Lessons in running libvirt at scale

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What we do @Nutanix:

- Self healing, dynamically scaling, auto-balancing clusters.
- Proprietary orchestration layer to work with Libvirt, Qemu, KVM
- Designed for scale: must support 1000 VMs per box and 100s of concurrent ops.
- Near-immediate host failure detection based on libvirt keepalives.
- Automated VM failover in less than a minute.
How do I measure the efficacy of management layer?

- **Reliability**: Do all requests complete deterministically, without impacting vital functions?
- **Throughput**: How many ops can be driven in a given time window.
Bulk Power ONs:

- During bulk power ops, libvirtd would “lock up” for long intervals.
  - All client communication { RPC / Keepalives } ignored.
- Libvirt liveness tied to Host HA.
- False alarm: Perfectly healthy VMs force-evacuated.

Catastrophe!
Analysis:

• Keepalives are enqueued right from the main loop, *each time* `epoll()` *detects a message could be sent.*[1]

Current Threading model (QEMU driver)

- Main epoll() loop listens on all sockets:
  - Client socket(s) for RPCs/keepalives(Ka)
  - VM Monitor(s) for replies + events + hangup
- Client communication:
  - Optimized keepalive handling.
  - All RPCs punted to threadpool.
Current threading model (contd)

• VM monitoring:
  • ‘reply’ messages wake up requisite worker thread (no overhead for main thread)
  • Hangups and async QMP events: *handlers run in main thread.*
    • All events need the per-VM lock.
    • Event races with existing RPC → lock contention holds down the main loop!
Solution #1:

- Introduce a dedicated thread(pool) in QEMU driver to handle async events.
  - Main thread just “posts” the event to this queue.
  - Events are picked up as they arrive, by a dedicated event handler thread.
  - Can be expanded to an event-threadpool based implementation.
  - Lock contention point moves from main thread to event handler thread.
Solution #1 (contd):

Drawback:

• Event processing can suffer latency.
  • Add more threads, burn more resources?
  • Dedicated event worker may still contend with RPC(s)
Solution #2:

- Introduce a dedicated thread(pool) in QEMU driver to handle async events.
  - Main thread just “posts” the event to this queue.
  - Events are picked up by the worker thread(s) as they arrive, leaving the RPC threadpool free to pursue client RPCs.
  - Event threads only pick an event if the respective VM lock is available.
  - Additionally, each RPC worker also “drains” queued event(s) just before giving up the lock.
Limitation:

• Increases time accounted for in RPC context:
  – Other worker threads may time out?
  – Non-deterministic client behaviour: same RPC may take varying times depending on size of event queue.

• Prioritizing Shutdown/hangup handling:
  – “standard” event worker vs priority worker?

• Blurred lines: When RPCs and events merge.
Returning to assessment mode: Throughput validation
Re-evaluating the current threading model:

- Worker threads running RPCs for the same VM contend for the same lock
  - Only one of all makes forward progress.
  - Unfair delay for non-contending RPCs stuck behind in the queue.
Evaluating libvirt throughput:

Test setup:

• Libvirtd configured with min, max workers of \{2,10\}
• Multithreaded C program used to drive >3x RPCs:
  • for the same VM.
  • As expected, RPCs exhibit sequential execution.
  • Behavior with heterogenous VM RPCs
Results:

1. **Disk add RPC calls of same VM**
   - X-axis: VM IDs (1-47)
   - Y-axis: Count
   - Colors: Blue for Start time, Orange for Duration (ms)

2. **Disk add RPC for heterogeneous VMs**
   - X-axis: VM IDs (1-47)
   - Y-axis: Count
   - Colors: Blue for Start_offset, Orange for Duration (ms)

3. **Idealized Duration (ms)**
   - X-axis: VM IDs (1-48)
   - Y-axis: Duration (ms)
   - Colors: Blue
Analysis:

• Impact:
  • Adversely hits a multi-tenant environment

Proposed solution:
Can we carve out per-VM queues?

• Better throughput.
• Easier to bake in event infrastructure.
• Libvirt daemon interacts with client in perfect async fashion, using serial numbers to tie requests to responses.
• Client translates API calls into async messages, but sends them using `virNetClientSendWithReply()`
• An application linked to the client has to work with blocking calls 😞
• Might need changes to the current multi-threaded dispatch model.
Questions ??
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