UNMAPPED PRIVATE MEMORY

Michael Roth

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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
• Description/topics here are somewhat SEV-SNP centric, but can hopefully still be extrapolated to some of these other use cases
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_VMEXIT
    - alloc/dealloc private/shared memory
    - VMM converts using REG/UNREG ioctl

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

<table>
<thead>
<tr>
<th>Guest A</th>
<th>Private?</th>
<th>VMM A (shared)</th>
<th>VMM Page Table</th>
<th>Mem FD</th>
</tr>
</thead>
<tbody>
<tr>
<td>GVA</td>
<td>GPA</td>
<td>GPA</td>
<td>HVA</td>
<td>offset</td>
</tr>
<tr>
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<td>0000h</td>
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<td>...</td>
<td>...</td>
<td>...</td>
<td>8000h</td>
</tr>
</tbody>
</table>

**VMM Page Table**

<table>
<thead>
<tr>
<th>HP A</th>
<th>HPA</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000h</td>
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<tr>
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<tr>
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<td>3000h</td>
<td>9000h</td>
</tr>
<tr>
<td>4000h</td>
<td>4000h</td>
</tr>
</tbody>
</table>

**Private?**

<table>
<thead>
<tr>
<th>GPA</th>
<th>offset</th>
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<tbody>
<tr>
<td>0000h</td>
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</tr>
<tr>
<td>1000h</td>
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<td>3000h</td>
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<tr>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>

**KVM_EXIT_MUNPROT**

- allocate/deallocate
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#NPF: GPA->HPA lookup/conversion (private memslot)
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
HANDLING FOR KERNEL DIRECTMAP

- Writes via 2M directmap mapping will generate RMP violation if it overlaps with private page
- 3 potential approaches:
  - Leave private page mapped, but split the directmap
    - We have set_memory_4k() for this, but no set_memory_2m() currently (solvable?)
  - Remove private page from directmap
    - Basically ends up splitting unless conversion covers whole 2M range
    - Easier to restore 2M mapping (but again, only if conversion covers whole 2M range)
  - Always allocate from private pool with 2M pages
    - No chance for other threads to write into range
    - No splitting needed
    - Feasible?
- Should UPM handle this at all? If so, which approach?
GUARDING HOST ACCESSES TO SHARED PAGES AGAINST SHARED->PRIVATE CONVERSIONS

- Host may be accessing shared pages for a number of difference purposes:
  - kvmclock
  - virtio buffers
  - GHCB pages
  - Accesses may be via kernel mappings (e.g. kvm_vcpu_map())

- Ideally:
  - A) If guest erroneously/maliciously flips the page to private, the host should be made aware of this
  - B) If host erroneously/maliciously writes to a page that is now private, the guest should be made aware of this

- SNP (non-UPM) will likely address this situation by using flipping the page back to shared state in the RMP table, this will result in the guest getting a #VC exception if the host did this in error. Provides ideal handling for both A) and B)

- UPM: Separate physical memory pools for shared and private:
  - Case A): helps avoid host crash, but host may not notice unless there’s some additional synchronization/invalidation mechanism (not UPM-specific issue, but still an argument in favor of platform-specific handling)
  - Case B): guest won’t know host is writing updates to a stale page and silently break, not necessarily corrupting guest memory, but similar end result
  - Also, some archs may not be able to use separate memory pools for shared/private

- Keep this handling platform-specific, or can UPM improve on this somehow?
SCATTER/GATHER SUPPORT FOR KVM_EXIT_MEMORY_FAULT

• SNP does explicit shared/private conversions via GHCB requests
  • Current UPM implementation forwards these to userspace via KVM_EXIT_VMGEXIT
  • Multiple KVM_MEM_ENCRYPT_REG_REGION handled “atomically” by VMM from KVM perspective

• Alternative:
  • Forward these to userspace as KVM_EXIT_MEMORY_FAULT, as with implicit conversions
  • Only handles 1 range at a time, KVM needs to generate multiple KVM_EXIT_MEMORY_FAULTs before completing GHCB request
  • SG list support for KVM_EXIT_MEMORY_FAULT might improve on this
    • Better performance
    • Less complexity in KVM GHCB request handling
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