# As time goes by -

Analysing Where We Spend Our Cycles During Exits


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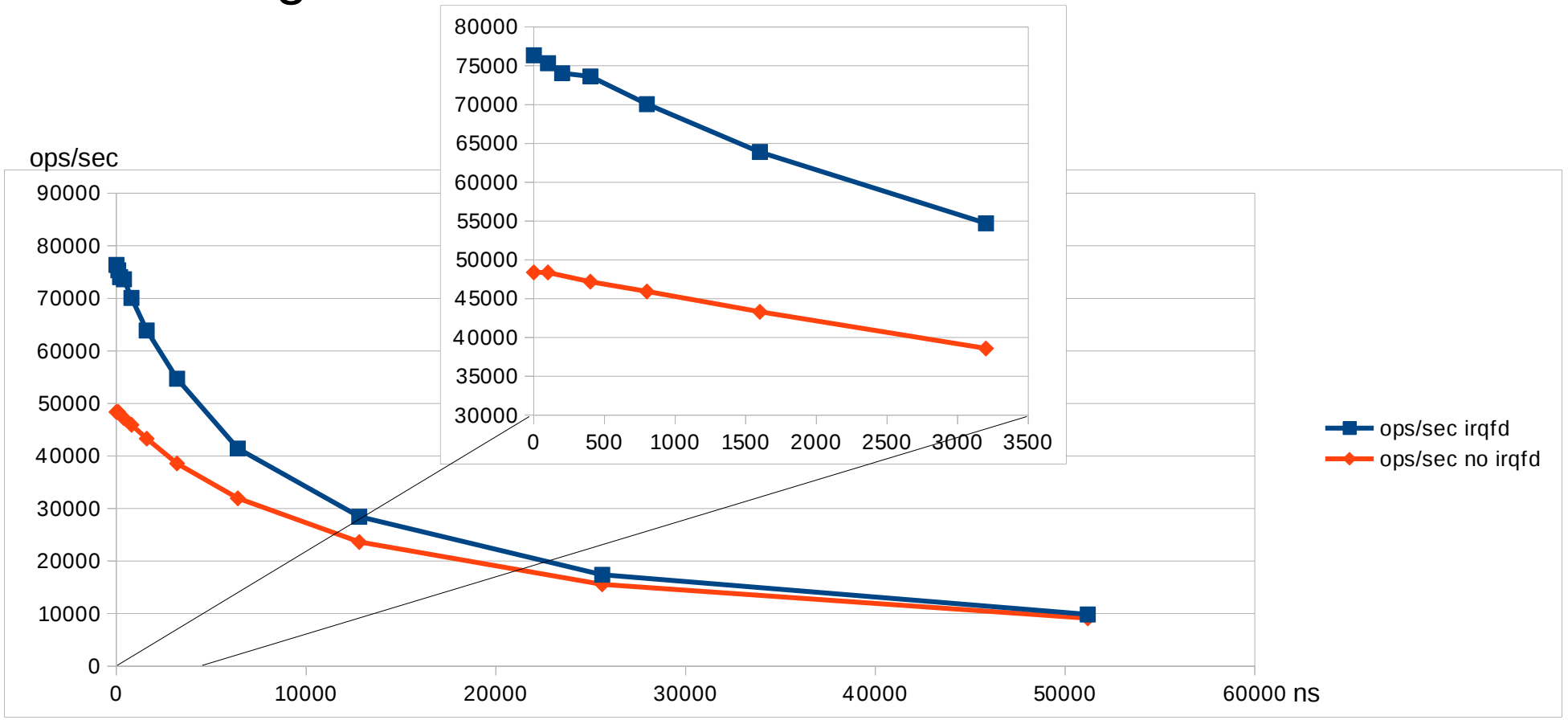
# Motivation (1)

“People say that you should not micro-optimize. But if what you love is micro-optimization... that's what you should do.” - Linus Torvalds

# Motivation (2)

- Sample uperf TCP RR 1:1
- 1 byte tcp ping pong
- Let's see what happens when you add ndelay() after each guest exit



# What did I do?

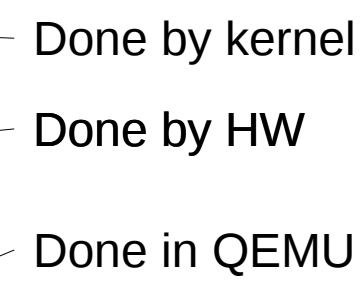
- Measuring how long it takes from guest->host->guest (guest exit handling exit and return to guest)
  - Initially with kernel module with timing and retries on s390
- Initial round trip time was 760ns (*)
  - Was surprised how far we exceed the HW overhead of entry/exit handling
  - Quickly identified several things down to 500ns
  - → Measuring and analysing can bring benefits very quickly for new architectures
- A lot more things after that
  - Fight against old code
  - Fight against new code
- Now at ~300ns (*) on my test system
  - Still much more than pure HW overhead

(*) Disclaimer: all numbers based on my as-is kernel config and my test systems (uncontrolled environment)

# Measuring 1/3

- Kvm-unit-tests
  - Available for most platforms
  - Gives times for typical exits
  - How long – not why (in cycles)

```
$ ./x86/run x86/vmexit.flat
[…]
cpuid 1552
vmcall 1448
mov_from_cr8 1
mov_to_cr8 15
inl_from_pmtimer 7220
inl_from_qemu 7002
[…]
```




- Kernel module for s390 as outlined

# Measuring 2/3

- So let's have a look at the why
  - Use ftrace!
  - Resolution for function tracer is microseconds

```
qemu-system-s39-4797  [000] ....   195.732618: kvm_s390_deliver_pending_inte...
```

  - Resolution for function graph is nanoseconds

```
0)   0.034 us    |          mutex_lock_killable();
```

  - Overhead > subject of measurement
    - Simple hypercall 300 ns → 1800 ns for function tracer
    - Simple hypercall 300 ns → 4800 ns for function_graph
    - Software uncertainty principle?
  - Still useful for finding interesting spots
  - Some functions (.s files) not prepared for ftrace :-/

# Measuring 3/3

- Use perf top/annotate
  - staring at samples in disassembly
  - Looking closer at hot samples
- Hand written “hacks”
- Disable “optional” code and retest

# History: early exits

- Request handling has many test_bits, clear_bits and memory barriers
- Requests are not the fast path, early exit if there are not requests
  - saves about 10ns for the common case on s390

```
 static int kvm_s390_handle_requests(struct kvm_vcpu *vcpu)
 {
[…]
+       if (!vcpu->requests)
+               return 0;
[…]
        if (kvm_check_request(KVM_REQ_MMU_RELOAD, vcpu)) {
[…]
```

- There was a followup idea from Paolo to pull this if into kvm_check_request such that gcc can optimize
  - I forgot about that
  - X86 and power already have a similar “if(vcpu->requests)”
  - Mips has only KVM_REQ_UNHALT
  - Arm sets KVM_REQ_VCPU_EXIT (but never checks?)

# History: irqsave/restore

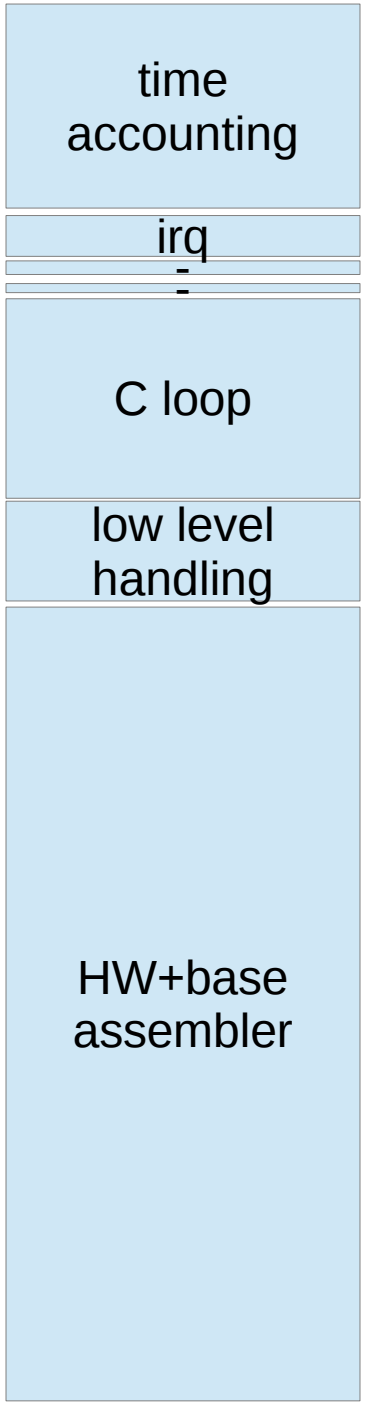
- irq_save/restore vs. irq_disable/enable
  - save/restore is about 5-8x slower than disable/enable on s390/x86
- How often when running KVM?
  - Around guest_enter_irqoff
  - rcu_note_context_switch might do it
  - Inside exit handlers
  - In scheduler code
- KVM now does disable/enable

# History: more s390 code

- S390 debug feature: pull condition check into header file
- S390 interrupt handling: do early exits
- Built-in vs. module
- Optimize irq_restore (ssm vs. stosm)

# Today

- Upstream s390 kernel, default config
- simple hypercall: ~300ns
- Lets start to remove code
  - Remove vtime_account_system: 255ns
    - About 50% arch code / 50% core code
  - + get rid of irq_disable_enable around guest_enter/exit: 246ns
  - + do not care about srcu locking 243ns
  - +get rid of tracing calls: 241ns
  - +shortcut in C (if special case just rerun the sie function): 197ns
  - +shortcut in assembler: 175 ns
- Still larger than pure HW time
  - possibly some misses/restarts in pipeline, caches, TLB and branch prediction
  - Still some code in hypervisor that needs to run



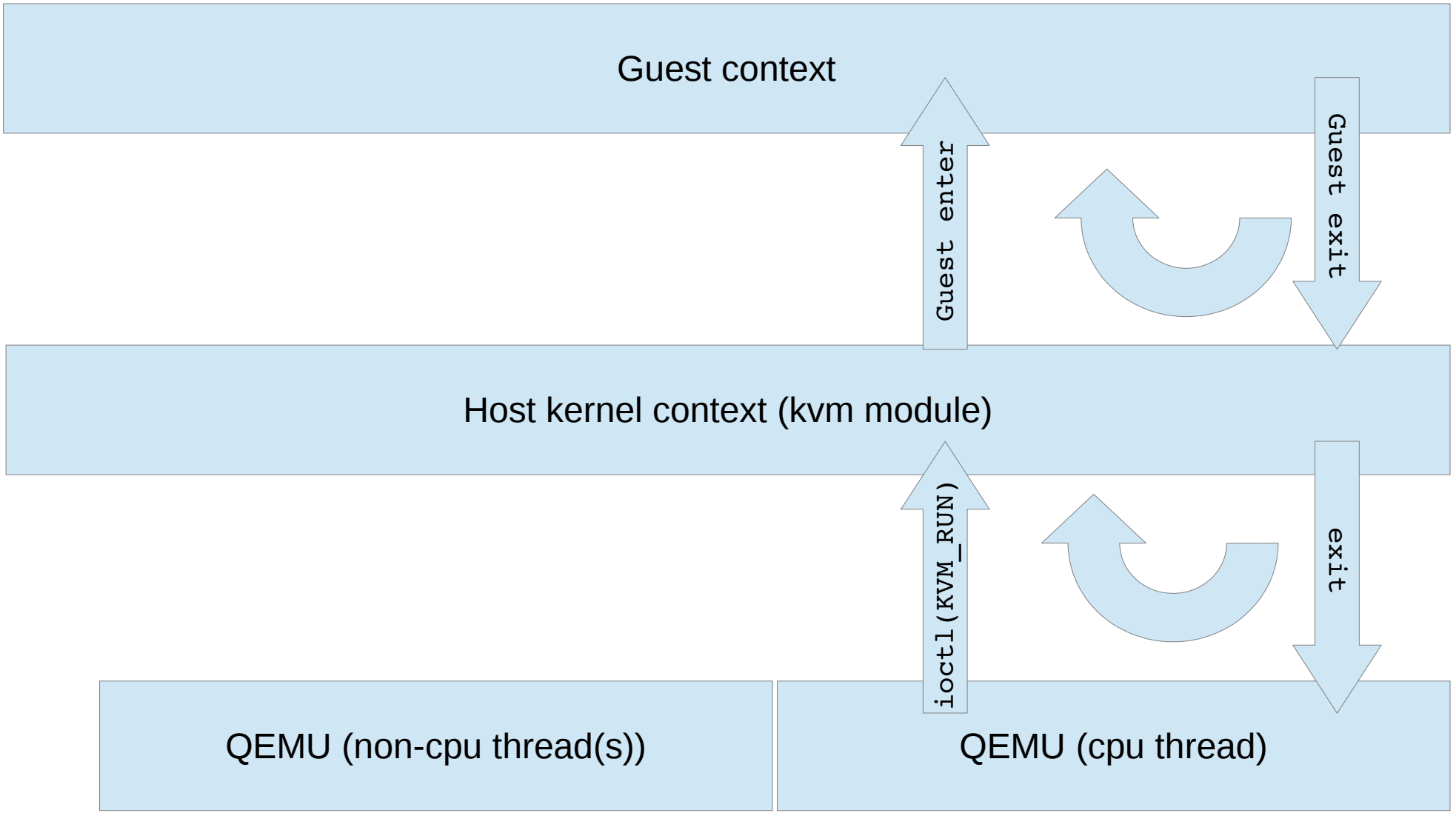
# QEMU

- Additional overhead of ~3000 cycles on x86 broadwell (~6000 on my ivy bridge)
  - Some things are known
    - Base overhead as seen before
    - signal mask restore
    - system call return
    - Glibc ioctl routine
    - KVM low level ioctl handling
    - KVM main loop
    - Glibc ioctl routine
    - system call enter
    - signal mask set
  - Some things can be hw related due to context change
    - Branch prediction
    - TLB
    - Caches
  - Some overhead due to horribly expensive things in QEMU

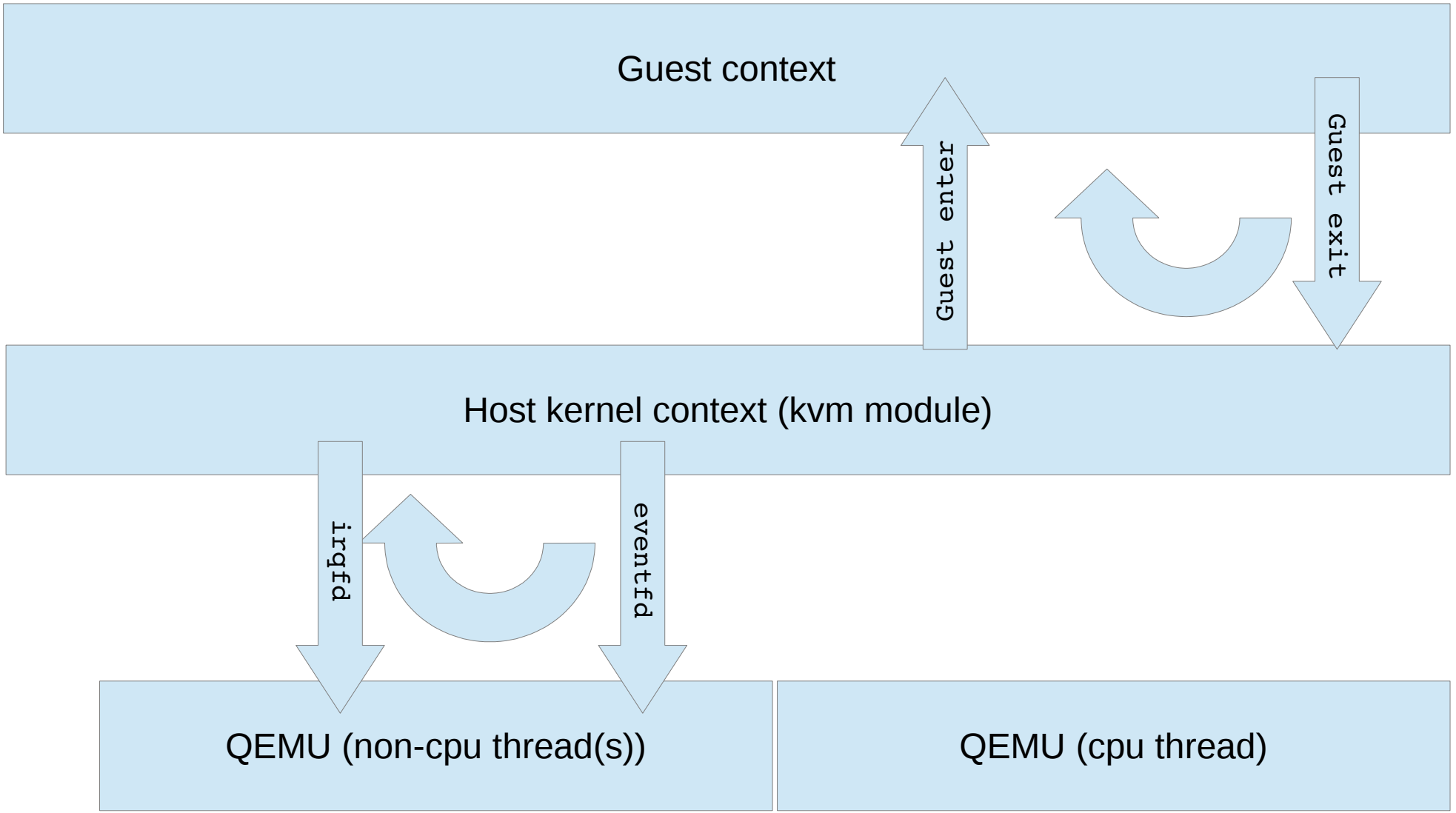
# QEMU

- Can we stay in the kernel for most exits?

# KVM exits


Guest context
Guest enter
Guest exit
Host kernel context (kvm module)
ioctl(KVM_RUN)
exit
QEMU (non-cpu thread(s))
QEMU (cpu thread)

# eventfd


Guest context
Guest enter
Guest exit
Host kernel context (kvm module)
irqfd
eventfd
QEMU (non-cpu thread(s))
QEMU (cpu thread)

# eventfd

- Using eventfd: 1400ns->400ns for the guest exit of the virtio kick
- Exit time seems to be constant, no matter how many devices (eventfd file descriptors) are being used → write to eventfd
- Performance (fio) also seems “flat”, as long as every disks has its own iothread

# vcpu_load vcpu_put

- With eventfd, most exits become lightweight exits
  - Can we avoid some things for lightweight exits?
  - The kernel does not use floating point
  - vcpu_load/vcpu_put
    - Floating point registers
    - Access registers
    - ...
  - Preempt notifier will ensure data integrity

# QEMU

- You said “Some overhead due to horribly expensive things in QEMU” on slide 12
  - Any examples?

# cpu_synchronize state

- cpu_synchronize_state when you need to read/write any CPU register state
  - call kvm_arch_get_registers
  - Schedules kvm_arch_put_registers
  - Two ioctl per register class (GET and SET)
    - KVM_GET_REGS
    - KVM_GET_XSAVE
    - KVM_GET_XCRS
    - KVM_GET_SREGS
    - KVM_GET_MSRS
    - KVM_GET_MP_STATE
    - KVM_GET_LAPIC
    - KVM_GET_PIT2
    - KVM_SET_REGS
    - KVM_SET_XSAVE
    - KVM_SET_XCRS
    - KVM_SET_SREGS
    - KVM_SET_MSRS
    - KVM_SET_MSRS
    - KVM_SET_PIT2

inl_from_qemu: 9183

inl_from_qemu: 59660

```
--- a/kvm-all.c
+++ b/kvm-all.c
@@ -1833,4 +1833,5 @@                    CPUState *cpu)

          run_ret = kvm_vcpu_ioctl(cpu, KVM_RUN, 0);
+         cpu_synchronize_state(cpu);
[…]
```

# Sync regs

- On s390 we often need one or the other register
  - Only one exit type (we would need one for each instructions)
  - We do call cpu_synchronize_state OFTEN
  - Why not use kvm_run as place for registers?

# Is this good enough?

- With all optimizations, arch_put/get_registers still visible in samples

```
for (i = 0; i < 32; i++) {
    cs->kvm_run->s.regs.vrs[i][0] = env->vregs[i][0].ll;
    cs->kvm_run->s.regs.vrs[i][1] = env->vregs[i][1].ll;
}
```

  - Due to aliasing rules and other things, gcc creates a loop with loads/stores instead of one big memcpy
  - Some cache effect as we are at the end of a context
- Long term solution could be to use access functions for registers
  - No mirroring necessary

# Object model

- Resolving an object is extremely expensive

inl_from_qemu: 9183

```
--- a/kvm-all.c
+++ b/kvm-all.c
@@ -1833,4 +1833,5 @@                    CPUState *cpu)

          run_ret = kvm_vcpu_ioctl(cpu, KVM_RUN, 0);
+         object_resolve_path_type("", TYPE_ACCEL, NULL);
[…]
```

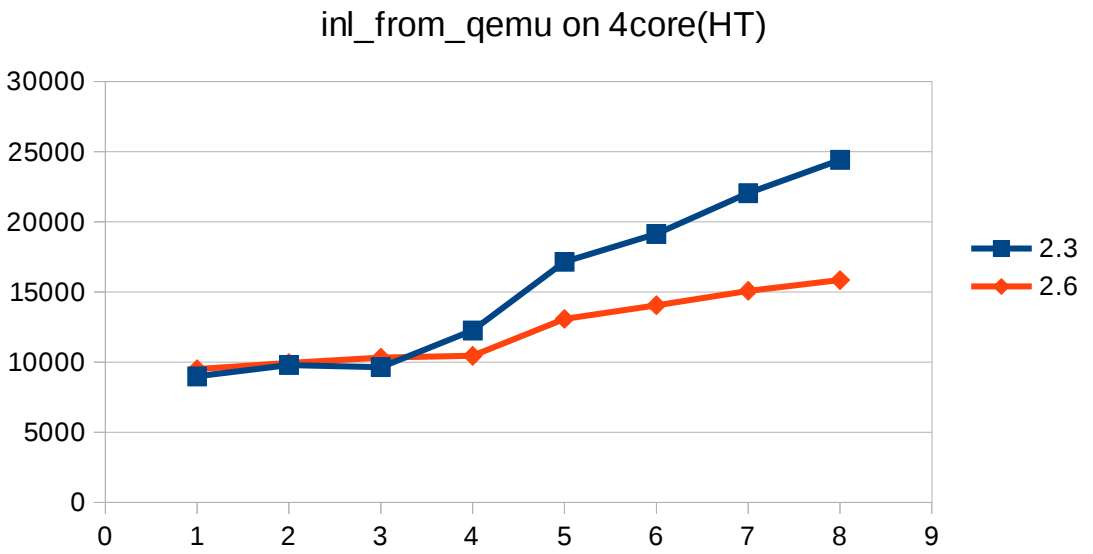
inl_from_qemu: 119780

# Big qemu lock

- Until QEMU 2.4, all KVM exits were handled serialized

```
qemu_mutex_unlock_iothread();
run_ret = kvm_vcpu_ioctl(cpu, KVM_RUN, 0);
qemu_mutex_lock_iothread()
```

- Pushdown efforts started in 2.4



# Future improvements

- Avoid exits
  - Use HW features
  - suggest HW features
  - Improve interfaces (e.g. virtio)
- On x86/s390 kernel offers only small potential
  - Request handling optimization in common code
  - Signal mask handling
- QEMU
  - Identify additional BQL pushdown areas
  - Understand object model cpu usage
  - Avoid/Optimize synchronize_state
  - Extend eventfd to other devices

# Fun facts

- Plugging in power cable in a Thinkpad W530 laptop improves exit times significantly even if the clock rate is the same
- Found 2 bugs in the s390 code while preparing these slides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