Scalability and stability of libvirt: Experiences with very large hosts

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NOTES: Linux penguin image courtesy of Larry Ewing (lewing@isc.tamu.edu) and The GIMP

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It all started with a performance bug

For multiple domains:

```
# while virsh start $vm && virsh destroy $vm; do : ; done
```

→ ~30s hang ups of the libvirtd main loop

Agenda

1. Test Setup and Scenarios
2. Stability
3. Performance
4. Summary and Outlook

Test Environment

All tests were conducted on the following system:

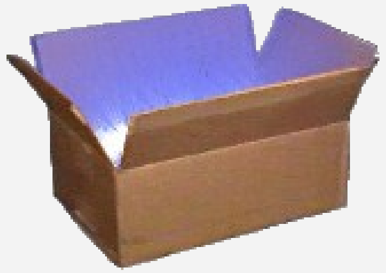
- 64 shared cores (z14)
- 4TB RAM
- Distro: Fedora 28, SELinux enforced
- Libvirt: commit 0a7101c89b78
- Kernel: 4.19+
- QEMU: 3.0.0

Source: https://mp.s81c.com/8034F2C/dal05/v1/AUTH_db1cfc7b-a055-460b-9274-1fd3f11fe689/266ef7f57b168d4e5dd7994d6a65327b/additionalOfferingImg__0_318d9711-7e49-4a46-ba5b-a262328c8204.png

Test Setup

Guest definition

- host kernel + minimal initrd (with Busybox)
- 1 vCPU
- 100mb RAM
- direct kernel boot
- SCLP console
- SCSI disks



```
<domain type='kvm'>
  <name>{{ name }}</name>
  <memory unit='MiB'>100</memory>
  <os>
    <type arch='s390x'>hvm</type>
    <kernel>/var/lib/libvirt/images/vmlinux-s390x</kernel>
    <initrd>/var/lib/libvirt/images/rfs-s390x.gz</initrd>
    <cmdline>root=/dev/ram</cmdline>
  </os>
  <devices>
    <console type='pty'>
      <target type='sclp'/>
    </console>
    {%- for disk in disks %}
    <disk type='block' device='disk'>
      <source dev="{{ disk.path }}"/>
      <target dev='{{ disk.dev }}' bus='scsi'/>
    </disk>
    {%- endfor %}
  </devices>
</domain>
```

Source: https://busybox.net/images/busybox1.png

Used system configuration

Adjusted the values suggested by the presentation from Jens Freimann *(“Pushing the limits: 1000 guests per host and beyond” - KVM forum 2015)*

- `sysctl -w kernel.pid_max=348160`
- `sysctl -w kernel.threads-max=33029620`
- `sysctl -w kernel.pty.max=20000`
- `sysctl -w fs.file-max=42653636`
- `sysctl -w fs.inotify.max_user_watches=524288`
- Increased `ulimit -n` for libvirtd accordingly

Used libvirt configuration

Default `libvirtd.conf` except

- `max_anonymous_clients = 100`
- `max_client_requests = 10`
- `max_workers = 64`
- `prio_workers = 10`

Default `qemu.conf` except

- `max_process = 16384`
- `max_files = 262144`

Test Setup

SCSI disks used for the guests

scsi_debug module used for the SCSI disks

- avoids the usage of real disks
- could be used for passthrough

```
# modprobe scsi_debug add_host=8 num_tgts=8 max_luns=256 \
    dev_size_mb=1
```

Test Scenarios

Trying to reproduce the bug

- Start/Destroy guests concurrently
- Define/Undefine guests concurrently
- Start/Managedsave concurrently

WHAT ELSE COULD POSSIBLY GO WRONG?

Encountered problems: deadlocks

Deadlock across fork() in virCommandExec()

- start/destroy in a loop for multiple domains
- fixed by commit 5fec1c3a5c0f

Race condition when counting unauthenticated clients

- results in a libvirtd that does not accept new connections
- connect/disconnect concurrently with multiple clients
- fixed by commit 94bbbcee1f23

Encountered problems: other race conditions

NULL pointer dereferencing when libvirtd reconnects to QEMU processes

- events were “handled” before the QEMU driver was initialized
- fixed by commit fef4d132c4e3

Double free’ing

- caused a segmentation fault
- define/undefine the same domain concurrently
- fixed by commit 7e760f61577e

after two days running...

after two days running… no segmentation faults

Back to the original bug

Main thread*

```
while True:
   poll(monitors, client sockets, …)
   virEventPollDispatchHandles
      qemuMonitorIO
         qemuProcessHandleMonitorEOF
            virObjectLock(vm)
```

Worker thread*

```
virNetServerHandleJob
   qemuDomainDestroyFlags
      qemuDomObjFromDomain
         virObjectLock(vm)
      qemuProcessStop
         qemuRemoveCgroup
            virDBusCall(..., timeout=30s)
```

* Very simplified

Back to the original bug

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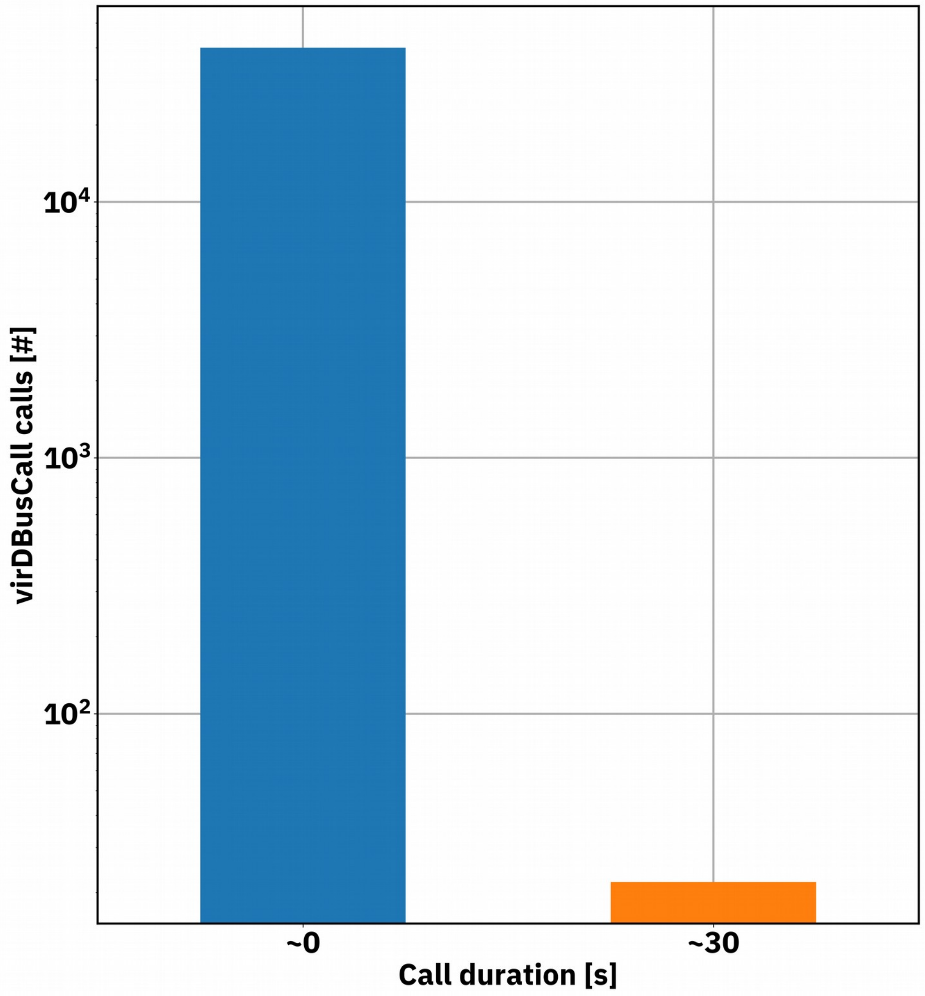
Problem observation

The D-Bus calls are

- either fast
- or they need the total timeout

but nothing in between.

No real timeout occurred!



* SystemTap used for instrumentation

Possible solutions

“If you use this low-level API directly, you're signing up for some pain.”*

Yep, we do so.

So we could either

- fix it within libvirt
- use another D-Bus library

* https://dbus.freedesktop.org/doc/api/html/ (visited on 2018.10.01)

NEVER EVER BLOCK YOUR MAIN LOOP!

Possible solutions

- no worker thread should block the main loop
- only dispatch the events in the main loop
- handle events in a thread pool*

* See presentation “Lessons in running libvirt at scale” from Prerna Saxena from last years KVM forum.

more on performance

How fast can we go?

Command line start of QEMU versus start via libvirtd

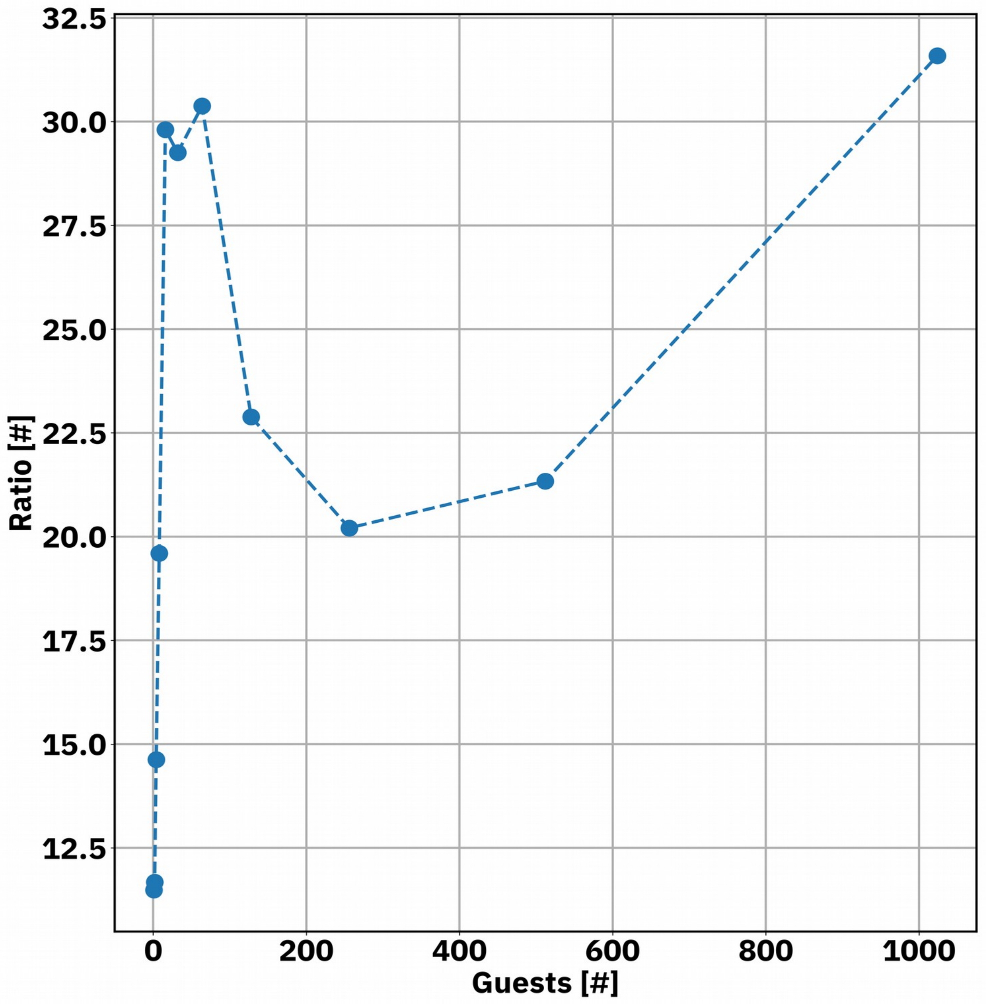
- it’s a real unfair comparison… since libvirt does so much more, but let’s approximate the “optimum”
- no disk per guest
- self-written Python3 test script:
  - using 64 threads
  - methods: direct command line and libvirt
- `# qemu-system-s390x -S $*`

Starting guests

Direct QEMU command line vs. libvirt

$$ratio(i) = \frac{t_{libvirt}(i)}{t_{cmdline}(i)}$$

Where does the time go?



Where does the time go?

Additionally, libvirt:

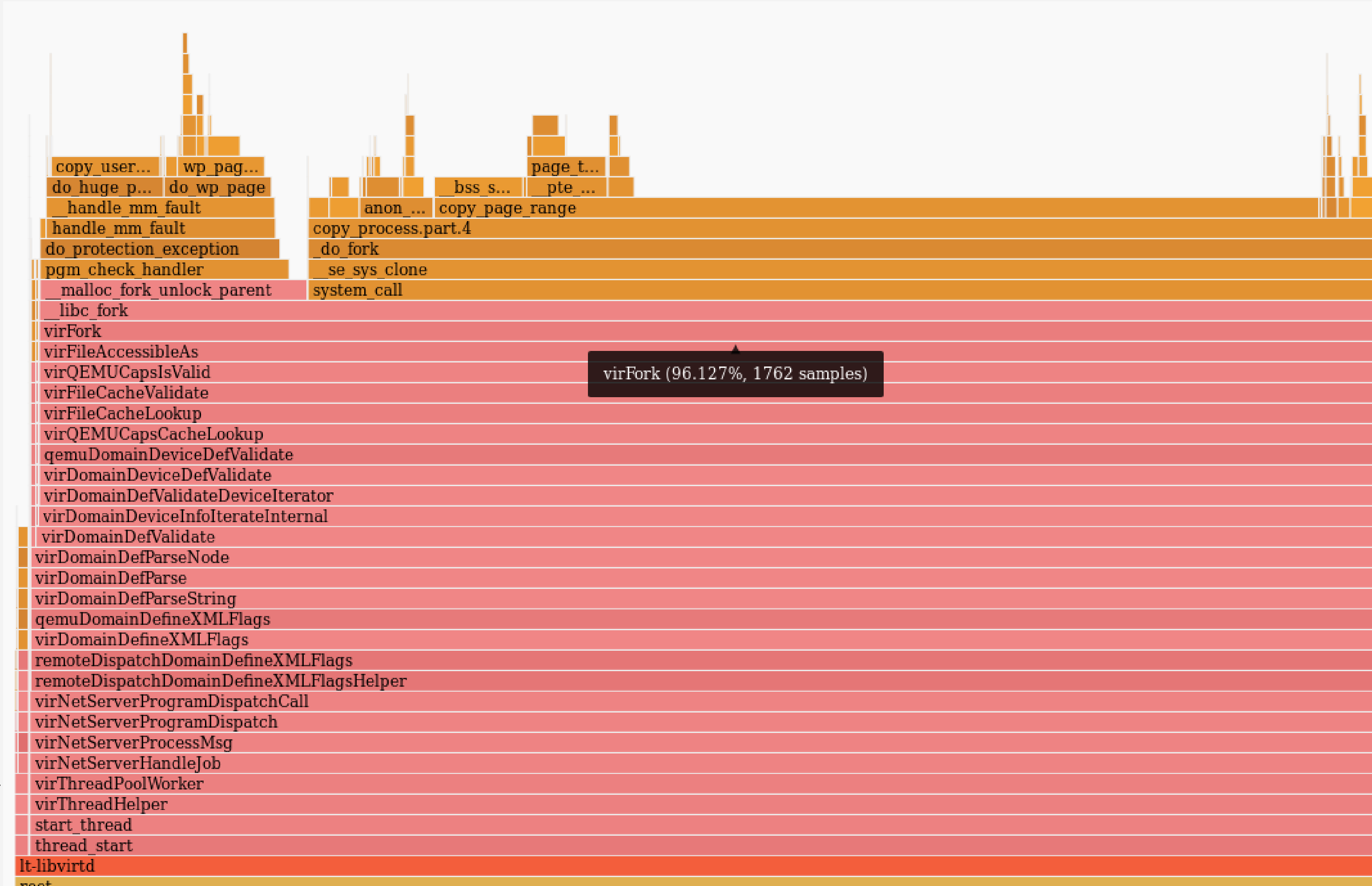
- prepares the host
  - vsock
  - hostdevs
  - …
- prepares the QEMU process
  - cgroups
  - namespaces
  - SELinux labels
  - …
- handles QEMU capabilities
- auditing
- logging
- …

Performance

Where does the time go for the **define** operation?

On-CPU flame graph* when defining guests for 60 seconds each with 20 SCSI disks

- 96.127% of the time is used for `virFork`
- which is called within `virDomainDefValidateDeviceIterator`



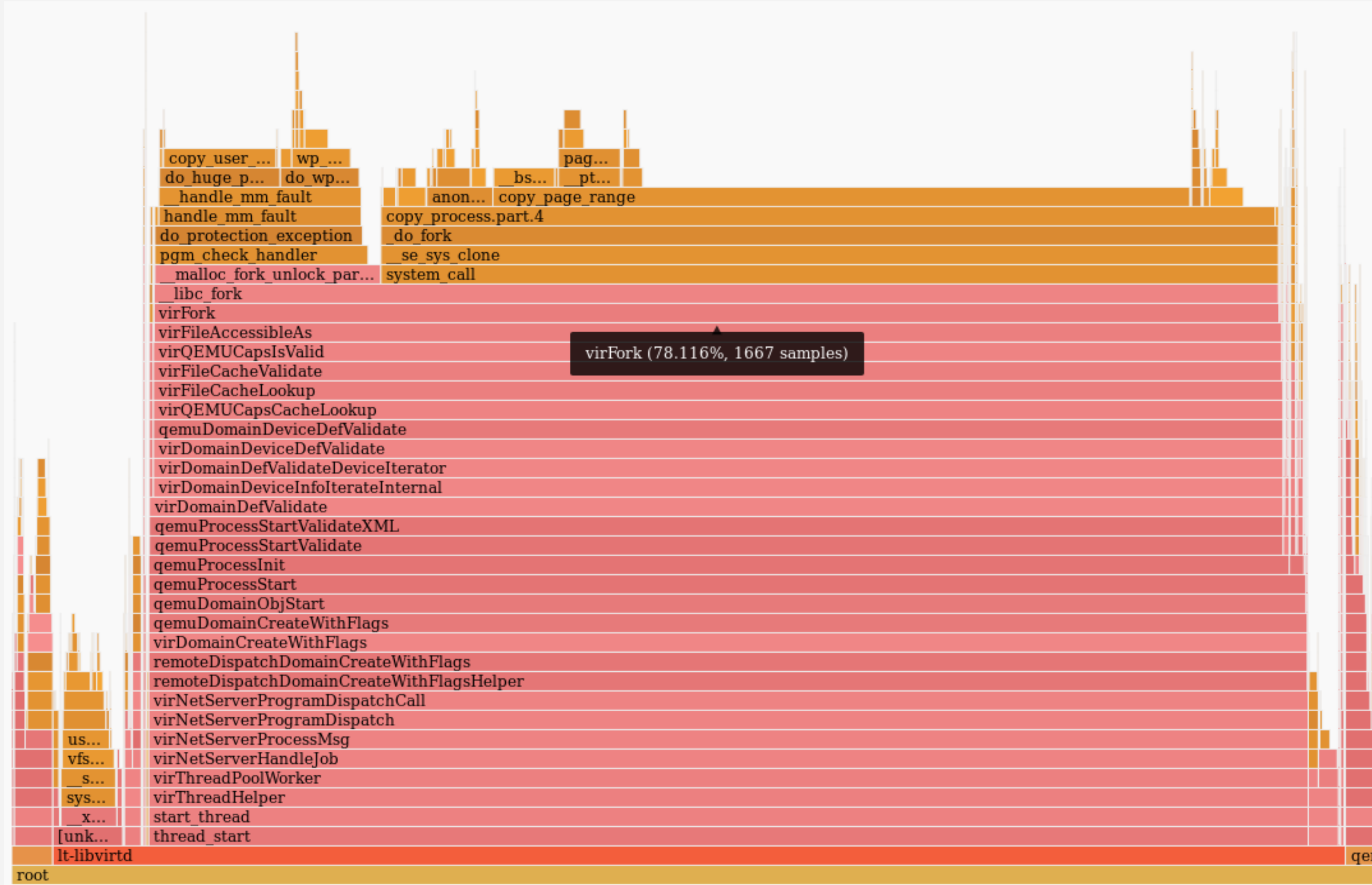
*See http://www.brendangregg.com/flamegraphs.html for more information

Performance

Where does the time go for the **start** operation?

On-CPU flame graph when starting guests for 60 seconds each with 20 SCSI disks

- 78.116% of the time is used for `virFork`
- which is called within `virDomainDefValidateDeviceIterator`



What does virQEMUCapsCacheLookup do?

- Probing the QEMU capabilities is expensive

  → Caching was introduced
- Looks up the QEMU capabilities for the domain in the cache + validates that these capabilities are still valid
  - Fork for verifying `/dev/kvm` is accessible as `qemu:qemu`

Do we really need this validation for **each** device of a domain?
Because the more devices a domain has the more expensive it is

Possible improvements

- Query the QEMU capabilities once for each task (e.g. define, start, ...)

  See my patch series “Avoid numerous calls of virQEMUCapsCacheLookup”*

  - this also avoids using different QEMU capabilities for the same task
- Use `vfork` + `execve` a dedicated program instead of a expensive fork

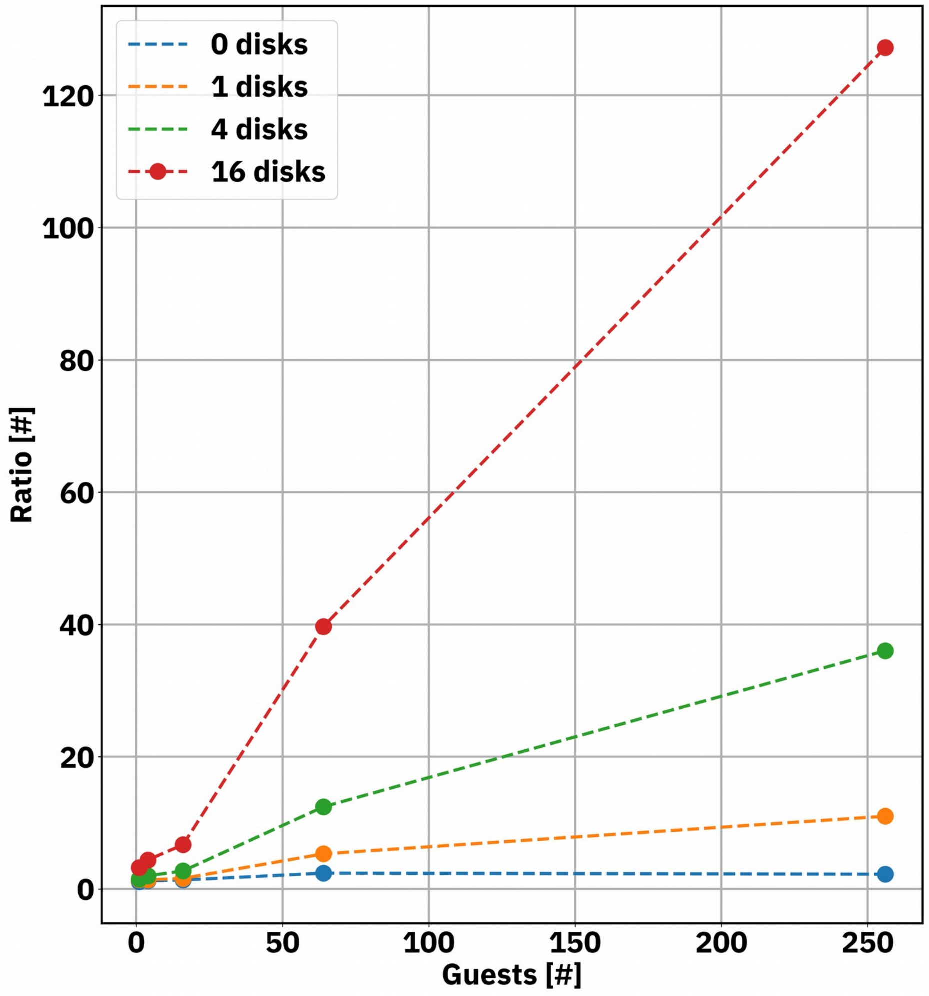
* https://www.redhat.com/archives/libvir-list/2018-September/msg01092.html

Performance results

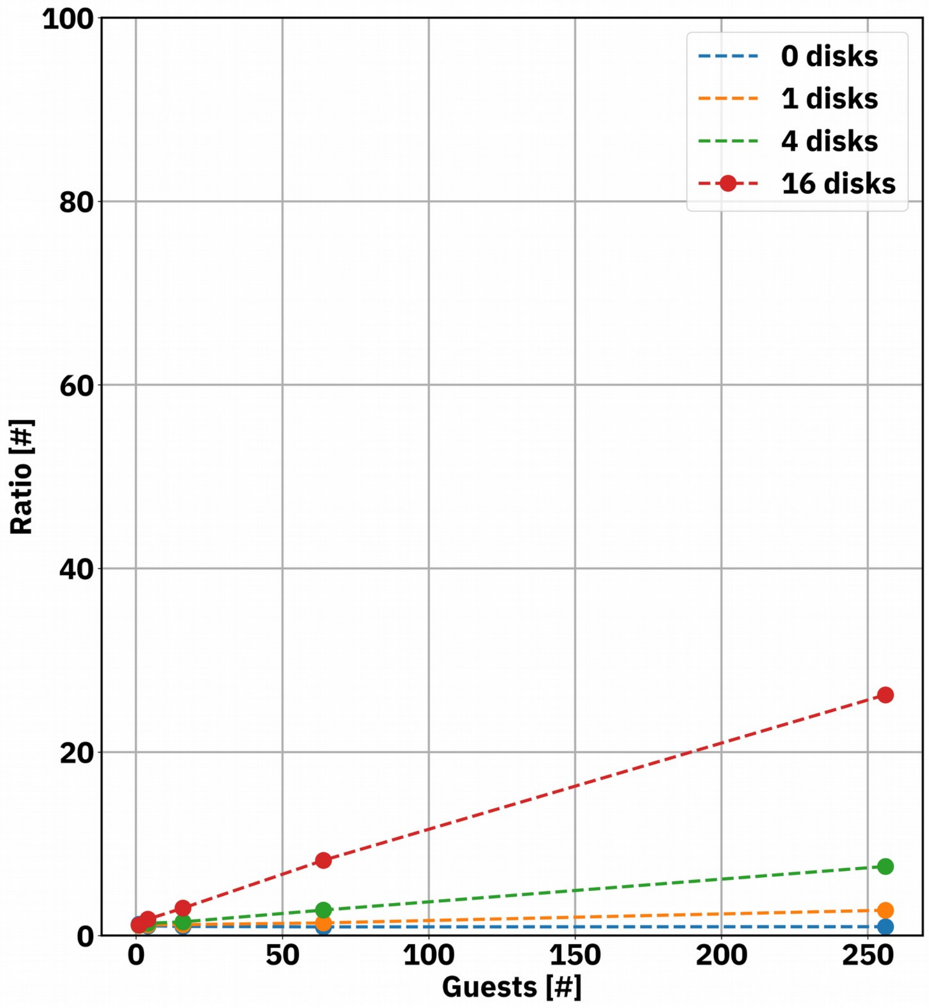
- baseline: libvirt (commit 0a7101c89b78)
- improved: libvirt (commit 0a7101c89b78) + my patch series “Avoid numerous calls of virQEMUCapsCacheLookup”

$$ratio(i) = \frac{t_{baseline}(i)}{t_{improved}(i)}$$

definition
256 guests
16 disks
127x



start
256 guests
16 disks
26x



What can be optimized?

- don’t block the main loop

  see “Lessons in running libvirt at scale”

- optimize QEMU capabilities usage

  see my patch series

- fix the 30 seconds D-Bus problem

Further analysis

- locking strategies
  - Optimize locking of `virDomainObjList` and `virDomainObj`
  - …

  → **Analyze Off-CPU times!**
- what happens for more sophisticated operations?

  e.g. live migration
- what happens if we kill QEMU processes randomly?

  e.g. during migration

Questions?