
- SEV-SNP lazy-pinning support (free with UPM)
- Lazy-PVALIDATE support for SNP guests (patches posted)
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Questions?
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