Observability in KVM

How to troubleshoot virtual machines

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In this talk we can only scratch the surface (sorry)

About me

QEMU contributor since 2010

- Block layer co-maintainer
- Tracing and net subsystem maintainer
- Google Summer of Code & Outreach Program for Women mentor and administrator

I work in Red Hat's KVM virtualization team

Common questions on #qemu IRC

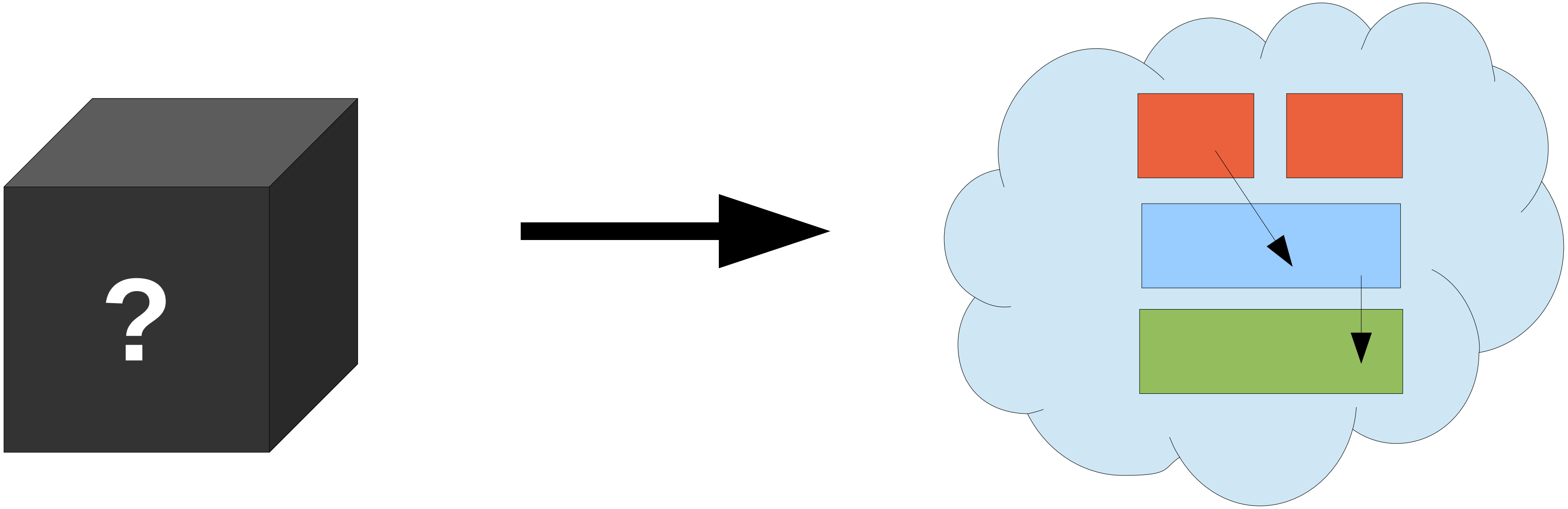
“My VM cannot connect to the internet. What's wrong?”

“Copying files is slow in the VM. How can I make it fast?”

These problems can be solved through **troubleshooting**, but QEMU is a **black box** to many users.

This talk is about how to get to the bottom of these types of issues.

What's required for troubleshooting?



Systematic approaches require a **mental model**

Knowing components and their relationships allows you to ask the right questions.

How to troubleshoot KVM issues

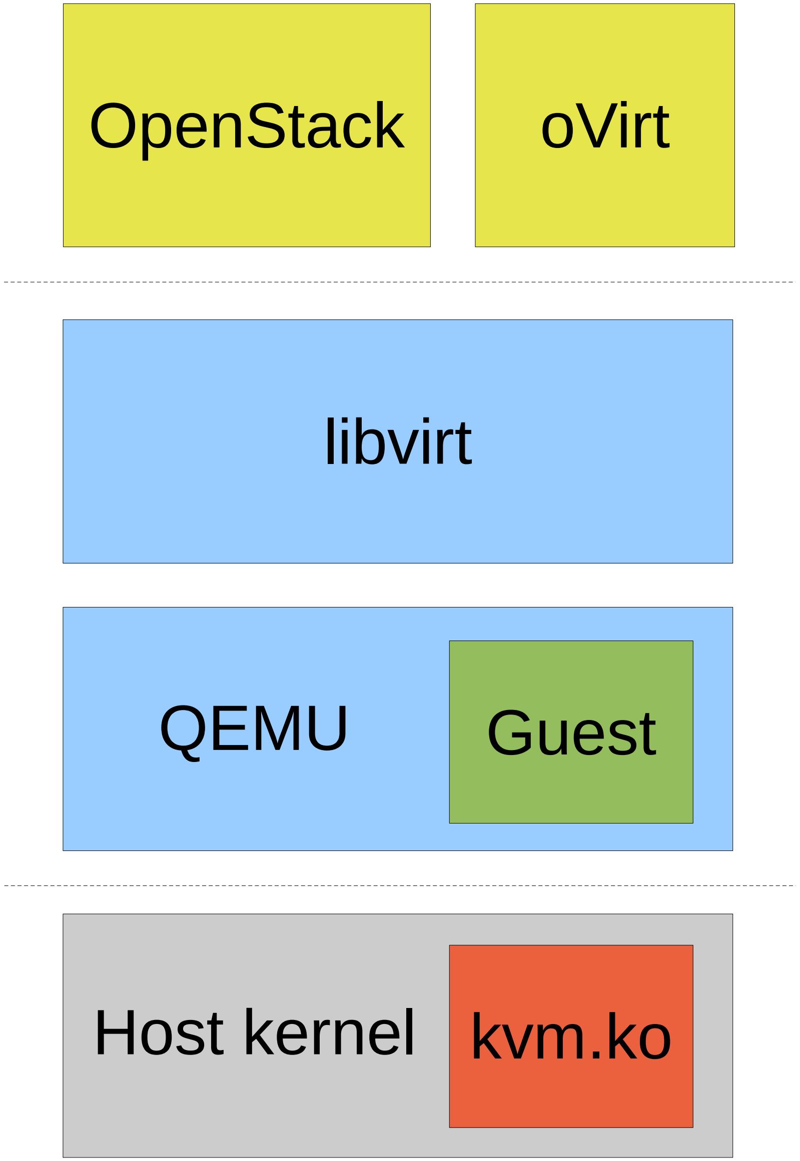
Get familiar with the components and key characteristics of KVM

Make use of observability tools:

- Performance statistics
- Network packet capture
- Log files
- Tracing

Use scientific process to determine root cause

Components in the KVM virtualization stack



Management for datacenters and clouds

OpenStack

oVirt

Management for one host

libvirt

Emulation for one guest

QEMU

Guest

Host hardware access and resource mgmt

Host kernel

kvm.ko

General troubleshooting with libvirt and KVM

Use **virsh(1)** to inspect virtual machines

- Far too many commands to list, see “virsh help”

Libvirt keeps logs for each virtual machine at /var/log/libvirt/qemu/<domain>.log

Also check dmesg(1) for kernel messages such as Out-of-Memory killer, segmentation faults, or error messages from kvm.ko module

Tracing

Tracing is useful for performance analysis, requires low-level knowledge and/or familiarity with code

Using **strace -f** on QEMU is noisy but can be done

kvm.ko kernel trace events available via **perf(1)** and **trace-cmd(1)**

Some distros ship QEMU with a **SystemTap** tapset

- Advantage: combine host kernel and QEMU traces

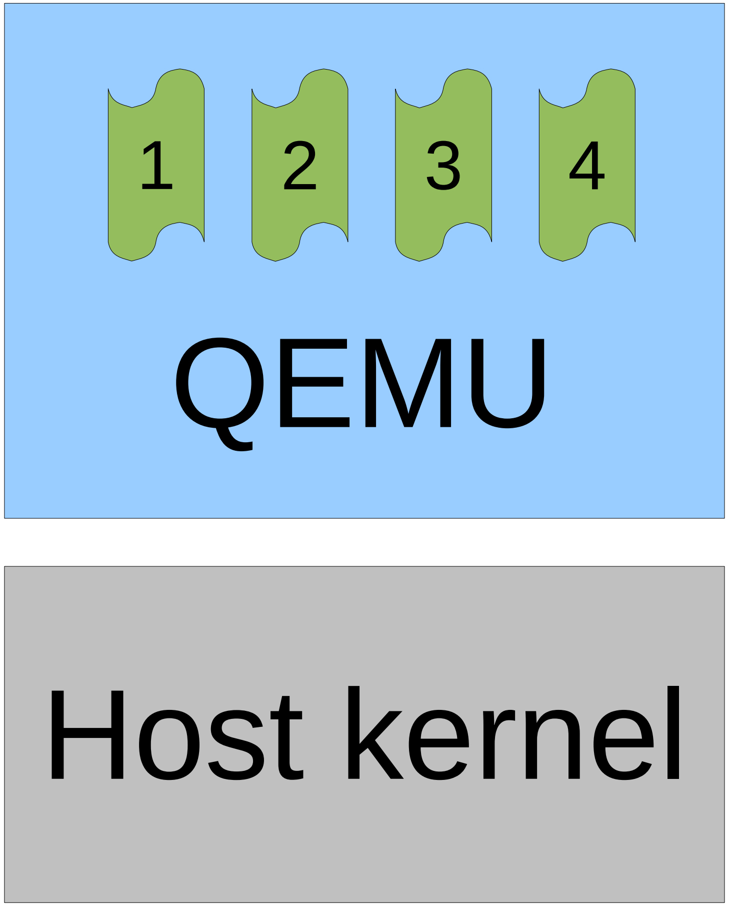
The big secret to troubleshooting KVM

Plain old Linux commands like ps(1), vmstat(1), tcpdump(8), etc work!

There is less virtualization magic than one might think.

Part 1 - CPU

Virtual machine CPU execution (overview)



1 QEMU process per guest

1 “vcpu thread” per guest CPU

Host kernel schedules vcpu threads like normal threads

CPU utilization breakdown on KVM hosts

Useful CPU utilization categories:

1) Guest code (%guest)
   - Kernel and userspace
2) QEMU (%usr)
   - Device emulation, live migration, etc
3) Other host userspace (%usr)
   - Are you running bitcoind on the host?!
4) Host kernel (%sys, %irq, %soft)
   - Caused by I/O or userspace activity

Host shows high CPU utilization, what's wrong?

top(1) on host shows 25% user process CPU time

Tool: mpstat(1) from the “sysstat” package offers detailed processor statistics

%usr	%nice	%sys	%iowait	%irq
0.40	0.00	0.40	0.30	0.00
%soft	%steal	%guest	%gnice	%idle
0.00	0.00	25.01	0.00	73.89

25.01% guest means 1 out of 4 host CPUs is maxed out running guest code.

Result: Check if guest is stuck in an infinite loop or use <cputune> libvirt XML for cgroups resource control

Is my cloud guest getting enough CPU?

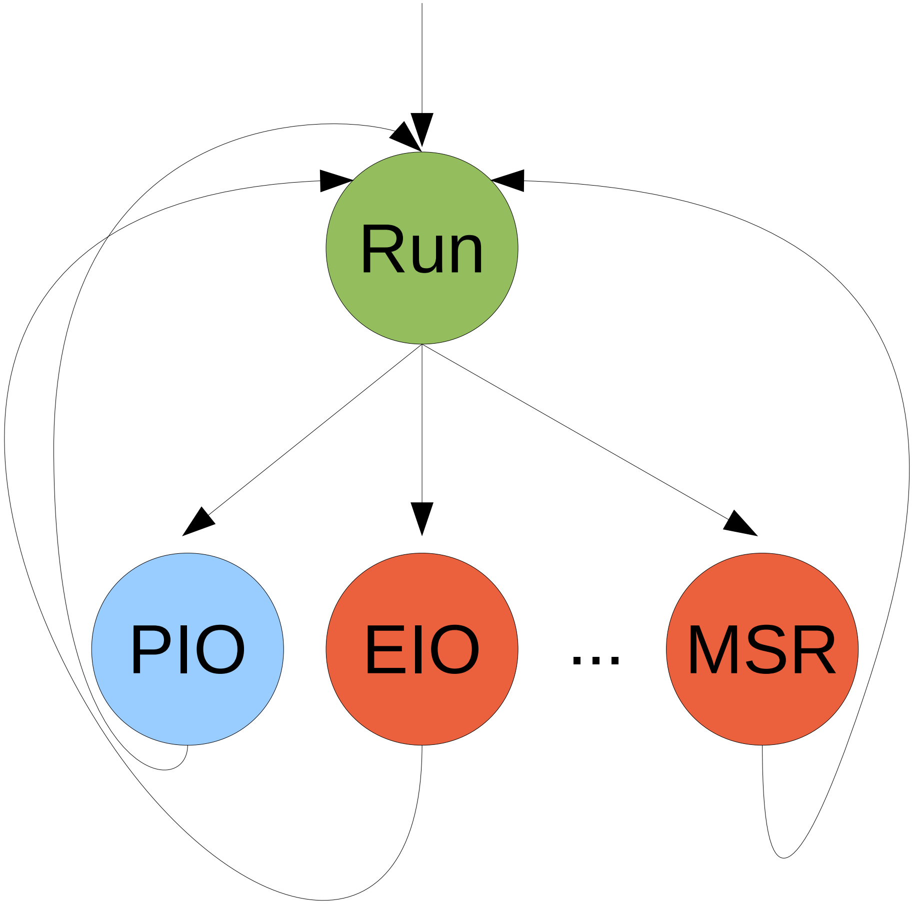
Host may report how long runnable vcpus wait to run on a physical CPU

Reported as **%steal** in mpstat(1)

Requires host to cooperate – may be disabled

Good for identifying overloaded hosts

Virtual machine CPU execution (low-level)



vcpu thread state machine

vcpu thread calls ioctl(KVM_RUN) repeatedly to run guest code

Kicked out of guest code by hardware register accesses, interrupts, model specific registers, etc

Observing low-level events with kvm_stat

kvm_stat is a top(1)-like tool for KVM event counters:

```
kvm_exit              809319   432
kvm_entry             809319   432
kvm_msr               593133   318
kvm_inj_virq          196268   112
kvm_eoi               196165   112
…
```

These KVM trace events can also be observed with perf record -a -e kvm:*

100% CPU while sitting at the GRUB menu?

Suspicious events are typically >10,000 events/sec:

kvm_exit … 880112

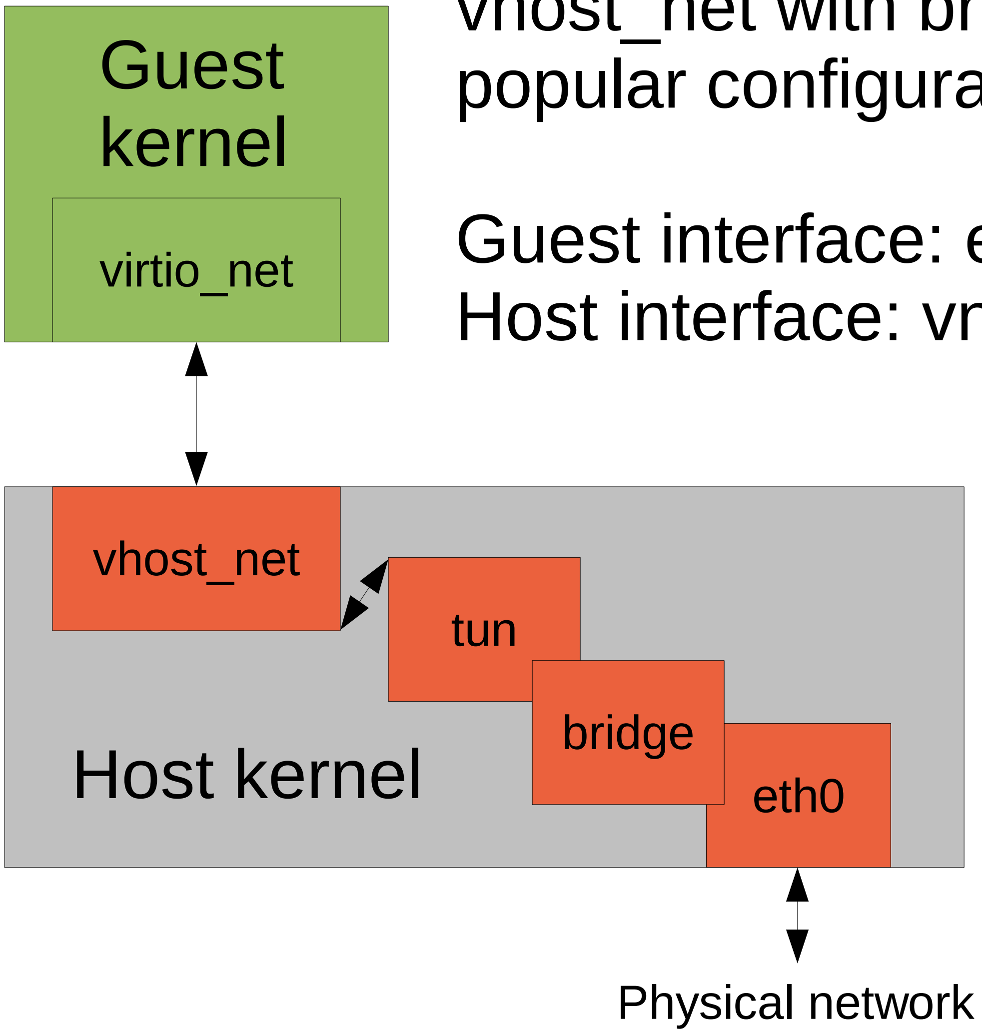
kvm_cr … 805440

“cr” ← x86 control registers (e.g. changing into protected mode)

This could be a guest is spinning in a loop that transitions back and forth between real mode and protected mode.

Part 2 - Networking

Virtual machine networking



vhost_net with bridged networking is a popular configuration

Guest interface: eth0 emulated virtio-net NIC
Host interface: vnet0 tun software interface

External network connectivity through software bridge (virbr0)

Other guests can be connected to same bridge for guest<->guest connectivity

Troubleshooting bridged networking

tcpdump eth0 inside guest

- Does guest receive traffic and get ARP responses?

tcpdump vnet0 on host

- Does host see guest outgoing traffic?
- Does the bridge forward guest incoming traffic?

tcpdump virbr0 on host

- Does the bridge see traffic?

tcpdump eth0 on host

- Does physical traffic look as expected?

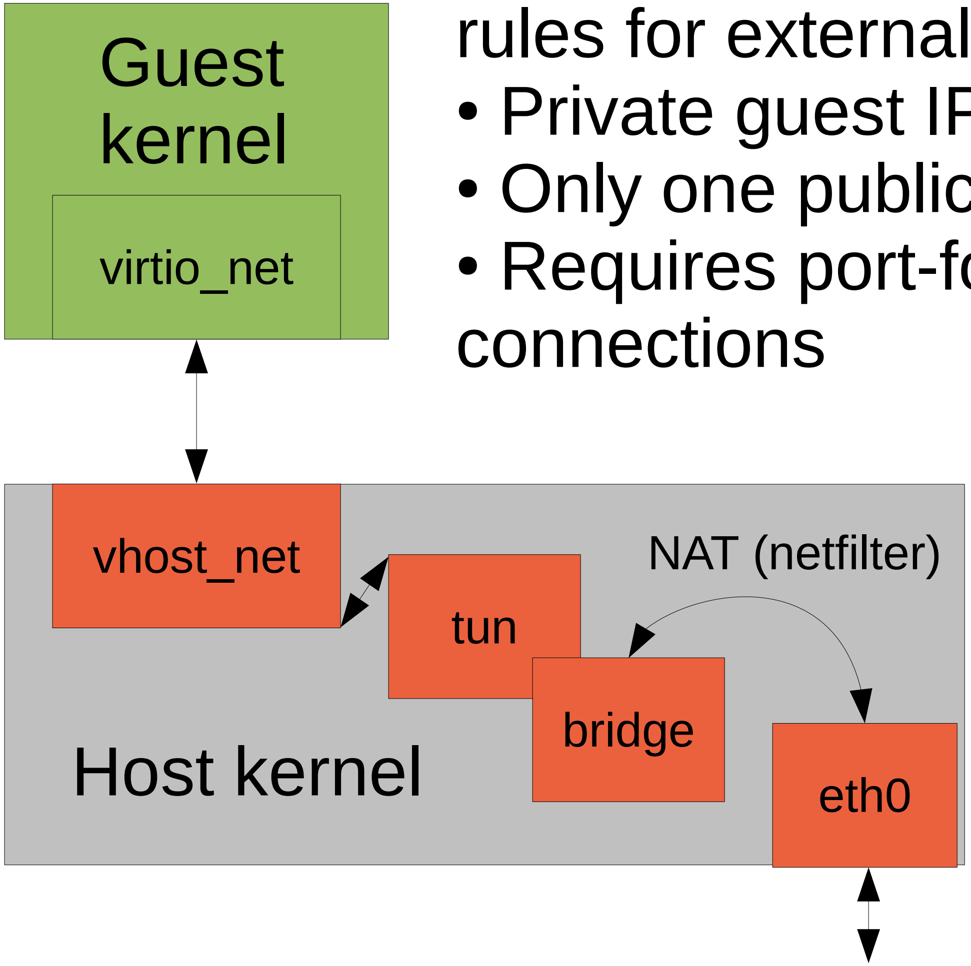
Host-wide interface statistics

```
# netstat -i
Iface      MTU    RX-OK …   TX-OK …
virbr0    1500     2669         4611
virbr0-n  1500        0            0
vnet0     1500       41          502
wlp3s0    1500  1500554       387876
```

Guest network interface names can be queried:

```
# virsh domiflist rhel7
Interface Type    Source  Model  MAC
vnet0     network default virtio 52:...
```

Popular NAT networking configuration



Guests on private bridge with iptables NAT rules for external connectivity

- Private guest IP range
- Only one public IP for host and guests
- Requires port-forwarding for incoming connections

DNS and DHCP services typically provided by host using dnsmasq

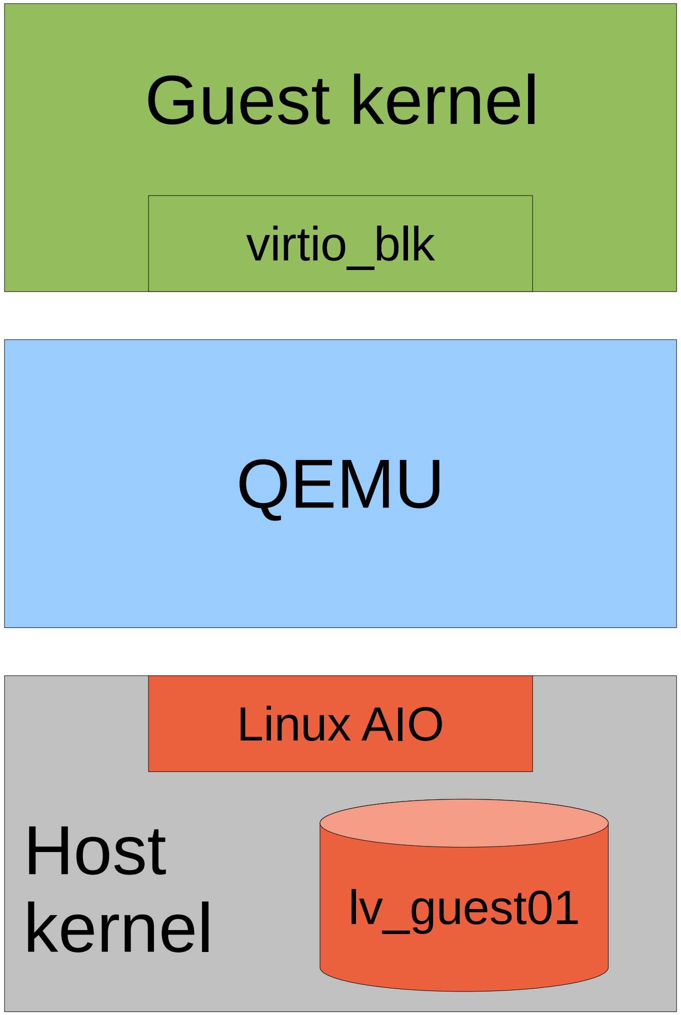
Now you can troubleshoot DHCP and DNS too

```
(host)# journalctl -r | head    # or syslog
```

```
dnsmasq-dhcp[1173]: DHCPDISCOVER(virbr0)
192.168.122.252 52:54:00:52:fe:24

dnsmasq-dhcp[1173]: DHCPOFFER(virbr0)
192.168.122.252 52:54:00:52:fe:24

dnsmasq-dhcp[1173]: DHCPREQUEST(virbr0)
192.168.122.252 52:54:00:52:fe:24

dnsmasq-dhcp[1173]: DHCPACK(virbr0)
192.168.122.252 52:54:00:52:fe:24
```

Part 3 – Disk I/O

Popular LVM local disk configuration



Storage provided to guest as virtio-blk PCI adapter

QEMU typically configured with cache=none to bypass host page cache

LVM offers good performance and storage management features

Why can't QEMU open the disk image file?

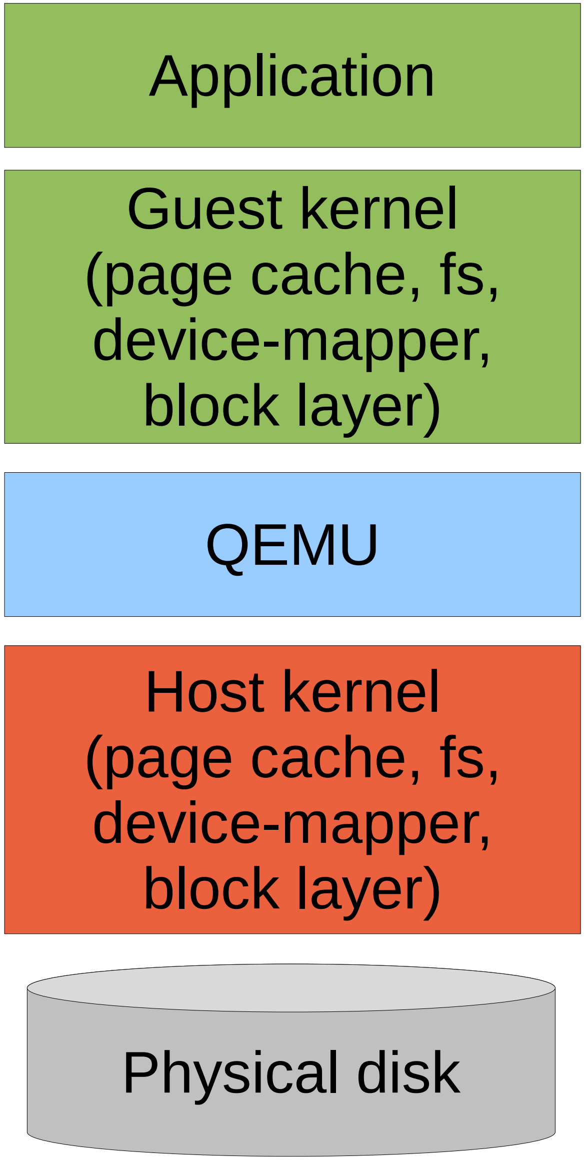
Libvirt can launch QEMU as an unprivileged user with SELinux isolation

Check that QEMU process uid/gid can access disk image file

Check SELinux audit logs in /var/log/audit/audit.log for denials

Libvirt SELinux configuration in /etc/libvirt/qemu.conf

Benchmarking disk performance



Application

Guest kernel
(page cache, fs,
device-mapper,
block layer)

QEMU

Host kernel
(page cache, fs,
device-mapper,
block layer)

Physical disk

Apples-to-oranges comparisons are very common!

Use **fio –direct=1** for benchmarking to bypass page cache

Use **fio –rw=randwrite** for a random pattern that avoids QEMU virtio-blk write merging

I/O statistics with iostat(1)

```
$ iostat -k -x 1
Device: …  r/s   w/s rkB/s  wkB/s
sda       0.00 13.00  0.00  51.20
           avgrq-sz avgqu-sz …
           7.88     0.01
```

Compare guest and host to identify unexpected changes including:

- Page cache usage (request not sent to device)
- Request merging
- Request parallelism (queue depth)

I/O patterns with blktrace(8)

To study the exact pattern of I/O requests:

```
8,0 3 1 0.000000000 21846  A   W …
8,0 3 2 0.000000770 21846  Q   W …
8,0 3 3 0.000004564 21846  G   W …
8,0 3 4 0.000006611 21846  I   W …
8,0 3 5 0.000017716 21846  D   W …
8,0 0 1 0.001158278     0  C   W …
```

This truncated example shows a write request on device 8,0 taking 1.16 milliseconds.

Questions?

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Blog: http://blog.vmsplice.net/

QEMU: http://qemu-project.org/

Slides available on my website: http://vmsplice.net/