SVSM – VM Privilege Level Instantiation and Execution

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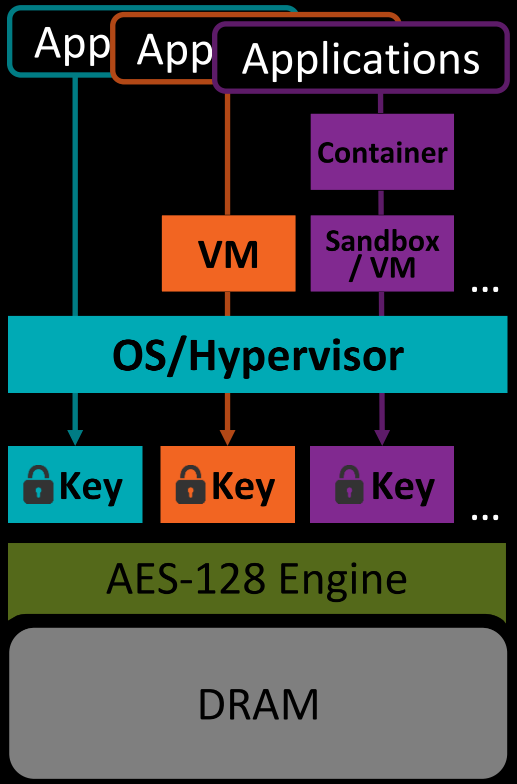
Agenda

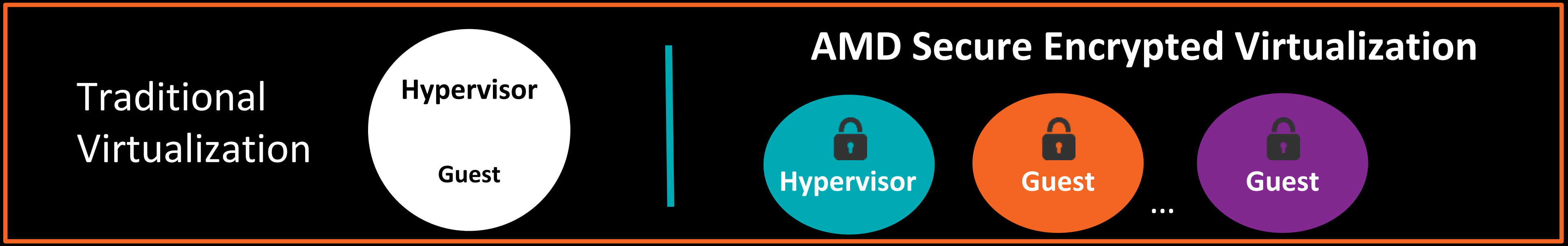
- Review
  - Secure Encrypted Virtualization (SEV)
  - Secure Encrypted Virtualization – Encrypted State (SEV-ES)
  - Secure Encrypted Virtualization - Secure Nested Paging (SEV-SNP)
  - VM Privilege Level (VMPL)
  - Secure VM Service Module (SVSM)

- Instantiation and Execution
  - Explore the options:
    - Creating VMPL levels
    - Switching a vCPU between VMPLs

SEV Review

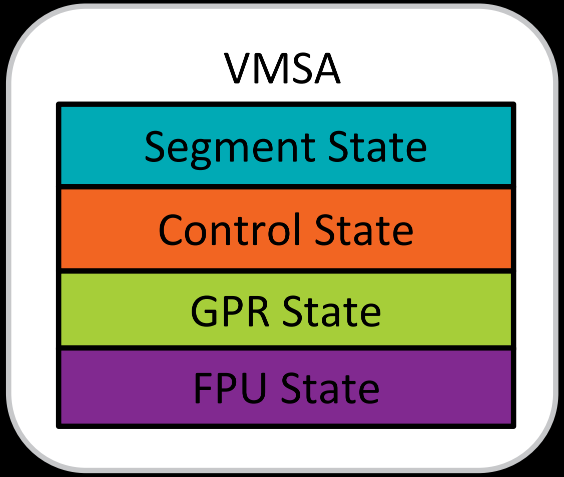
- Protects VMs/Containers from each other, administrator tampering, and untrusted Hypervisor
- One key for Hypervisor and one key per VM or VM/Sandbox with multiple containers
- Cryptographically isolates the hypervisor from the guest VMs
- Integrates with existing AMD-V™ technology
- System can also run unsecure VMs

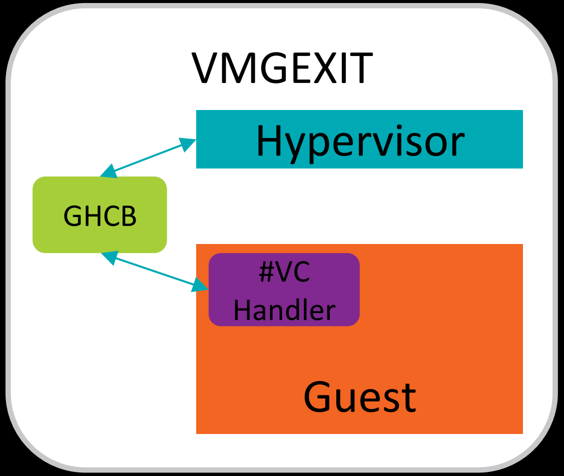



Traditional Virtualization
Hypervisor
Guest
AMD Secure Encrypted Virtualization
Hypervisor
Guest
...
Guest

SEV-ES Review

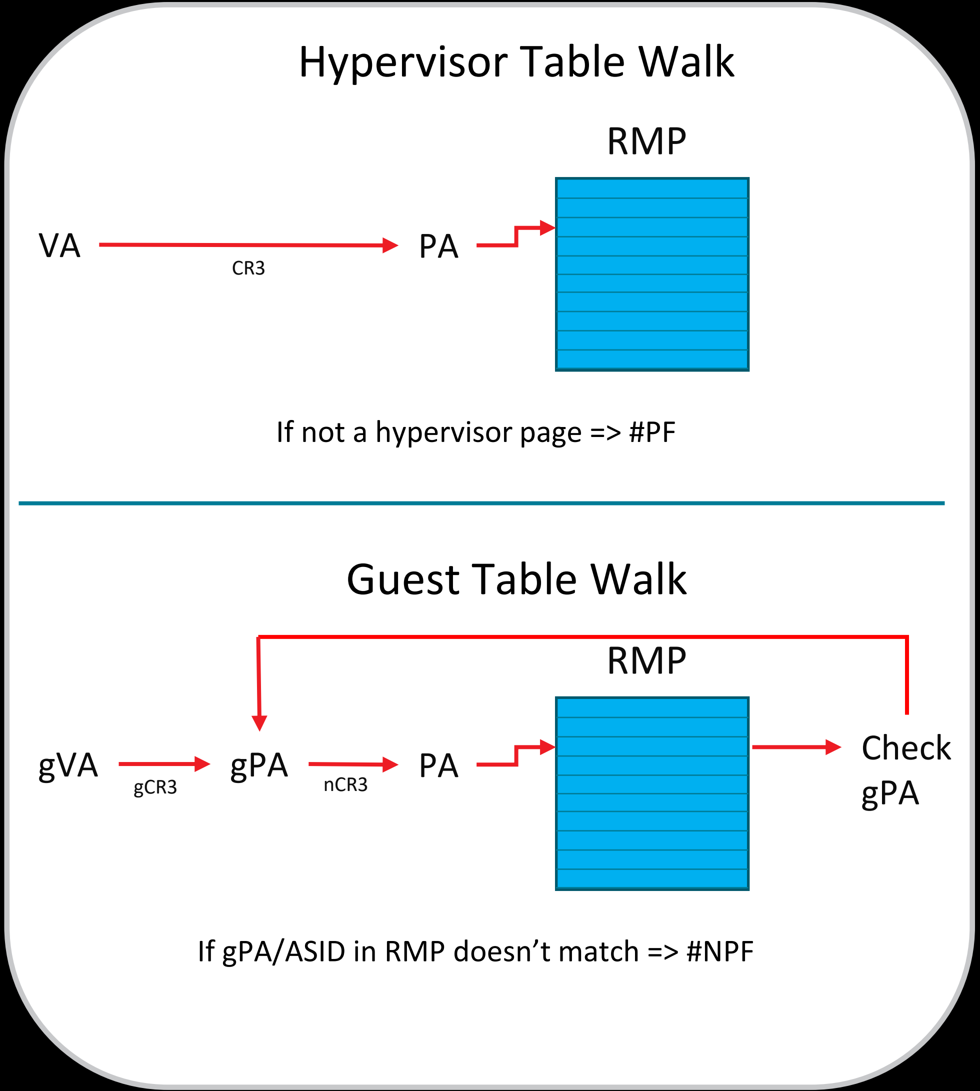
- Guest register state protection
  - Initialized with known state (Initial Processor State)
  - Encrypted and measured as part of the SEV LAUNCH process
  - Integrity check performed on each VMRUN
  - World switches now swap ALL register state
- VMCB under SEV-ES
  - Control Area (VMCB) and Save Area (VMSA) now separated
  - VMCB now points to VMSA
  - VMSA extended to save more state
- Guest-Hypervisor Communication Block (GHCB)
  - Allows guest ←→ hypervisor communication of the state needed to satisfy the guest service request
  - Shared (un-encrypted) page between the hypervisor and the guest
  - GHCB specification
    - Defines the format of the GHCB and how to communicate with the hypervisor





SEV-SNP Review

- Secure Nested Paging
  - Next step in the evolution of SEV
  - SEV/SEV-ES provides Confidentiality
    - SEV – encryption of VM memory
    - SEV-ES – adds encryption of VM registers
  - SEV-SNP builds on SEV-ES and adds Integrity Protection
    - Prevents replay attacks, corruption attacks, remapping attacks
    - Utilizes the Reverse Map Table (RMP) and RMPUPDATE instruction to track:
      - Page Ownership: Hypervisor, Guest/PSP
      - Page Size: 4KB or 2MB
      - Guest Physical Address and ASID
      - VMSA (can be used with a VMRUN instruction)
        - LAUNCH_UPDATE or RMPADJUST instruction
      - Validation
        - PVALIDATE instruction
        - #VC if validation is changed by the hypervisor

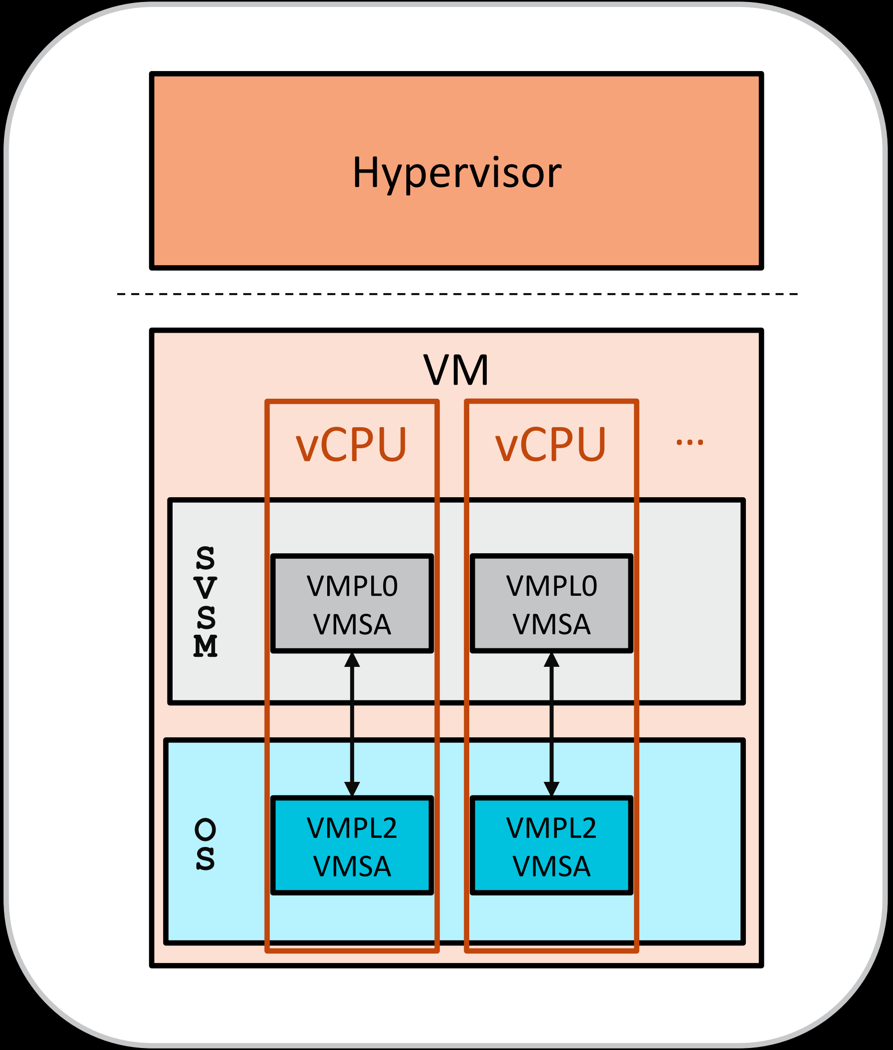


VMPL Review

- Virtual Machine Privilege Level (VMPL)
  - Allows a SEV-SNP guest to divide its address space in up to 4 levels
  - VMPL0 - VMPL3 (VMPL0 being most privileged)
    - Higher privileged VMPL can provide secure services for lesser privileged VMPL
      - e.g., VMPL0 can provide secure services for VMPL2
    - VMPL level is set in the VM Save Area (VMSA) page
    - KVM/Linux SEV-SNP guests run at VMPL0 today
  - Each RMP entry has page permissions for each VMPL level
    - Read, Write, Execute (User/Supervisor), Supervisor Shadow Stack
    - Guest can set permissions for a lesser privileged VMPL using RMPADJUST
      - Only VMPL0 can set the VMSA attribute for use in running a vCPU
    - Allows a higher privileged VMPL to protect itself from a lesser privileged VMPL

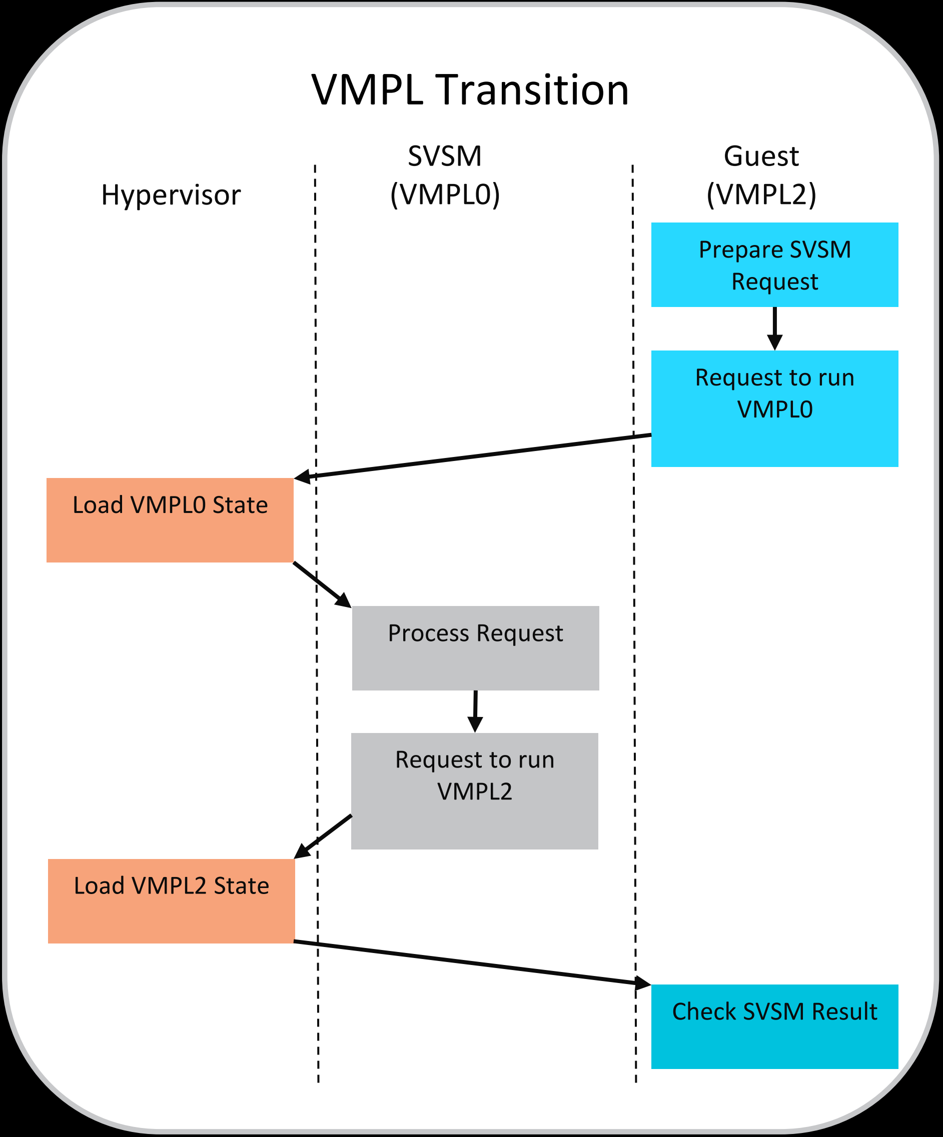
SVSM Review

- Secure VM Service Module (SVSM)
  - Runs at VMPL0
  - Creates VMPL0 VMSA pages for all APs
  - Creates VMPL2 VMSA for the BSP
    - Up to the VMPL2 to create VMSA's at VMPL2 for APs
  - Initiates execution of the VMPL2 target
  - Provides an API to allow VMPL2 to request services from VMPL0
  - Uses:
    - Live Migration
    - vTPM
    - … and more



VMPL Transition

- Create a vCPU at a VMPL level
  - GHCB AP Create hypercall
    - Issued by current VMPL to create the same or new VMPL
- Request to run a VMPL level
  - GHCB Run VMPL hypercall
    - Issued by current VMPL to request running a new VMPL
      - KVM always runs the current VMPL until requested to change
- VMM/Hypervisor is responsible for creating/running the requested VMPL
  - Possible approaches:
    - One VM* and each vCPU is multiple VMPLs
    - One VM* and each vCPU is a dedicated VMPL
    - One VM* per VMPL



* a VM is a KVM object structure created using the KVM_CREATE_VM ioctl

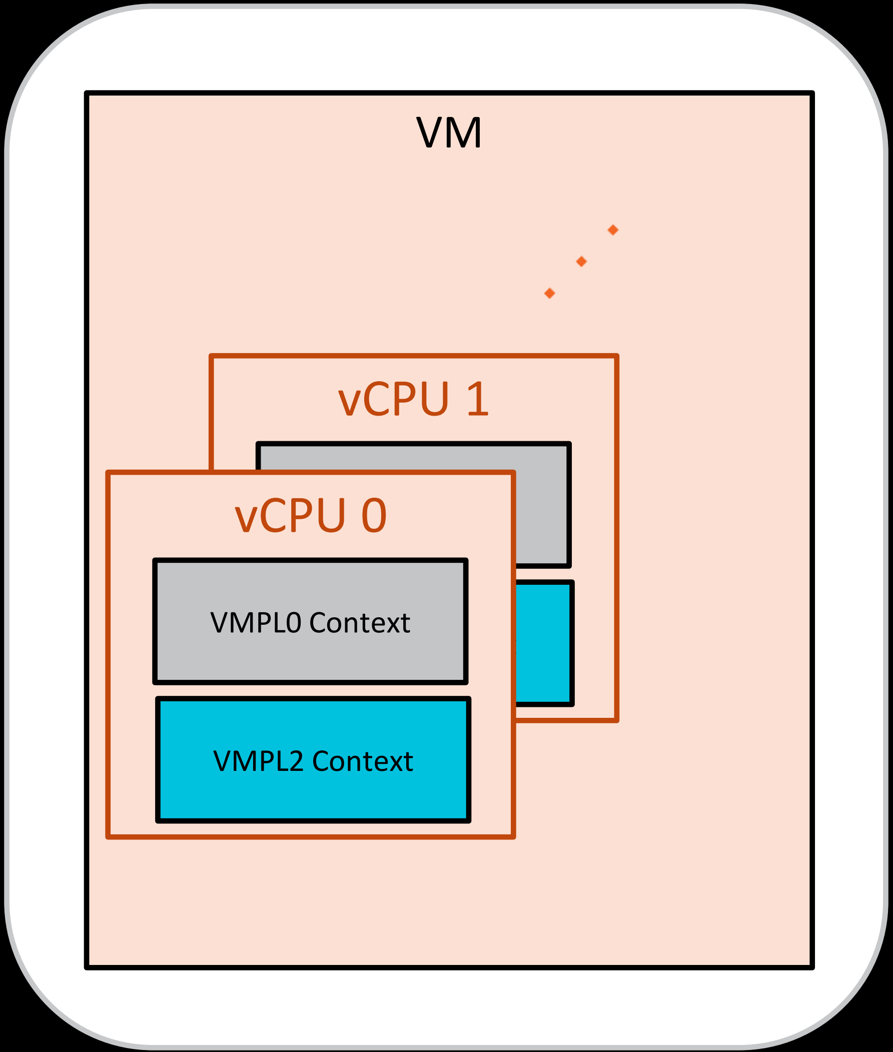
VMPL Instantiation & Execution Approaches

VMPL Instantiation & Execution

- One VM and each vCPU is multiple VMPLs
  - All performed within KVM

  - Instantiation – AP Create
    - Saves VMSA GPA in target vCPU struct
    - Kicks target vCPU
    - Target vCPU validates/translates VMSA GPA
    - Target vCPU creates/resets APIC instance

  - Execution – Run VMPL
    - Fields within VM Control Block (VMCB) swapped
      - VMSA SPA
      - GHCB GPA
      - Tracking registers (EFER, CR0, etc.)
    - Next VMRUN now runs a different VMPL



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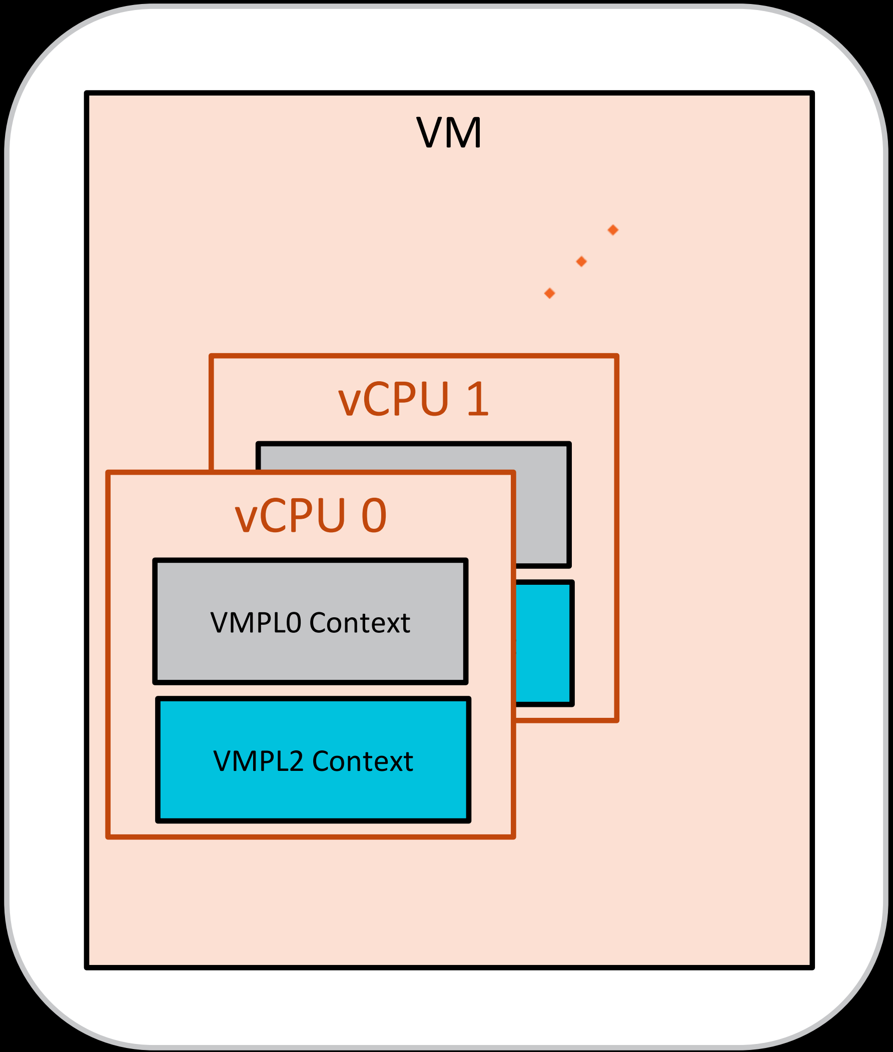
VMPL Instantiation & Execution…

- One VM and each vCPU is multiple VMPLs
  - All performed within KVM
  - Pros
    - Fast
      - AP Create kicks target vCPU
      - Run VMPL stays in the VMRUN loop
    - VMM Agnostic
      - KVM localized changes
      - No VMM API changes
  - Cons
    - Need to save/restore defined set of data
    - APIC Support
      - Multiple APIC instances per vCPU



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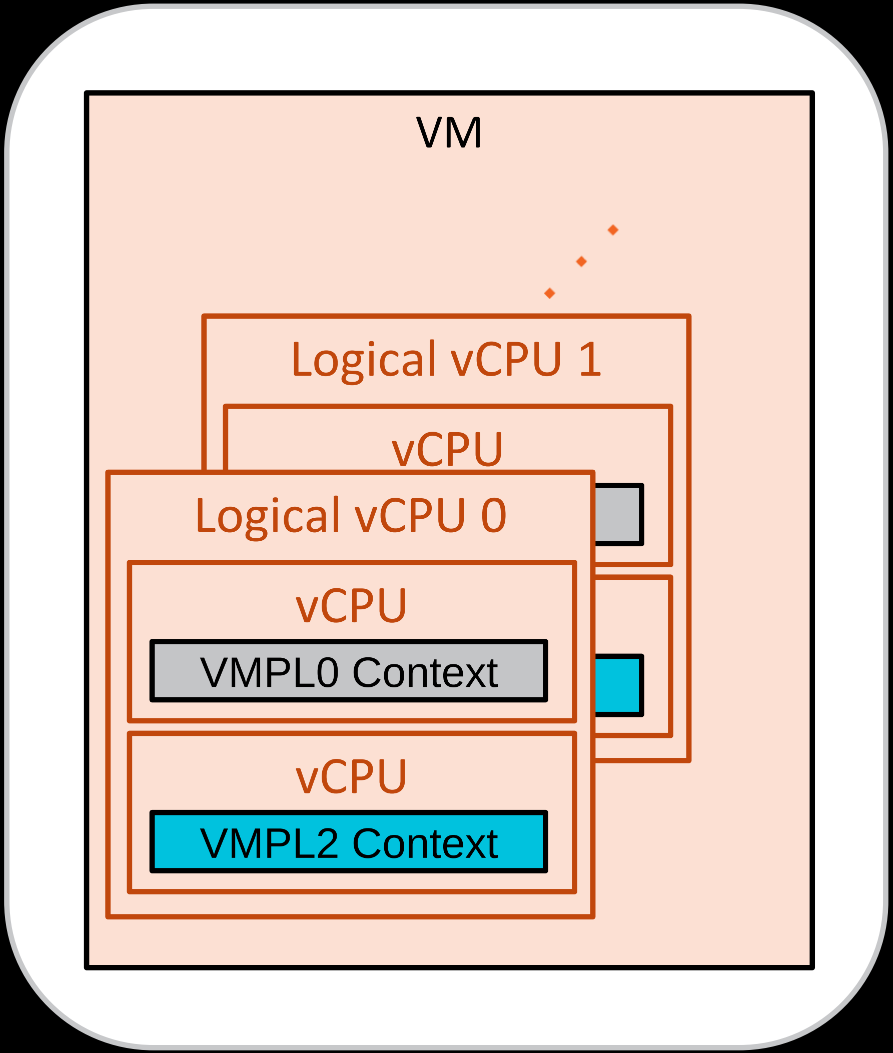
VMPL Instantiation & Execution…

- One VM and each vCPU is a dedicated VMPL
  - Instantiation – AP Create
    - Request sent to VMM
      - VMM creates new vCPU
      - New vCPU validates/translates/sets VMSA GPA
  - Execution – Run VMPL
    - Request sent to VMM
      - VMM pauses the current VMPL vCPU
      - VMM resumes the target VMPL vCPU



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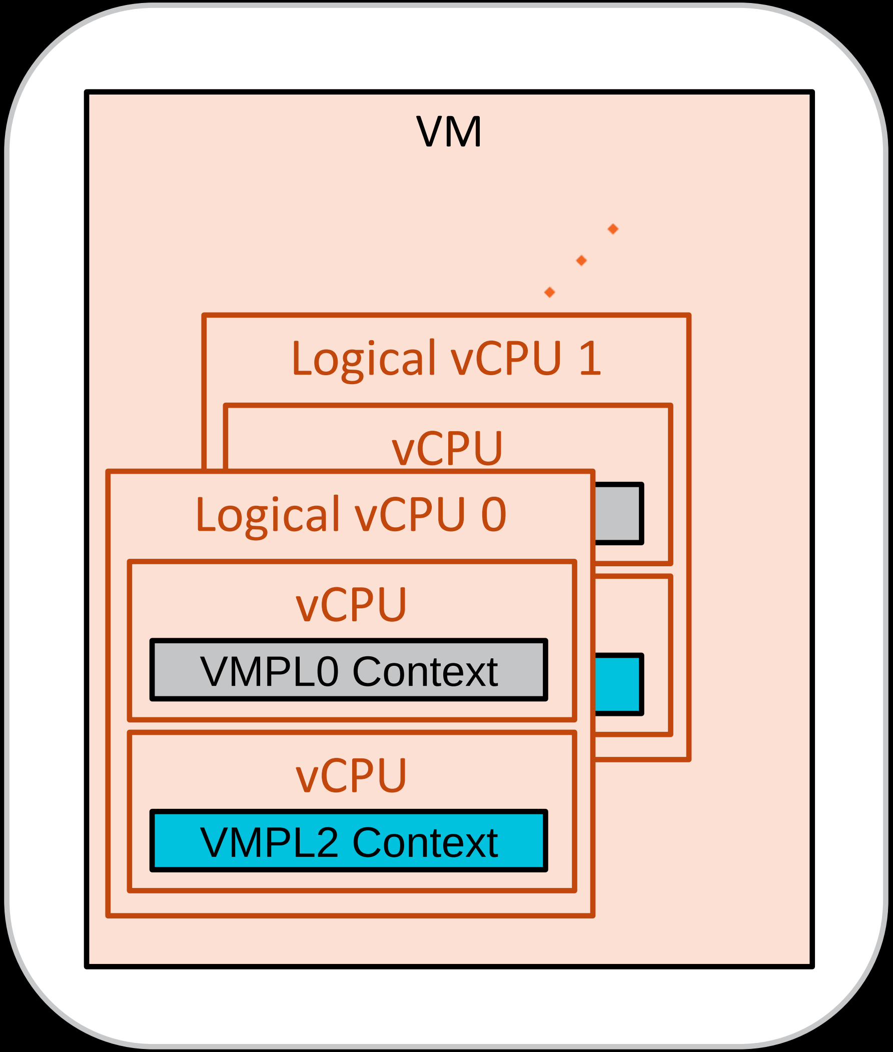
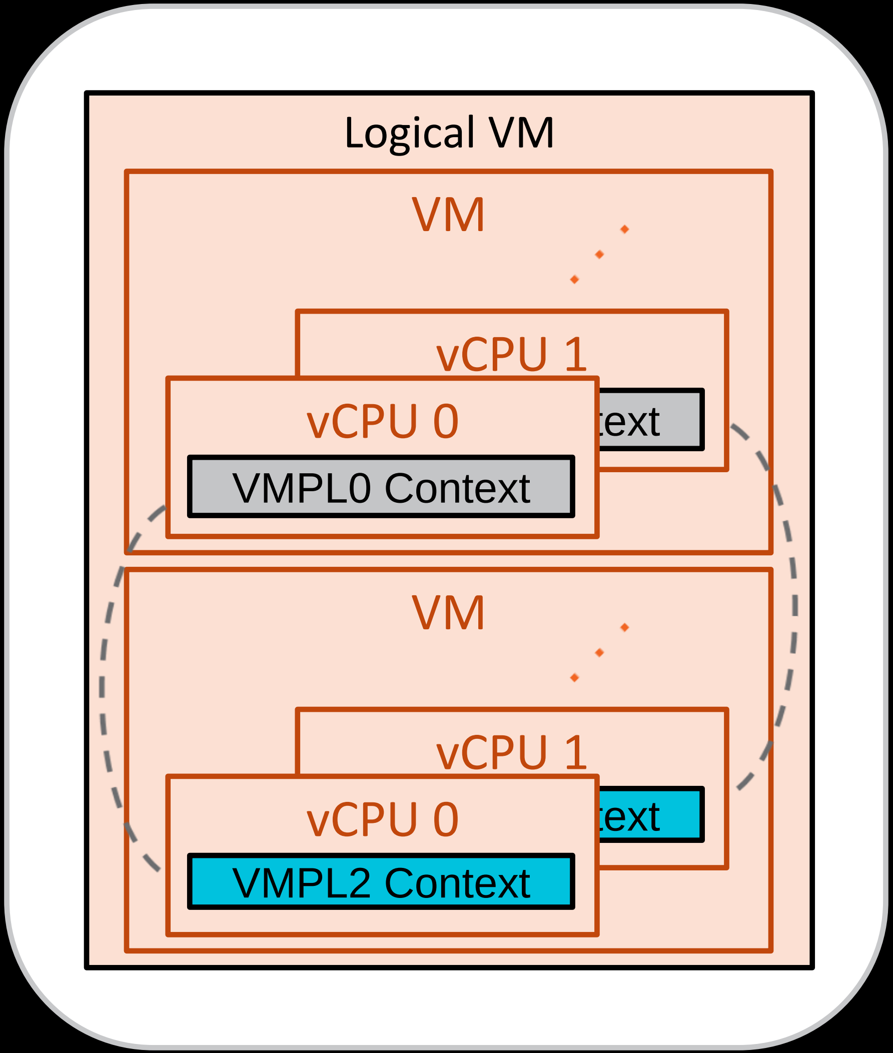
VMPL Instantiation & Execution…

- One VM and each vCPU is a single VMPL
  - Pros
    - Separate vCPU object
      - Maintains separate VMSA, GHCB, APIC, etc. contexts
  - Cons
    - Need to transition to userspace (VMM)
    - Multiple vCPU threads
      - vCPU pinning becomes more difficult
    - Qemu requires vCPU namespace support
      - Affects interrupt routing
    - KVM requires vCPU namespace support
      - Index is APIC ID based
      - Affects interrupt routing



VMPL Instantiation & Execution…

- One VM per VMPL
  - Instantiation – AP Create
    - Request sent to VMM
      - VMM creates new VM (KVM Object)
      - VMM creates new vCPUs within new VM
        - New vCPU validates/translates/sets VMSA GPA
  - Execution – Run VMPL
    - Request sent to VMM
      - VMM pauses the current VM (VMPL) vCPU
      - VMM resumes the target VM (VMPL) vCPU



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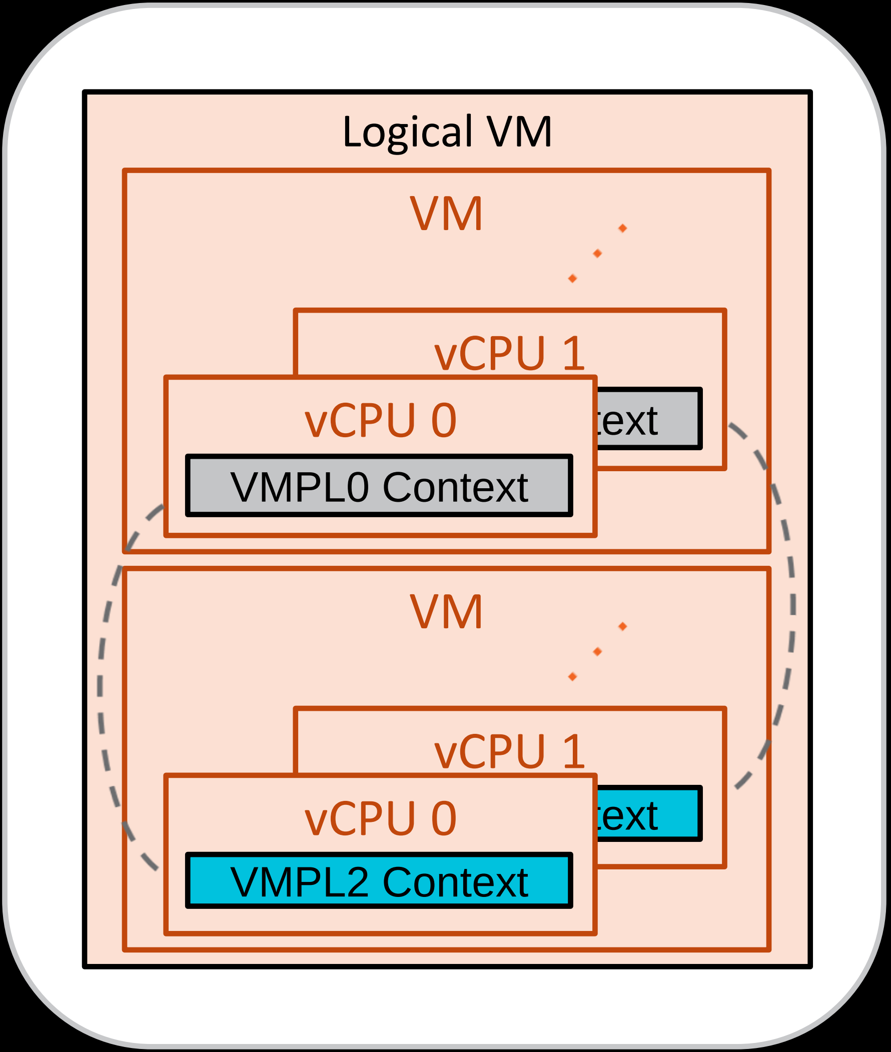
VMPL Instantiation & Execution…

- One VM per VMPL
  - Pros
    - Separate VM results in a separate vCPU object
      - Maintains separate VMSA, GHCB, APIC, etc. contexts
  - Cons
    - Need to transition to userspace (VMM)
    - Multiple vCPU threads
      - vCPU pinning becomes more difficult
    - Qemu requires VM-to-device association
      - Affects interrupt routing
    - Gmem memory can’t be shared across VMs (currently) [1]



[1] – https://lore.kernel.org/lkml/cover.1691446946.git.ackerleytng@google.com/

Summary

- Which approach is best?
  - RFC of the first approach submitted to get the conversation started
    - TODO: Multi-VMPL Interrupt Routing/APIC Support
      - Only two VMPL levels
      - No injection into VMPL0

  - Transitions to userspace will be expensive
    - VMPL switch needs to be fast
      - Memory acceptance, Alternate Injection, vTPM
    - Rules out the approaches that require exit to the VMM, unless:
      - Can it be avoided with KVM changes/optimizations?
      - Create some association between vCPUs with same APIC ID
        - Kick vCPU across VMs/KVM Objects?

REFERENCES

- Links to the following reference material can be found at https://developer.amd.com/sev
  - White Papers & Specifications
    - AMD SEV-SNP: Strengthening VM Isolation with Integrity Protection and More
    - Guest Hypervisor Communication Block Specification
    - Secure VM Service Module Specification
    - AMD64 Architecture Programmer’s Manual Volume 2: System Programming

- Code/Patches (https://github.com/coconut-svsm)
  - COCONUT SVSM: https://github.com/coconut-svsm/svsm
  - Hypervisor Patches:
    - Linux Kernel: https://github.com/coconut-svsm/linux
    - Qemu: https://github.com/coconut-svsm/qemu
  - Guest Patches: Upstream in EDKII/OVMF and Linux

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