Seamless Cloud System Upgrade with VMM Fast Restart

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The Headache of System Upgrade

• Frequent urgent security updates
  • Firmware/microcode/OS/VMM

• System update & reboot take long time

• Cloud vendor sees more service breakage to customers
Existing Solutions

• Live patching
  • Good for small fixes (no service down)
  • High failure rate for big changes

• VM live migration
  • Mature feature in most VMMs
    • Typically <1s service shutdown
  • Limitations
    • Poor support of passthrough devices
    • Unfriendly to memory-intensive workloads
    • Requires space machine to migrate into
    • Infrastructure-imposed failures (e.g. network configuration, etc.)
New Proposal – VMM Fast Restart

• Leverage Kexec reboot to bypass firmware

• Seamless guest state saving/reloading through DRAM-as-PMEM

• Sustain passthrough device state across reboot

• Reuse DMA/IRQ remapping in new kernel
VMM Fast Restart (Cont.)

• A new option when OS/VMM upgrade is required

• Benefits
  • Higher success rate than prior approaches
  • Invisible to guest OS
    • Although with relatively longer down time
  • Support passthrough devices
DRAM-as-PMEM

• Reserve DRAM to emulate PMEM
  • [https://pmem.io/2016/02/22/pm-emulation.html](https://pmem.io/2016/02/22/pm-emulation.html)

• Allocate guest memory from PMEM
  • Create DAX filesystem in PMEM
  • Mmap guest memory in DAX filesystem

• Simplified memory model
  • Avoid intrusive changes to Linux MM
  • Naturally sustain VM state due to the persistent attribute
Saving/Reloading VM State across Reboot

• Optimized snapshot - “savevm-in-pmem”
  • Keep VM memory in DAX, instead of saving to disk
  • Non-memory state could be either in disk or memory (except storage)

• “loadvm-in-pmem” when relaunching Qemu
  • Remap guest memory from DAX filesystem

• Pass DRAM-as-PMEM reservation info through kexec
  • Same “memmap=8G!4G” boot parameter between old/new kernels
Passthrough Device Support

• Keep DMA/Interrupt alive for passthrough devices

• Avoid clobbering hardware state during reboot

• Keep upstream devices (IOMMU, switch/root ports, etc.) alive

• Reconnect on resume various hardware resources with VM & passthrough devices
Keep Interrupt Alive

• Leverage Posted-Interrupt (PI)

• Pass PI-Desc & IR-Table to new kernel

• Hardware continues using old PI-Desc & IR-Table
  • Pending guest IRQ is recorded in PI-Desc

• New KVM/IOMMU allocates new PI-Desc & IR-table
  • Update the content based on old structure
Keep DMA Alive

• Pass IOMMU configuration to new kernel

• IOMMU HW continues using old page table in reboot
  • DMA on-going during reboot

• IOMMU driver re-allocates page table post reboot
  • Copy the mapping from old table
Kexec Reboot Processing

• Skip shutdown of passthru device & its upstream devices before reboot

• Data passing from old kernel to new kernel
  • Passthru device list & memory reservation
  • May need to extend boot protocol

• Special handling in device enumeration & driver matching
  • Avoid attaching of native driver for passthru devices

• Host drivers pick up hardware state (IOMMU & upstream devices)
  • Avoid clobbering hardware state
New VFIO Device Assignment Model

• VFIO driver probe/open skip reset & PCI initialization

• VFIO snapshot saving/reloading
  • Record VFIO internal states, including MSI/MSIX state

• Complete re-assignment in 2 steps
  • vfio_realize() reattach group/domain etc., w/o hardware clobbering
  • Reload VFIO snapshot to re-connect DMA/IRQ state

• New ioctl cmd/flags to indicate re-assignment
  • Or VFIO handles automatically by recognizing in passthru device list
High Level Flow

- Save Snapshot in Memory (in old Linux) & VM Quit
  - DAX filesystem in DRAM-as-PMEM
  - Don’t free HW resources (IRTE, etc.)
- Record Resource Occupation
  - Device list, memory, etc.
- KEXEC Reboot
  - No hardware clobber in driver shutdown
- VMM Boot (new Linux)
  - Reserve resources
- Device Enumeration
  - No hardware clobber in PCI enumeration
  - No native driver attaching
- Driver State Reload
  - IOMMU driver reload state
- Reload Snapshot from Memory (in new Linux)
  - Re-enable DAX filesystem in DRAM-as-PMEM
- Resume VM
  - Reload DMA mapping
  - Re-enable MSI/MSIX
Opens

• How to handle trusted boot?
• Handling memory resizing with DRAM-as-PMEM?
Status & Plan

• Milestones:
  • VMM fast restart w/o passthru devices
    • Done
  • Qemu fast restart w/ passthru devices, but w/o host reboot
    • Done
  • VMM fast restart w/ passthru devices, w/ host reboot
    • On-going

• Next Step: Upstreaming
Questions? Thanks!