Hyper-converged OpenStack and Ceph

Deployment, Resource Isolation, and NFV Performance

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Agenda

● What is Hyper-converged Infrastructure (HCI)?
● HCI Automation and Deployment
● HCI Resource Isolation
● HCI and NFV
What is Hyper-converged Infrastructure (HCI)?

- A server which runs both compute and storage processes is a hyper-converged node.

- Today’s focus is on running OpenStack Nova Compute and Ceph Object Storage Daemon services on the same server.

- HCI is not a step backwards to local storage because it does not introduce a single point of failure.
Local Compute/Storage: Single Point of Failure

Each server only uses its local disks
Separate Storage/Compute: No SPoF

Servers store their data on separate storage cluster
HCI: Local Storage without SPoF

Each server adds to Compute and Storage resources without being a single point of failure

Two clusters, Compute and Storage, but both are using resources from the same servers
OpenStack/Ceph HCI Architecture
Why is there demand for HCI?

- HCI lets us deploy a *smaller footprint*
  - HCI: 6 nodes for HA (+ director)
    - 3 controllers/monitors + 3 computes/OSDs
  - Non-HCI: 9 nodes for HA (+ director)
    - 3 controllers/monitors + 3 computes + 3 OSDs

- Further standardization of hardware
  - Hardware vendors may offer a discount for more of the same type of server
  - Fewer server types simplify operations
  - May enable more efficient use of hardware resources
Small Footprint Benefits

- An implication of NFV is putting more power on the edge of the network
- Devices put on the edge of the network should be small and dense
- PoC requires a smaller initial investment
What are the tradeoffs?

- Deployment Complexity
  - Deploy OpenStack and Ceph on the same server

- Resource Management
  - Compute and Storage are resource intensive and may contend

The above are my focus today and are covered in more detail in a Reference Architecture.
HCI Reference Architecture

https://access.redhat.com/articles/2861641

All Heat environment files and scripts available at https://github.com/RHsyseng/hci
HCl Support

- HCl as described today is in Technology Preview* for Red Hat OpenStack Platform 10
- Full support for HCl is targeted for Red Hat OpenStack Platform 11

* [https://access.redhat.com/support/offerings/techpreview](https://access.redhat.com/support/offerings/techpreview)

It is possible to file a support exception for HCl in Red Hat OpenStack Platform 10
Deploying HCI with Director
Deploying Red Hat OpenStack Platform

- Red Hat OpenStack Platform should be deployed with director
  - By deploy I mean bare metal installation, scale up/down, and config management

- You cannot efficiently deploy an OpenStack cloud without automation

- Red Hat OpenStack Platform director is Red Hat’s solution to this problem
New environment file in v10

Red Hat OpenStack director 10 ships the following new environment file:

~/templates/environments/hyperconverged-ceph.yaml

Including the above in a deployment will result in Ceph OSDs and Nova Computes residing on the same node.
Code: hypercovnerged-ceph.yaml

resource_registry:
  OS::TripleO::Compute::Ports::StorageMgmtPort: ../network/ports/storage_mgmt.yaml

parameter_defaults:
  ComputeServices:
    - OS::TripleO::Services::CephOSD
    - OS::TripleO::Services::NovaCompute
    - OS::TripleO::Services::NovaLibvirt
    - OS::TripleO::Services::Timezone
    ...

The list above continues with all services found on a compute node
Explanation: hyperconvnerged-ceph.yaml

- Add the storage management port to the compute node
- Add the Ceph OSD service to the compute node role
- Keep the list of standard services for a compute node

The above are now possible because of composable services
Can I mix converged and non-converged?

- Yes, Red Hat OpenStack Platform director’s composability is powerful and flexible

- Custom roles may be combined and a mixed-nodes scenario is available from the reference architecture’s GitHub site: https://github.com/RHsyseng/hci

- Scenario covered:
  - Standard Nova Compute
  - Standard Ceph Storage with 10 OSDs
  - Converged Compute/Storage with 12 OSDs
  - Converged Compute/Storage with 6 OSDs

- This is not ideal for balancing load but Red Hat OpenStack director is not the limit
Applying Resource Isolation with Director
Why Isolate Resources?

- Contention between Ceph and OpenStack could result in degradation of either service
- A spike in one service could negatively affect the other
- Neither service is aware of the other’s presence on the same physical host
Tuning Nova Compute for HCI

- Limit Nova’s memory and CPU resources so Ceph can use what it needs of them

- Appropriately change the following defaults in /etc/nova/nova.conf

  reserved_host_memory_mb = 512
  cpu_allocation_ratio = 16.0
Nova Reserved Memory

- The amount of memory to reserve for the host
- Should normally be tuned to maximize the number of guests while protecting host
- For HCI, it should maximize guests while protecting host and Ceph
- How much to reserve?
  - Reserve 3G of RAM per OSD
  - Reserve 0.5G of RAM overhead per guest for the host

The above could be modified after testing but are a good starting point
Nova Reserved Memory for HCI

We can figure out the reserved memory with a formula

\[
left_{\text{over}}_{\text{mem}} = \text{mem} - (\text{GB}_{\text{per}}\_\text{OSD} \times \text{osds})
\]

\[
\text{number}_{\text{of}}\_\text{guests} = \text{int}\left(\frac{left_{\text{over}}_{\text{mem}}}{(\text{average}_{\text{guest}}\_\text{size} + \text{GB}_{\text{overhead}}\_\text{per}\_\text{guest})}\right)
\]

\[
\text{nova}_{\text{reserved}}\_\text{mem}_{\text{MB}} = \text{MB}_{\text{per}}\_\text{GB} \times \left( (\text{GB}_{\text{per}}\_\text{OSD} \times \text{osds}) + (\text{number}_{\text{of}}\_\text{guests} \times \text{GB}_{\text{overhead}}\_\text{per}\_\text{guest}) \right)
\]
Nova CPU Allocation Ratio

- Used by Nova scheduler when choosing compute nodes for guests

- If the ratio has default of 16:1 and a node has 56 cores on a node, then the scheduler may schedule enough guests to consume 896 vCPUs before it considers the node full

- Nova scheduler does not know about Ceph so modify it to not allocate Ceph’s CPUs
Nova CPU Allocation Ratio for HCI

We can figure out the the CPU allocation ratio with a formula

```
cores_per_OSD = 1.0
average_guest_util = 0.1 # 10%
nonceph_cores = cores - (cores_per_OSD * osds)
guest_vCPUs = nonceph_cores / average_guest_util
cpu_allocation_ratio = guest_vCPUs / cores
```

- The above is for rotational hard drives.
- Increase the core per OSD if you use an NVMe SSD to keep up with it
Nova Memory and CPU Calculator

- Takes the following inputs
  1. Total host RAM in GB
  2. Total host cores
  3. Ceph OSDs per server
  4. Average guest size in GB
  5. Average guest CPU utilization (0.0 to 1.0)

- Returns `nova.conf reserved_host_memory_mband cpu_allocation_ratio`
Nova Memory and CPU Calculator: Busy VMs

$ ./nova_mem_cpu_calc.py 256 56 10 2 1.0
Inputs:
- Total host RAM in GB: 256
- Total host cores: 56
- Ceph OSDs per host: 10
- Average guest memory size in GB: 2
- Average guest CPU utilization: 100%

Results:
- number of guests allowed based on memory = 90
- number of guest vCPUs allowed = 46
- nova.conf reserved_host_memory = 75000 MB
- nova.conf cpu_allocation_ratio = 0.821429

Compare "guest vCPUs allowed" to "guests allowed based on memory"
$
Nova Memory and CPU Calculator: Many VMs

$ ./nova_mem_cpu_calc.py 256 56 10 2 0.1

Inputs:
- Total host RAM in GB: 256
- Total host cores: 56
- Ceph OSDs per host: 10
- Average guest memory size in GB: 2
- Average guest CPU utilization: 10%

Results:
- number of guests allowed based on memory = 90
- number of guest vCPUs allowed = 460
- nova.conf reserved_host_memory = 75000 MB
- nova.conf cpu_allocation_ratio = 8.214286

Compare "guest vCPUs allowed" to "guests allowed based on memory"

$
Pass Nova Tunings to Director

The following could be added to a Heat environment template and passed to a deployment

parameter_defaults:
  ExtraConfig:
    nova::compute::reserved_host_memory: 75000
    nova::cpu_allocation_ratio: 8.2
Nova Memory and CPU Calculator Download

Tuning Ceph OSDs for HCI

- We limited Nova’s memory and CPU resources so Ceph and the OS can use them
- We now want to use `numactl` to pin the Ceph process to a NUMA node
- The socket to which Ceph should be pinned is the one that has the network IRQ
  - If a workload is network intensive and not storage intensive, this may not true.
NUMA pinning Ceph

- RHCS2’s systemd unit file has a \$cmd variable for the osd binary to start the cluster

- The unit file can be modified to redefine \$cmd with the numactl command like so:

  Before:
  
  $cmd --cluster $cluster -f

  After:
  
  numactl -N $numasocket --preferred=$numasocket $cmd --cluster $cluster -f
Automating the NUMA Change

A Red Hat OpenStack director [post-deploy Heat environment file](#) modifies the systemd unit file

**ExtraConfig:**

```yaml
type: OS::Heat::SoftwareConfig
properties:
  group: script
  inputs:
    - name: OSD_NUMA_INTERFACE
      config: {get_file: numa-systemd-osd.sh}
```

**ExtraDeployments:**

```yaml
type: OS::Heat::SoftwareDeployments
properties:
  servers: {get_param: servers}
  config: {get_resource: ExtraConfig}
  input_values:
    OSD_NUMA_INTERFACE: 'em2'
  actions: ['CREATE']
```
[stack@c10-h01-r730xd ~]$ lstopo-no-graphics
Machine (128GB total)
NUMANode L#0 (P#0 64GB)
...
HostBridge L#0
  PCIBridge
    PCI 1000:005d
    Block(Disk) L#0 "sda"
    Block(Disk) L#1 "sdb"
...
PCIBridge
  PCI 8086:1572
    Net L#17 "em1"
    PCI 8086:1572
    Net L#18 "em2"
...
...
NUMANode L#1 (P#1 64GB)
...
HostBridge L#11
  PCIBridge
    PCI 8086:1572
    Net L#23 "p4p1"
    PCI 8086:1572
    Net L#24 "p4p2"
[stack@c10-h01-r730xd ~]$
Heat Environment Files

Templates used to deploy HCI/DPDK in Scale Lab:

https://github.com/redhat-performance/openstack-templates

Navigate to RDU-Scale/Newton/R730xdHciDpdk
HCI for NFV
Typical VNF deployment today

Depending on the VNF, it will be connected to one or more fabric network, typically:

- One fabric for control plane
- One fabric for user plane (end user data: mobile traffic, web, ...)

RHOSP director deployment schema
SR-IOV Host/VNFs guests resources partitioning

Typical 18 cores per node dual socket compute node (E5-2599 v3)

This looks like RT but is not RT, just partitioning

SR-IOV interfaces bonding handled by the VNF

All host IRQs routed on host cores

All VNFx cores dedicated to VNFx

- Isolation from others VNFs
- Isolation from the host
- Isolation from Ceph Mon
- 21 Mpps/core with zero frame loss, 12 hours run (I/O bound due to Niantic PCIe x4 switch): equal to bare-metal performances
- The number above show that virtualization/SR-IOV cost is null, and that the VNF is not preempted/interrupted.
OVS-DPDK NFV deployment

VNF0
- eth0
- DPDK
- kernel

VNF1
- eth0
- DPDK
- kernel

DHCP+PXE

compute node

Base (VNFs mgt)
(provided network)

regular NICs
bonded

DPDK NICs
bonded

OVS-DPDK bridges

fabric 0
(provider network)

fabric 1
(provider network)
RHOSP10 OVS-DPDK
Host/VNFs guests resources partitioning

Typical 18 cores per node dual socket compute node (E5-2599 v3)

Same as SR-IOV, except of a 4th partition for OVS-DPDK

- CPUs list dedicated to OVS-DPDK
- Huge Pages reserved for OVS-DPDK

Not mixing VNF management traffic and Telco Traffic requires additional NICs as NICs cannot be shared between OVS-DPDK and the host:

- 3.5 Mpps/core for PVP configuration (OVS-DPDK 2.5) with zero packet loss
Host/VNFs guests resources partitioning

How do we partition VNF resources?

- Tuned cpu-partitioning reserves CPUs for exclusive use
  - Assign “isolated_cores” in /etc/tuned/cpu-partitioning-variables.conf

- By default all user processes and most kernel threads are excluded from using the CPUs configured with this profile

- Applications must move threads to these CPUs in order to use them:
  - Openvswitch:
    - Thread assignment: ovs-vsctl set Open_vSwitch . other_config:pmd-cpu-mask=
  - Nova:
    - Configuration: vcpu_pin_set in /etc/nova/nova.conf
    - Usage: hw:cpu_policy=dedicated for flavor
Performance Testing HCI with NFV

NFV performance is highest priority

- The network service of the VNF should never degrade
- VNFs should have adequate disk IO performance, even when at 100% network service utilization

A test is conducted, having three phases:

- Phase 1 has only VNF network activity in all VMs
- Phase 2 has VNF and Disk activity in all VMs
- Phase 3 returns to only network activity in the VMs

During phase 2 there should be no degrade in VNF network performance
Performance Testing HCI with NFV

How do we test VNF performance?

- We have opted for a test which uses several VNFs across several compute nodes (1 per compute node).

- The VNFs are performing L3 routing (bidirectional) between two Openstack provider networks, using a DPDK application, VPP[1].

- VNFs are “chained” to form a series of routes that network traffic will traverse, and therefore, a degrade in throughput from any VNF will affect overall throughput.

- The traffic generator transmits and receives on two interfaces (interface-1 Tx to interface-2, interface-2 Tx to interface-1).

- The traffic generator transmits 64-byte frames at sustained rate equal to maximum capability of the VNFs, in this case, 5.5 million packets per second per interface, for a total of 11 Mpps.

Performance Testing HCI with NFV

Configuration Details for NFV: compute node

- Ceph on node0, NFV on node1
- Openvswitch with DPDK:
  - Enable 2-queue per device: options:n_rxq=2
  - Use 8 PMD threads on dedicated CPUs
- VM:
  - Dedicated 6 cores / 12 CPU-threads
  - Enable multi-queue for virtio-net: hw_vif_multiqueue_enabled=true
Performance Testing HCI with NFV

Configuration Details for NFV: VM

- Tuned cpu-partitioning used again, this time inside VM:
  - isolate last 4 cores for VPP
- VPP using 1 CPU-thread per core (from last 4 cores) for PMD threads
- First 2 cores used for OS, disk IO, and non-polling threads for VPP
Performance Testing HCI with NFV: Results

Performance Testing HCI with NFV: Results

Summary

- When disk I/O activity started, VNFs experienced a ~4% degrade in throughput momentarily, then experienced ~2% variation in throughput, but on average maintained 99% of the throughput without disk I/O

- Each VM was reading an average ~200MB/sec, lower I/O should reflect much lower impact to VNF

- Investigations into interactions between disk I/O and VNF effects underway @RH

- Our goal is to completely eliminate the disk I/O effects on the VNF performance
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ENABLE AGILITY WITH INFRASTRUCTURE AS CODE

Stephane Lefrere, Cloud Infrastructure Practice Lead
Julio Villarreal Pelegrino, Principal Infrastructure Architect

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