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:

```bash
# 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

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

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
Test Setup

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

```bash
# modprobe scsi_debug add_host=8 num_tgt=8 max_luns=256 \ dev_size_mb=1
```
Test Scenarios

Trying to reproduce the bug

- Start/Destroy guests concurrently
- Define/Undefined guests concurrently
- Start/Managersave concurrently
WHAT ELSE COULD POSSIBLY GO WRONG?
Stability

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 94bcbbee1f23
Stability

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
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
Performance

Back to the original bug

Main thread*

while True:
    poll(monitors, client sockets, ...)
    virEventPollDispatchHandles
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Worker thread*

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* Very simplified
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
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

\[ \text{ratio}(i) = \frac{t_{\text{libvirt}}(i)}{t_{\text{cmdline}}(i)} \]

Where does the time go?
Performance

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 **virDomainDefValidadeDeviceIterator**

*See [http://www.brendangregg.com/flamegraphs.html](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 \texttt{virQEMUCapsCacheLookup} do?

- Probing the QEMU capabilities is expensive
  \rightarrow Caching was introduced

- Looks up the QEMU capabilities for the domain in the cache + validates that these capabilities are still valid
  \begin{itemize}
  \item Fork for verifying \texttt{/dev/kvm} is accessible as \texttt{qemu:qemu}
  \end{itemize}

Do we really need this validation for \textbf{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

Performance results

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

\[
\text{ratio}(i) = \frac{t_{\text{baseline}}(i)}{t_{\text{improved}}(i)}
\]
Performance

definition
256 guests
16 disks
127x
start

256 guests

16 disks

26x
Summary

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
Outlook

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?