Nesting KVM on s390x

… nesting nested virtualization on IBM z Systems ®

David Hildenbrand, Software Engineer Virtualization and Linux Development
If you're not confused, you're not paying attention.

Tom Peters, *Thriving on Chaos: Handbook for a Management Revolution*
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Agenda

- Nested Virtualization
- Virtualization / KVM on s390x
- Nesting KVM on s390x
- Current status (Features, Migration, Security, Performance)
- Summary and Outlook
- Questions?
Nested Virtualization (1)
Nested Virtualization (2)

- Turn guest into hypervisor: *run virtual machines*
  - *Test / debug environment* (e.g. for new KVM releases)
  - *Simulate different hardware variants*

- Without HW support for nested virtualization
  - *Trap and emulate* (like „KVM-PR“ e.g. for PowerPC ®) *in guest*
  - *Emulate HW virtualization* (using HW virtualization) *in host*

- Nested guest can also run nested guests ... *it usually simply cascades*

- Until now *only x86* emulates HW virtualization in KVM for its guest
Virtualization / KVM on s390x (1)

- At least one level of virtualization (logical partitioning)
- Hardware provides support for two levels
- SIE (Start Interpretive Execution) instruction is the entry point to HW virtualization
  - Interpretes most instructions + guest interrupts
- SIE facilities add aditional interpretation mechanisms (performance / features)
Virtualization / KVM on s390x (2)

Address space representing guest physical memory

CPU

execute SIE

interrupt / intercept

VCPU

Guest state + HW virtualization configuration

Memory / swap

QEMU

GMAP

map segments (share page tables)

SIE Control blocks

SCB

ITDB

FAC

GVR

CRYCB

RI

Other SCB of VM

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Nesting KVM on s390x (1)

- Emulation is called **Virtual SIE a.k.a vSIE**

- Control blocks / page tables contain **addresses only valid in the guest**
  - **Create shadows in the host**, containing valid host addresses
  - SCB vs. Shadow SCB
  - GMAP vs. Shadow GMAP
Nesting KVM on s390x (2)

1. **Intercept SIE instruction** executed by KVM guest VCPU
2. **Validate/Copy/Filter** provided SCB, creating a **shadow SCB**
3. **Pin/Shadow/Filter** satellite control blocks referenced in the SCB
   - 31bit addresses in the SCB: shadow on DMA page 😐
4. **Execute the SIE** using the shadow SCB and shadow gmap
4. **Fill/manage GMAP shadow on vSIE faults**
   - Create *shadow table hierarchy*
     - Walk guest provided tables by *reading in guest memory*
     - All tables are *initially empty* and *filled on demand* *(shadowing a lower level table)*
   - Lowest level (page tables) reference real host pages
   - Use *protection mechanism on GMAP* to detect
     - Guest changes to the guest GMAP (tables)
     - Host changes to page tables (e.g. paged out)
   - *Unshadow* table hierarchies / page table entries
 Nested KVM on s390x (4)

5. *Re-execute the SIE* as long as possible (VCPU run not required)

6. Inject interrupts *into the KVM VCPU guest only* if required (due to vSIE faults)
   - We never inject anything into the nested KVM guest VCPU

7. *Unshadow/unpin* control blocks
   - Unpin satellites only – *no other blocks have to be unshadowed*

8. *Re-execute KVM guest VCPU*
Current state

- >= 248 CPUs, transactional execution, vector registers, huge pages (1M, 2G) ...
  - Basically everything a KVM guest has, except CMM because ...

- vSIE doesn't support all SIE facilities (e.g. CMMA or SIGP interpretation like z/VM)
  - shadow table entries could be empty although they are not in the shadowed one
  - SCA contains pointers to invalid SCBs – shadowing is not an option

- No, known bugs – still "kvm.nested=1" required for now

- No know „incompatibilities“ with the SIE specification (okay, there is a small one ...)

- CPU model support required to turn it on („-cpu host“)

- Migration simply works: guest memory contains all nested guest state
  - Shadow structures (GMAP, SCB ...) are silently recreated on the new host
  - GMAP shadow code should be able to deal with user fault just fine

- Really hard to break out of vSIE, even into its hypervisor:
  - We don’t emulate any vSIE instructions – SIE handles everything for us
  - We don’t inject any vSIE interrupts – SIE handles everything for us
  - When shadowing, we heavily filter the SCB, to not allow e.g. strange addressing modes
  - GMAP shadow is based on GMAP only
**Performance**

**Kernel compile time (s) (8 VCPUs, 2 GB,(virtio) disk, no swap)**

- **LPAR: 8 CPUs (not dedicated), 8 GB, SCSI disks, no swap**
  - *First memory access is expensive*
    - The GMAP shadow has to be filled on first memory access
    - Building a GMAP shadow on a GMAP shadow is horribly expensive (Guest-4)
  - Once memory is faulted into the gmap shadow, *overhead is quite small*
    - *Lockless lookup/reuse* of shadow SCB (to avoid TLB flush) + shadow gmap

- **Kernel src on multi-paravirtualized disk** via virtio-blk
  - Rebooting the compiling guest (clear caches) didn’t affect compile times
How deep can we go?

Summary and Outlook

- I was able to *start a kernel in guest-6* ... while having lunch
  - Can we improve the gmap shadow/unshadow + pagefault pingpong somehow?
- KVM is now able to run with a *minimum amount of SIE facilities*
- We found *one random memory overwrite* + minor bugs in KVM code
- Can we *reduce the amount of DMA pages*?
  - This would allow us to keep more shadow SCBs in the cache
- Can we *reuse data in the shadow SCB*, not shadow/check everything again?
- „*kvm.nested=1“*, can it ever be dropped completely?
- *CPU model support* in QEMU to finally turn it on
- Support all *new HW features as KVM support is added*
Thank you!