Enhancing KVM for Guest Protection and Security

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Agenda

- Security Implications of KVM
- “Secure Virtualization” for KVM
- Degree of Guest VMs Protection
- Proof of Concept
- Next Steps
Security Implications of KVM

KVM piggybacks on Linux systems
More attack surfaces, making guest more exposed
Guests could exploit host via user-space VMM

Full access by user-space VMM:
Guest VM memory, vCPU states, etc.

Full access by KVM/Linux Kernel:
Any guest VM memory, vCPU states, etc.
Secure Virtualization for KVM

• Inspired by memory encryption technologies
• Protect guest VMs from a benign but vulnerable VMM
• Degree of “Protection” depends on what can be removed from TCB:
  - User-space VMM
  - Misc. kernel-space subsystems/drivers
  - Hypervisor
## Degree of Guest VMs Protection — what to remove from TCB

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<td>Deny access to guest register state</td>
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<td>Deny access to guest private memory</td>
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<td>Kernel-space (except KVM) + above</td>
<td>Remove direct mapping</td>
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<td>Hypervisor (KVM) + above</td>
<td>Hardware-based security feature</td>
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Secure Virtualization for KVM

- Guest specifies shared regions out of private memory
  - QEMU can access only shared
  - KVM may access private if in TCB

- KVM denies access to guest vCPU state by user-space VMM (e.g. QEMU)
Modifications to Guest VM (Linux) when KVM is in TCB

- PV operations
  - Controls shared guest memory (GPA)
    - All private at boot time
  - Use swiotlb bounce buffer to force DMA operations in shared memory
  - Etc.

- (Optional) Hypervisor denies access by other kernel subsystems/drivers to guest private memory
Modifications to Guest VM (Linux) when KVM is not in TCB

• Additional PV operations
  - Avoid VM exiting operations that would require KVM to access guest VM memory
    ▪ E.g. MMIO operations (replace them with Hypercall)
  - Or, handle them in guest VM via virtual exceptions
    ▪ E.g. #VE (Virtual Exception) and emulate operations inside VM (and Hypercall)

• Useful even if KVM is in TCB
Proof Of Concept

• KVM and other changes
  - Remove mapping from QEMU and kernel
  - “Ideal/optimal memory management for future VMs”, Isaku Yamahata, November 1 (11:30 - 12:00)

• Average CPU% overhead (virtio)*:
  - 1.2% (1 VM), 1.3% (10+ VMs) for disk read, 1.1% (1 VM), 1.2% (10+ VMs) for disk write
  - 2.6% for network send (1 VM), 3.8% (10+ VMs)

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*:
- Xeon Platinum 6140, Skylake processors @ 2.3GHz
- 2 sockets x 18 cores each
- HT OFF, P States OFF, Turbo OFF, C states OFF
Deny Access to Guest Private Memory (Kernel)

Use EPT to isolate/protect memory

*VBH: Virtualization Based Hardening

Thursday, October 31 • 14:45 - 15:15

Virtualization Based Hardening: Securing Container Workloads and Beyond
- Jun Nakajima, Intel & Andrei Lutas, Bitdefender
Making Type-1 Hypervisor From KVM

- KVM
- Linux Kernel
- User-level
- Dom0
- VMs
- KVM++
Next Steps

• Complete PoC and share the patches
  - Changes to Linux, KVM, etc.
    ▪ Linux guest changes: use existing code for AMD SEV as much as possible

• Propose how to remove guest memory mapping from user-space
  - In Backups

• PoC of “Making Type-1 Hypervisor From KVM”
Backups
Remove User-space VMM from TCB

- Deny access to guest register state:
  - Reject ioctls() that get/set guest state
  - Other changes required to hide guest state

- Deny access to guest private memory (example):
  - Add new flag, e.g. VM_PRIVATE or so, to vm_flags
  - Kernel removes PTEs for VM_PRIVATE memory from user-space page tables
  - Guest controls shared vs. private GPAs
  - KVM returns -EFAULT to user-space on private access to memory without VM_PRIVATE