Debugging the Virtualization layer (libvirt and QEMU) in OpenStack

Kashyap Chamarthy <kchamart@redhat.com>

DevConf 2016
Brno

Part I
Problem background and overview

Problem background

- Lots of moving parts: OpenStack services, Virt drivers, System components, etc
- Tracking interactions between multiple components is challenging
- Finding relevant log patterns in complex systems can become cumbersome

$\rightsquigarrow$ Effective root cause analysis with right tooling

What *kind* of bugs?

- Unexpected guest crashes
- Heisenbugs! (e.g. Nova bug: #1334398)
- Bugs introduced by load (e.g. OpenStack CI infra: ~800 test jobs/hr[*])
- Subtle issues in complex features

  (e.g. live migration), perf. degradation

[*] http://status.openstack.org/zuul/

OpenStack Nova

- Compute workloads
- Pluggable Virtualization drivers

  ```
  [libvirt]
  virt_type=kvm|qemu|xen|[...]
  ...
  ```

- `nova-compute`: faciliates interactions between hypervisors (libvirt/KVM) & VMs, via the virt driver interface

KVM Virtualization building blocks

KVM – Linux hardware virt (`vmx`|`svm`)

QEMU – Emulator: Devices (disk, networks, display, sound, PCI, etc); CPU

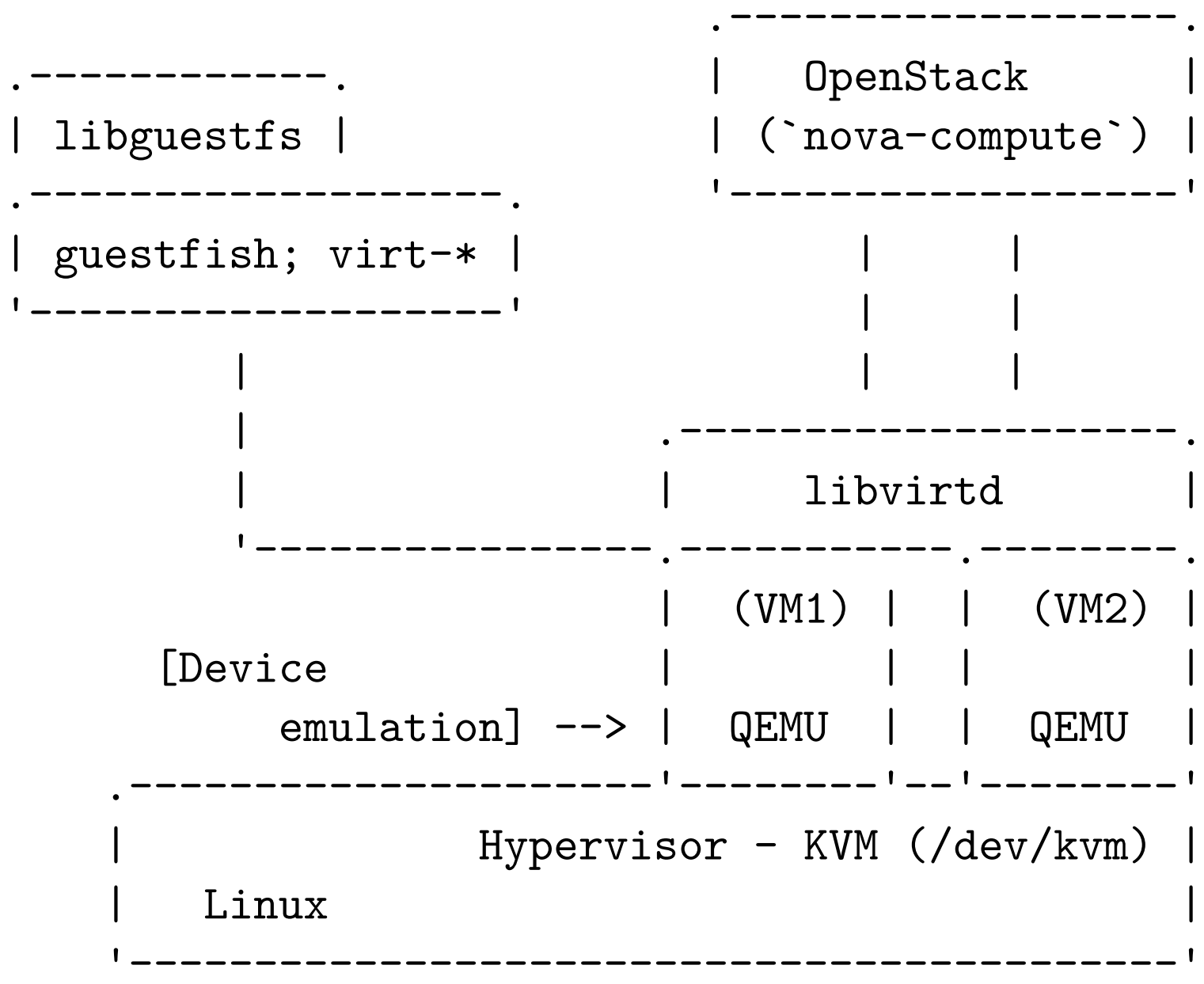
```
$ qemu-system-x86_64 -device \?
$ qemu-system-x86_64 -cpu \?
```

– Interactions with libvirt: **QMP** JSON RPC interface, **command-line**

libvirt – Hypervisor agnostic virtualization library

$\rightsquigarrow$ Default virtualization drivers in OpenStack

OpenStack KVM Virtualization building blocks

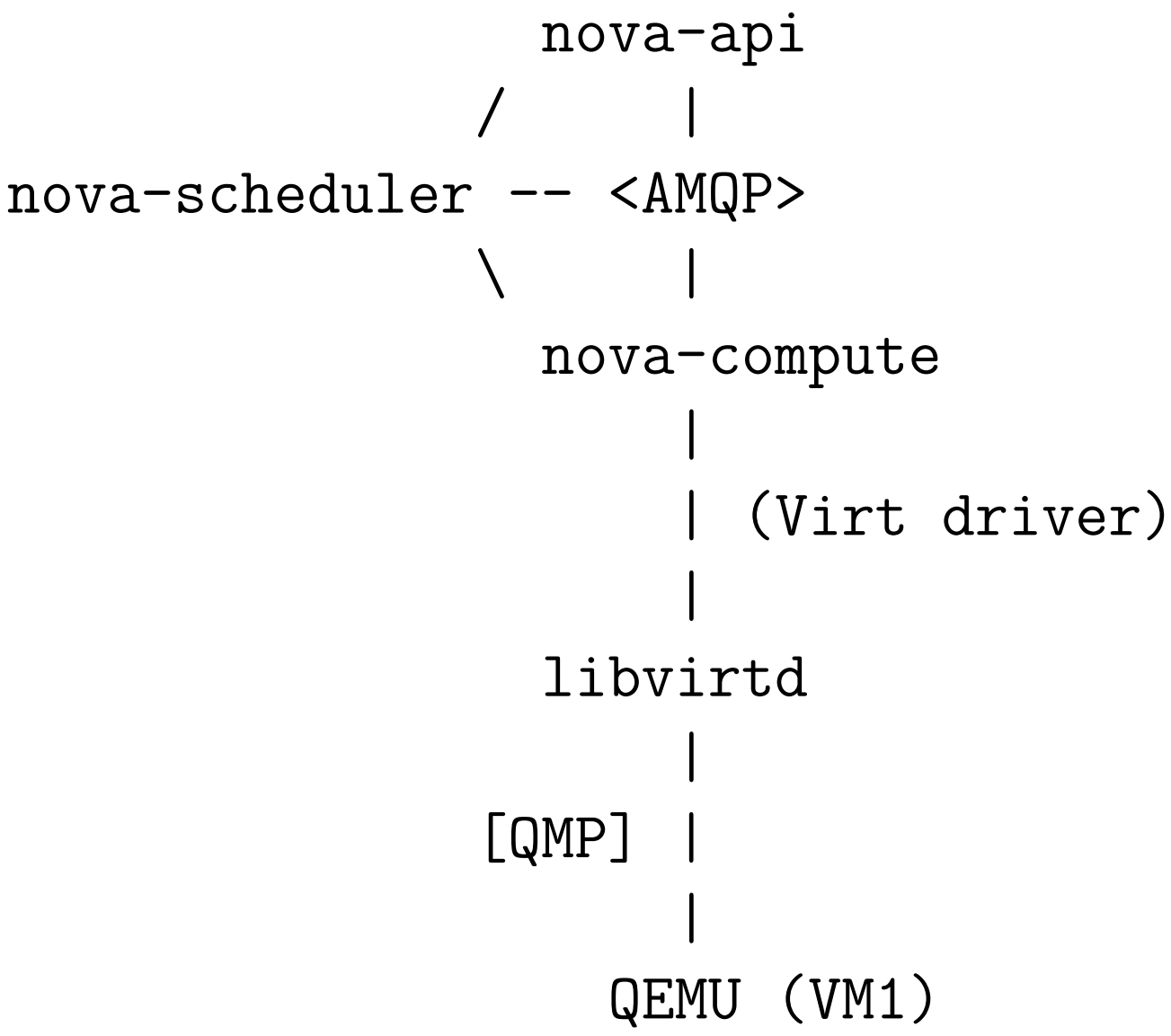


redhat.

Part II

OpenStack Compute/Virt debugging utilities

Nova and Virt drivers



Debugging utilities (in no order)

Component	Tools
Nova	debug/verbose = True
Compute	"Guru Meditation" Error Reports
libvirt	log_filters, virsh, journalctl
QEMU	QMP/HMP commands, mpstat, coredumpctl, `gdb -p $QEMU-PID`
KVM	kvm_stat(1) perf(1), trace-cmd(1), tcpdump(1)

Oslo "Guru Meditation" Error Reports (1)

To get live error report (will be redirected to stderr) of a Nova Compute process:

```
$ kill -s USR1 `pgrep nova-compute`
```

- `SIGUSR1`, `SIGUSR2` == User-defined signals
  - Refer: `man 7 signal`

⇝ From *'Mitaka'* release, default: `USR2`

Oslo "Guru Meditation" Error Reports (2)

Sections of the error report:

- Distribution package versions
- Running processes
- Green Threads, Native Threads
- Nova configuration details

$\rightsquigarrow$ No prior action required by the admin!

Example report:

http://docs.openstack.org/developer/oslo.reports/usage.html

redhat.

Part III

Libvirt and QEMU debugging controls

Virtual Machine specific logs

Located here:

`/var/log/libvirt/qemu/$vm.log`

Contains:

- libvirt-generated QEMU command-line arguments
- QEMU error messages
- libvirt `stderr` is redirected here

Granular logging infrastructure with libvirt

Log messages, filters and outputs.

– A set of patterns & priorities to accept or reject a log message.

E.g. Capture `DEBUG` for QEMU & libvirt but only `WARN` + `ERROR` for the rest.

Libvirt daemon logging: filters, log prorities

In */etc/libvirt/libvirtd.conf*, set:

```
log_filters="1:qemu 1:libvirt 3:security
             3:event 3:util 3:file"
log_outputs="1:file:/var/log/libvirt/libvirtd.log"
```

Restart libvirt daemon:

```
$ systemctl restart libvirtd
```

$\rightsquigarrow$ Better signal-to-noise ratio with log filters

Libvirt library logging: env. variables, outputs

To log all libvirt API calls, `export`:

```
LIBVIRT_DEBUG=1
LIBVIRT_LOG_FILTERS="1:qemu"
LIBVIRT_LOG_OUTPUTS="1:journald 1:file:virsh.log"
```

Specify multiple log outputs:

- systemd `journald`
- `file`

$\rightsquigarrow$ Applicable for libvirt daemon logging, too

Querying systemd journal for libvirt messages(1)

Structured logging with libvirt specifc journal fields:

- `LIBVIRT_SOURCE`, `CODE_FILE`
- `CODE_FUNC`, `CODE_LINE`
- `LIBVIRT_CODE`, `LIBVIRT_DOMAIN`

Querying systemd journal for libvirt messages(2)

Examples:

```
$ journalctl /usr/sbin/libvirtd [-f]

$ journalctl -o verbose \
             /usr/sbin/libvirtd

$ journalctl -u libvirtd -l -p err \
             --since=today
```

Live querying the VM: libvirt primitives

`virsh` command	Summary
qemu-monitor-command	Inspect/Modify VM state
qemu-monitor-event	Observe QMP Events
domblkstat	Fetch device block stats
[. . .]	[. . .]

⇝ For plenty more utilities: **man virsh**

Live querying VM state: `qemu-monitor-command`

- Query (or optionally modify) VM state.
- Enumerate all available QMP commands:

```
$ virsh qemu-monitor-command \
        vm1 --pretty \
        '{"execute":"query-commands"}'
```

Query available QMP commands: `query-commands`

```
$ virsh qemu-monitor-command vm1 -pretty \
        '{"execute":"query-commands"}'
        [...]

            "name": "query-events"
        ,

            "name": "query-cpu-definitions"
        ,

            "name": "drive-mirror"
        ,

            "name": "block-commit"
        ,
        [...]
```

For storage migration

Query block device info: query-block

```
$ virsh qemu-monitor-command vm1 -pretty \
        '{"execute":"query-block"}'
        [...]
            "io-status": "ok",
            "device": "drive-virtio-disk0",
            [...]
                "iops_rd": 0,
                ...
                "image": {
                    "backing-image": {
                        "virtual-size": 3221225472,
                        "filename": "[...]/_base/6b3d28"
                        "format": "raw"
                    ...
                    "virtual-size": 21474836480,
                    "filename": [...]/instances/disk",
                    ...
                    "format": "qcow2",
        [...]
```

Live querying VM: `qemu-monitor-event`

During a live block operation (e.g. in-progress live disk copy/migration), invoke this on a Nova instance:

```
$ virsh qemu-monitor-event \
        instance-00000001 \
        --pretty --loop
```

Prints details of the events as they occur

⇝ Can observe arbitrary QMP events

redhat.

Part IV

Example: Tracing the flow of a guest crash during Nova live block migration

Nova live block migration: Why this example?

- Multiple: `nova-compute` processes, libvirt daemons, QEMU instances

- No need for a shared storage setup

- Examine commands libvirt requests QEMU to execute (src $\leftrightarrow$ dest)

$\rightsquigarrow$ Observe interactions at different layers

Live block migration: Nova invocation

Invoke the Nova live block migration command:

```
$ nova live-migrate \
        --block-migrate vm1 $DEST-HOST
```

Sets libvirt migration flags as config attributes:

. . .

`live_migration_flag=VIR_MIGRATE_LIVE`,[...]

`block_migration_flag=VIR_MIGRATE_NON_SHARED_INC`,[...]

. . .

[NB: These are default (but configurable), no admin action needed.]

Live block migration: libvirt `virsh` invocation

Perform live block migration via libvirt's shell interface:

```
$ virsh migrate -verbose \
        --copy-storage-inc \
        --p2p --live vm1 \
        qemu+ssh://root@dest/system
```

⇝ Under the hood, Nova is making calls to the equivalent Python bindings, `migrateToURI2()`, of the above

Live block migration: libvirt invocation result

`stderr` says. . .

```
$ virsh migrate -verbose \
    --verbose \
    --copy-storage-inc \
    --p2p --live vm1 \
    qemu+ssh://root@dest/system
error: internal error: guest unexpectedly quit
```

Oops!

Guest doesn't run anymore!

Debug VM crash: Inspect for libvirt daemon errors

In libvirt daemon logs, on relevant Compute hosts:

```
$ less /var/log/libvirt/libirtd.log
[...]
error : qemuMonitorIO:662 : internal error:
End of file from monitor
[...]
debug : qemuMonitorIO:738 : Triggering EOF callback
debug : qemuProcessHandleMonitorEOF:307 :
        Received EOF on 0x7f2be0003bb0 'vm1'
debug : qemuProcessHandleMonitorEOF:325 : Monitor
connection to 'vm1' closed without SHUTDOWN event;
assuming the domain crashed
[...]
```

?

Assumption

Debug VM crash: Inspect for QEMU errors

In guest-specific logs, maintained by libvirt:

```
$ tail /var/log/libvirt/qemu/vm1.log
[. . .]
/usr/bin/qemu-kvm -name vm1 -S
-machine pc-i440fx-2.3,accel=kvm,usb=off
-cpu Nehalem -m 1024 -realtime mlock=off
-smp 1,sockets=1,cores=1,threads=1
-drive file=/export/cirros-0.3.3.qcow2,if=none,
 id=drive-virtio-disk0,format=qcow2
[. . .]
Co-routine re-entered recursively
2015-09-28 10:45:26.232+0000: shutting down
```

Error from QEMU

Debug VM crash: Look for Core dumps (1)

Use tools like `coredumpctl` (or equivalent):

```
$ coredumpctl
TIME    PID    UID    GID  SIG  PRESENT EXE
[...]   7194   107    107  11 */usr/bin/qemu-system-x86_64
```

Libvirt's assumption confirmed

Debug VM crash: Look for Core dumps (2)

Extract the coredump for the crashed QEMU process, report/fix bug:

```
$ coredumpctl dump 7194
           PID: 7194 (qemu-system-x86)
           UID: 107 (qemu)
           GID: 107 (qemu)
        Signal: 11 (SEGV)
      . . .
  Command Line: /usr/bin/qemu-system-x86_64 -machine[...]
     Coredump: /var/lib/systemd/coredump/core.qemu[...].xz
       Message: Process 7194 (qemu-system-x86)
                of user 107 dumped core.

             Stack trace of thread 7194:
             #0  0x00007fa52fa4680b __libc_siglongjmp (libc.so.6)
             #1  0x00007fa53d1670c9 longjmp (libpthread.so.0)
             #2  0x00005632def06370 qemu_coroutine_switch (qemu-system-x86_64)
             #3  0x00005632def05a05 qemu_coroutine_enter (qemu-system-x86_64)
             [. . .]
```

Debug VM crash: Root cause, resolution

- Turns out to be a bug (RH#1266936)
  in the guts of QEMU's disk mirroring code
- Fixed upstream:

```
$ git show e424aff

commit e424aff5f307227b1c2512bbb8ece891bb895cef
Author: Kevin Wolf <kwolf@redhat.com>
Date:   Thu Aug 13 10:41:50 2015 +0200

    mirror: Fix coroutine reentrance

    This fixes a regression introduced by commit dcfb3beb ("mirror: Do
    zero write on target if sectors not allocated"), which was reported
    to cause aborts with the message "Co-routine re-entered
    recursively".
    [. . .]
```

In a *successful case*, observe src ↔ dest flow

Observe commands (`drive-mirror` in this case) constructed by source libvirt (during live block migration) for dest:

```
$ grep "Send command" /var/log/libvirt/libvirtd| less
[. . .]
debug : qemuMonitorJSONCommandWithFd:290 : Send command

'"execute":"drive-mirror",
    "arguments":"device":"drive-virtio-disk0",
    "target":"nbd:devstack2:49153:exportname=drive-virtio-disk0",
    "speed":8796093022207,"sync":"top","mode":"existing",
    "id":"libvirt-11"'
[. . .]
```

Likewise, for **dest → src**

References

- "Guest operating system debugging" by David Hildebrand
  http://www.linux-kvm.org/images/9/92/01x10-David_Hildebrand-Guest-operating_system_debugging.pdf
- "Observability in KVM" by Stefan Hajnoczi
  https://archive.fosdem.org/2015/schedule/event/observability/
- Blog:
  http://kashyapc.com

"We don't much talk about debugging. Many of us spend much of our time doing it, but not talking or writing about this important activity. We should talk about it more. If there's time it would be good to swap war stories."

– 'Hunting the bug from hell',
Andrew Haley, FOSDEM 2016

Thanks for listening.