OpenStack performance optimization

NUMA, Large pages & CPU pinning

Daniel P. Berrangé <berrange@redhat.com>

About me

- Contributor to multiple virt projects
- Libvirt Developer / Architect 8+ years
- OpenStack contributor 2 years
- Nova Core Team Reviewer
- Focused on Nova libvirt + KVM integration

Talk Structure

- Introduction to OpenStack
- NUMA config
- Large page config
- CPU pinning
- I/O devices

What is OpenStack ?

- Public or private cloud
- Multiple projects (compute, network, block storage, image storage, messaging, ...)
- Self-service user API and dashboard

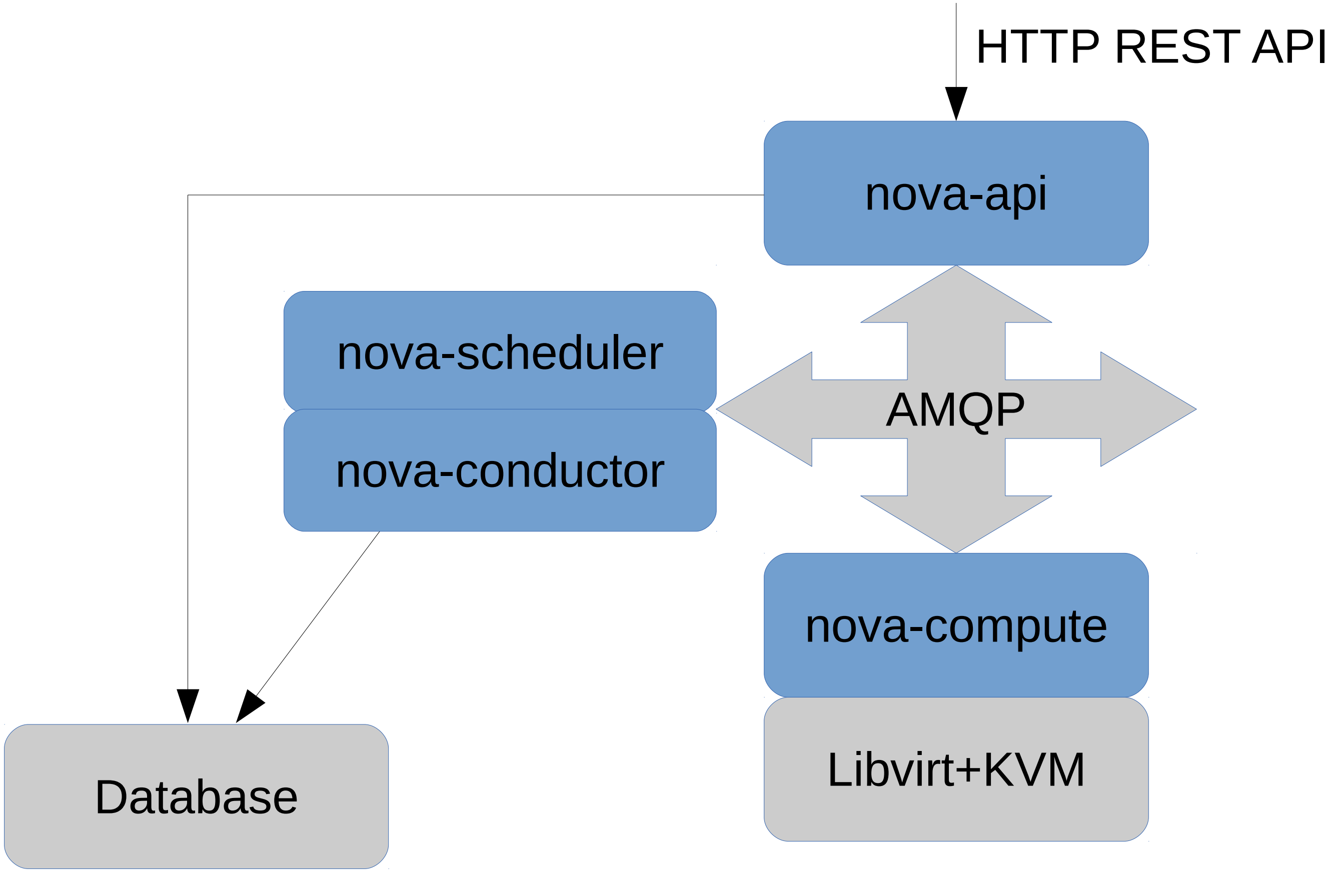
What is OpenStack Nova?

- Execution of compute workloads
- Virtualization agnostic
  - Libvirt (KVM, QEMU, Xen, LXC), XenAPI, Hyper-V, VMware ESX, Ironic (bare metal)
- Concepts
  - Flavours, instances, image storage, block storage, network ports

Nova approach

- Cloud infrastructure administrators
  - Flavours for VM instance policy
  - Minimal host provisioning / setup
  - No involvement in per-VM setup
- Guest instance users
  - Preferences via image metadata
  - No visibility of compute hosts / hardware

Nova architecture (simplified)



Current VM scheduling

- VM scheduler has multiple filters
- Filters applied to pick compute host
- Overcommit of RAM and CPUs
- VMs float across shared resources
- Assignment of I/O devices (PCI)

Scheduling goals

- Motivation: Network function virt (NFV)
  - Support “dedicated resource” guest
  - Support predictable / low latency
- Motivation: Maximise hardware utilization
  - Avoid inefficient memory access on NUMA

NUMA

- Factors for placement
  - Memory bandwidth & access latency
  - Cache efficiency
  - Locality of I/O devices
- Goal – small guests
  - Fit entirely within single host node
- Goal – large guests
  - Define virtual NUMA topology
  - Fit each guest node within single host node

libvirt host resource info

```
<capabilities>
  <host>
    <topology>
      <cells num='2'>
        <cell id='0'>
          <memory unit='KiB'>4047764</memory>
          <pages unit='KiB' size='4'>999141</pages>
          <pages unit='KiB' size='2048'>25</pages>
          <distances>
            <sibling id='0' value='10'/>
            <sibling id='1' value='20'/>
          </distances>
          <cpus num='4'>
            <cpu id='0' socket_id='0' core_id='0' siblings='0'/>
            <cpu id='1' socket_id='0' core_id='1' siblings='1'/>
            <cpu id='2' socket_id='0' core_id='2' siblings='2'/>
            <cpu id='3' socket_id='0' core_id='3' siblings='3'/>
          </cpus>
        </cell>
        <cell id='1'>....
```

Nova NUMA config

- Property for number of guest nodes
  - Default: 1 node
  - `hw:numa_nodes=2`
- Property to assign vCPUS/RAM to guest nodes
  - Assume symmetric by default
  - `hw:numa_cpu.0=0,1`
  - `hw:numa_cpu.1=2,3,4,5`
  - `hw:numa_mem.0=500`
  - `hw:numa_mem.1=1500`
- **NO** choice of host node assigment

NUMA impl

- Scheduling
  - Hosts NUMA topology recorded in DB
  - VM Instance placement recorded in DB
  - Filter checks host load to identify target
  - Schedular records NUMA topology in DB
  - Compute node starts VM with NUMA config

libvirt NUMA config

- VCPUs pinned to specific host NUMA nodes
- VCPUs float within host NUMA nodes
- Emulator threads to union of vCPU threads

```
<vcpu placement='static'>6</vcpu>
<cputune>
  <vcpupin vcpu="0" cpuset="0-1"/>
  <vcpupin vcpu="1" cpuset="0-1"/>
  <vcpupin vcpu="2" cpuset="4-7"/>
  <vcpupin vcpu="3" cpuset="4-7"/>
  <vcpupin vcpu="4" cpuset="4-7"/>
  <vcpupin vcpu="5" cpuset="4-7"/>
  <emulatorpin cpuset="0-1,4-7"/>
</cputune>
```

Libvirt NUMA config

- VCPUS + RAM regions assigned to guest NUMA nodes
- RAM in guest NUMA nodes pinned to host NUMA nodes

```
<memory>2048000</memory>
<numatune>
  <memory mode='strict' nodeset='0-1'/>
  <memnode cellid='0' mode='strict' nodeset='0'/>
  <memnode cellid='1' mode='strict' nodeset='1'/>
</numatune>
<cpu>
  <numa>
    <cell id='0' cpus='0,1' memory='512000'/>
    <cell id='1' cpus='1,2,3,4' memory='1536000'/>
  </numa>
</cpu>
```

Large pages

- Factors for usage
  - Availability of pages on hosts
  - Page size vs RAM size
  - Lack of over commit
- Goals
  - Dedicated RAM resource
  - Maximise TLB efficiency

Large page config

- Property for page size config
  - Default to small pages (for over commit)
  - `hw:mem_page_size=large|small|any|2MB|1GB`

Large page impl

- Scheduling
  - Cloud admin sets up host group
  - NUMA record augmented with large page info
  - Filter refines NUMA decision for page size

libvirt large page config

- Page size set for each guest NUMA node

```
<memoryBacking>
  <hugepages>
    <page size='2' unit='MiB' nodeset='0-1'/>
    <page size='1' unit='GiB' nodeset='2'/>
  </hugepages>
</memoryBacking>
```

CPU pinning

- Factors for usage
  - Efficiency of cache sharing
  - Contention for shared compute units
- Goals
  - Prefer hyperthread siblings for cache benefits
  - Avoid hyperthread siblings for workload independence
  - Dedicated CPU resource

CPU pinning config

- Property for dedicated resource
  - hw:cpu_policy=shared|dedicated
  - hw:cpu_threads_policy=avoid|separate|isolate|prefer

CPU pinning impl

- Scheduling
  - Cloud admin sets up host group
  - NUMA info augmented with CPU topology
  - Filter refines NUMA decision with topology

libvirt CPU pinning config

- Strict 1-to-1 pinning of vCPUs <-> pCPUs
- Emulator threads pinned to dedicated CPU

```
<cputune>
    <vcpupin vcpu="0" cpuset="0"/>
    <vcpupin vcpu="1" cpuset="1"/>
    <vcpupin vcpu="2" cpuset="4"/>
    <vcpupin vcpu="3" cpuset="5"/>
    <vcpupin vcpu="4" cpuset="6"/>
    <vcpupin vcpu="5" cpuset="7"/>
    <emulatorpin cpuset="2"/>
</cputune>
```

I/O devices

- Factors for usage
  - Locality of PCI device to NUMA node
  - Connectivity of PCI network interface
- Goals
  - Assign PCI device on local NUMA node

Libvirt device info

```
  <device>
  <name>pci_0000_80_16_7</name>
  <path>/sys/devices/pci0000:80/0000:80:16.7</path>
  <capability type='pci'>
    <domain>0</domain>
    <bus>128</bus>
    <slot>22</slot>
    <function>7</function>
    <product id='0x342c'>5520/5500/X58 Chipset QuickData Technology</product>
    <vendor id='0x8086'>Intel Corporation</vendor>
    <iommuGroup number='25'>
      <address domain='0x0000' bus='0x80' slot='0x16' function='0x0'/>
    </iommuGroup>
    <numa node='1'/>
    <pci-express/>
  </capability>
</device>
```

I/O device impl

- Scheduling
  - Hosts record locality of PCI devices in DB
  - Filter refines NUMA decision for device
- Guest config
  - TBD: Tell guest BIOS NUMA locality of PCI dev

http://libvirt.org - http://openstack.org

https://wiki.openstack.org/wiki/VirtDriverGuestCPUMemoryPlacement
http://people.redhat.com/berrange/kvm-forum-2014/