Real–Time Cloud

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Motivation

- Communication systems
  - media streaming, switching
- Trading systems
  - stocks, goods
- Control systems
  - industry, healthcare, transportation

All in the Cloud
- Consolidation
- Hardware standardization
- Simpler maintenance
- Fast fail–over
Starting point

- we know RT–VMs with KVM are possible
- Preempt–RT host
- start them with hand–crafted scripts
- I/O (NICs) through device assignment
- a few hosts with a couple of VMs each

Does not scale!

- scripts are hard to maintain
  - manual resource assignment
  - error prone
- #NICs limits #VMs
- ...

→ We want that in the Cloud!
Target

- hundreds of VMs, both RT and best–effort
- many networks, again RT and non–RT
- local deployment needs to be possible
  - not somewhere far away
  - close to the process that should be controlled
  - it is all about CPU + networking latency
- flexible management, multiple users, accounting etc.

Cloud–grade, RT–capable VM management stack required
→ Openstack

- already broadly used for private clouds
- good integration with KVM
Basic Architecture
Preempt-RT as kernel
  - configuration and tuning according to https://rt.wiki.kernel.org
  - *rt thread throttling*
  - scheduling priorities: *kworker, ksoftirq, rcu*
  - interrupt affinities, power management

isolcpus
  - for vCPUs
  - hyperthread siblings disabled
  - further isolated with cpuset.cpu_exclusive

sufficient non-isolated CPUs
  - QEMU event threads
  - Linux base system, libvirtd, nova, neutron, ...
libvirt

- only executes higher layers commands, no policy
- foundation Openstack builds on
- for RT–vCPUs all required controls upstream ($\geq 1.2.13$)
  - CPU affinity setting for QEMU–threads (cgroups/cpuset)
  - scheduling parameter setting (policy, priority)
  - memory pinning (mlockall())

**Issues with CPU affinity setting**

- cgroup operation ordering problems
- causes disturbance and starvation
- mostly solved in prototype
- WiP together with upstream
Openstack

- several features already available
  - vCPU affinity setting
  - dedicated pCPUs
- RT–blueprint was available
  - introduced flavor property `hw:cpu_realtime`
    - memory pinning
    - vCPU scheduling policy and priority
  - implementation by Red Hat
  - similar implementation by Siemens

Deficits

- scheduling policy/priority were hard–coded
- second CPU mask required in nova, differentiate between RT and non–RT pCPUs for Openstack and other pCPUs

Corrected version merged

- about 2 weeks ago, implemented by Red Hat
PCI–Device assignment

- should be easy to do
  - libvirt and Openstack support it
- shortest possible way from guest to pNIC
- have to choose pNICs that the guest supports
- does not scale

Issues

- Openstack lets you choose devices by device- and vendor–IDs
- have several NICs with matching IDs on different networks?
- problem is known upstream

Solution

- QEMU–wrapper script to rewrite arguments based on a name passed down by Openstack
Architecture with I/O
• get host kernel out of the loop
  • Ethernet, IP-stack, *–tables
  • device drivers

• implement RT–Switch with DPDK
  • uio device driver for all common NICs
  • Ethernet–stack
  • Real–Time scheduling parameters
  • small packet bursts and polling for low latency

• short way from guest to software–switch
  • shared ring memory with switch
    vhost–user
  • signaling via socket, but mostly polling
DPDK–based network virtualization

- requires another set of RT–pCPUs
  - can now be modeled in Nova
  - isolated against cgroup problems with cpuset.cpu_exclusive
- polling on high priority has potential to starve others
  - helps you find tuning problems, affinity bugs in libvirt, …
- guests need virtio device driver

**Issues**

1. Openstack wants to fully manage networks (IPs, DNS, topology)
2. Openstack could not set memory backing store shared – might be solved upstream

**Solution**

1. implemented unmanaged network–class
2. QEMU–wrapper script to change arguments
Summary and Outlook

- Real-Time Cloud is feasible
- prototype available
- still requires good understanding of the stack
  - a lot was already there, still configuration is not trivial
  - found some issues on the way
    - partially fixed upstream
    - ongoing work
- open issues
  - how to properly protect your isolcpus from cgroups
  - cgroups2 are coming soon . . .
  - RT–network integration with neutron, Open vSwitch
  - PCI–device assignment based on bdf ?
  - share=on for virtio memory backing store ?
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