Do more Apache Cassandra distributed database work with AMD EPYC 7601 processors

Versus servers based on Intel Xeon processors E5-2699 v4

Businesses that provide private cloud services with demanding NoSQL applications—from social media to ecommerce to media streaming—can run Apache Cassandra® distributed databases in their clouds to take advantage of its distributed, highly reliable architecture. Private clouds can provide this NoSQL service while also bolstering control and security, but enterprises need to know what they're getting from their hardware before they invest.

The new AMD EPYC™ 7601 processor allows for more cores per socket and higher memory capacity per server compared to the previous generation Intel® Xeon® processors we tested,[1] which could improve the performance of certain workloads in a private cloud infrastructure. In our datacenter, we compared the distributed database performance of two six-node clusters: one built on AMD EPYC 7601 processors, and another based on Intel Xeon processors E5-2699 v4.

Compared to the Intel solution, the AMD solution handled significantly more Cassandra write operations per second on the same number of servers, which could allow for faster updates and shorter data load times.

up to
50%
more
operations per second

AMD EPYC processors helped boost Cassandra performance

Moving your company's data and applications to a private cloud can provide resiliency and flexibility for your most important Cassandra databases. Apache Cassandra databases are replicated across multiple servers or datacenters for fault tolerance, so no single point of failure exists. Cassandra databases are also highly scalable and elastic, so businesses that can see rapid growth often use these databases to minimize downtime for mission-critical data.[2]

The AMD EPYC 7601 series of processors are based on a new chip and system architecture, which offers resources such as 32 cores that could prove useful to certain distributed database workloads.

About the AMD EPYC 7601 processor

The AMD EPYC processor has up to up to 32 cores and can run with 2 TB of DDR4 memory spread across eight channels.

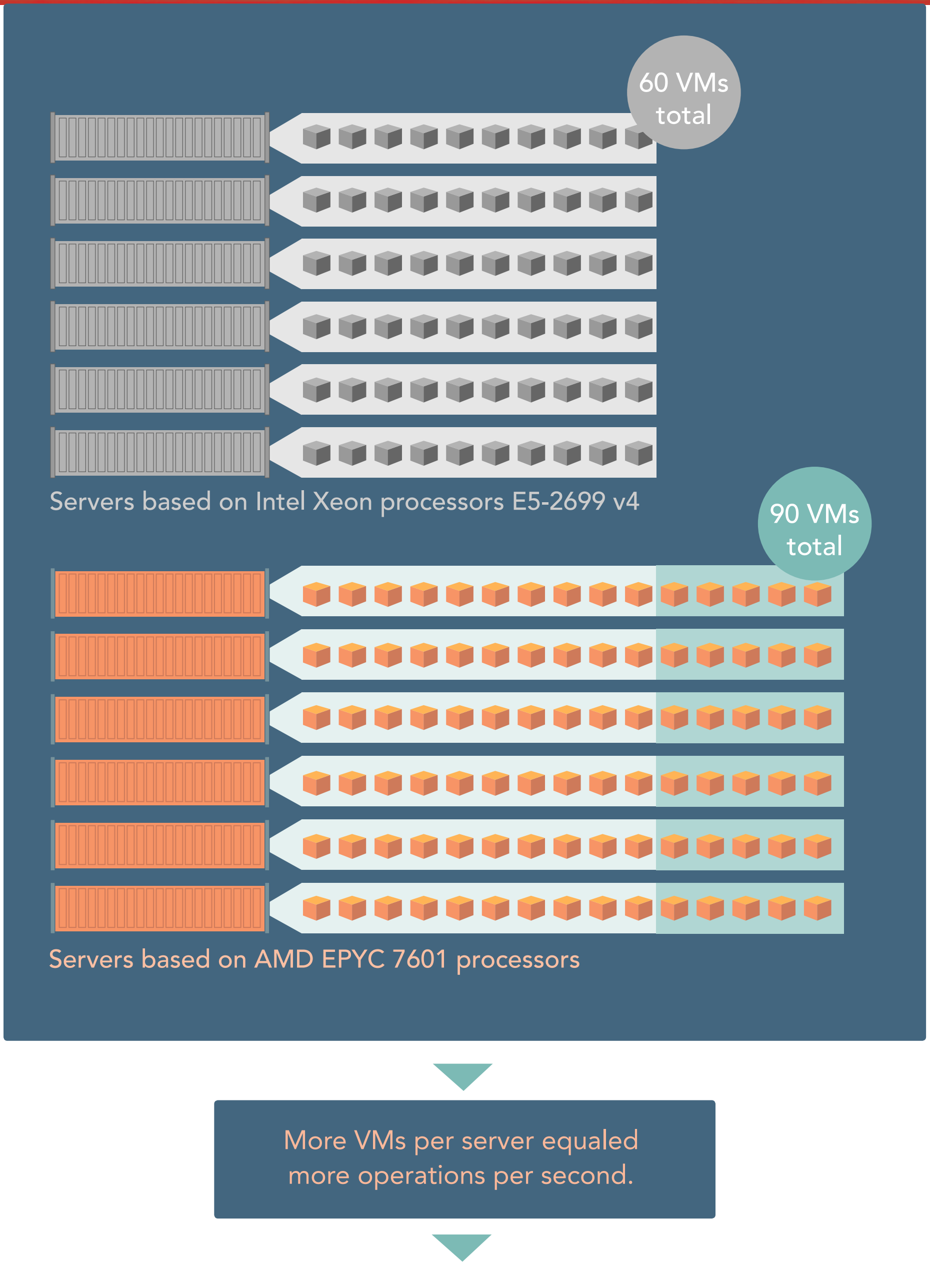
AMD EPYC processors provide performance and power management features that let you balance performance with power usage at boot time, depending on the needs of your workload and your datacenter.

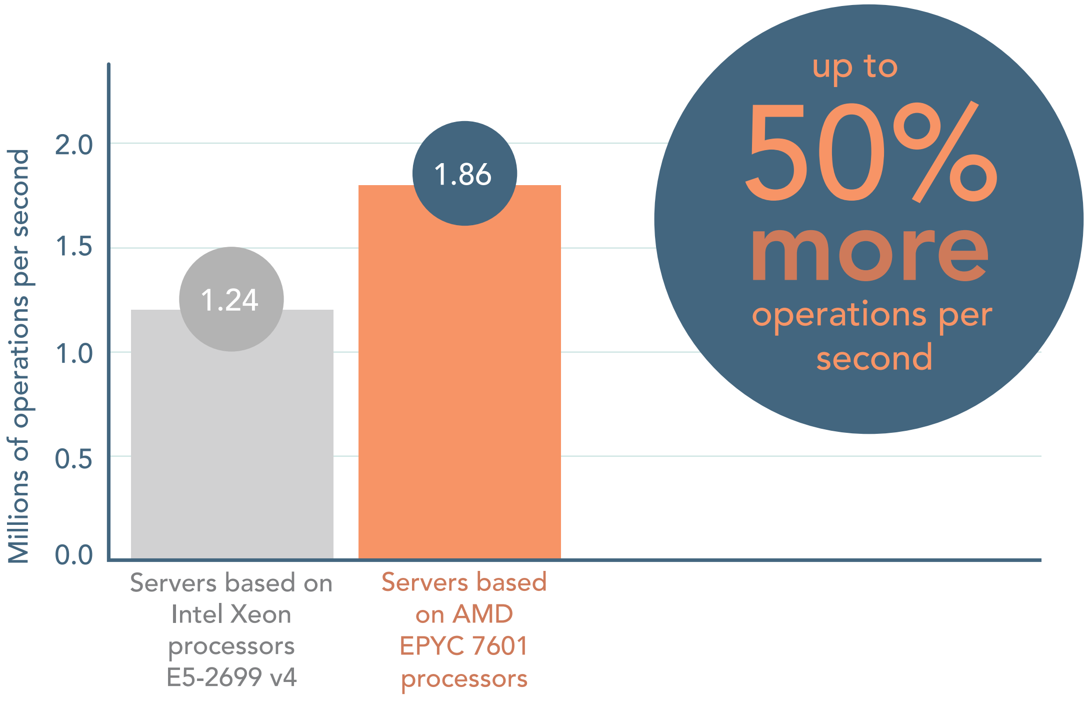
The AMD EPYC line includes security features that we did not test in our datacenter, including AMD Secure Root-of-Trust technology, Secure Run Technology, and Secure Move Technology. AMD also states that the EPYC family supports encrypted memory features, which include three different modes: transparent mode, Secure Encrypted Memory mode, and Secure Encrypted Virtualization mode, all of which give you the opportunity to choose the security features that are right for you.

To learn more about the AMD EPYC 7601 processor and the complete AMD EPYC family, visit www.amd.com/epyc.

Comparing distributed database performance

Using the cassandra-stress tool, which assesses the load a server can handle when running a NoSQL database workload, we compared a cluster powered by the new AMD EPYC processor with Mellanox ConnectX4-LX NICs and Mellanox SN2700 Open Ethernet swtiches to another six-node cluster based on previous generation Intel Xeon processors E5-2699 v4. The AMD EPYC 7601 processor-based cluster handled 50 percent more operations per second when running a cassandra-stress workload, which means it could serve a significant number more users and potentially cut hardware investment costs for a private cloud implementation. The operations per second numbers we report from the cassandra-stress tool are 100% write operations. Increased write operations per second could mean quicker data updates and inserts.


60 VMs total
Servers based on Intel Xeon processors E5-2699 v4
90 VMs total
Servers based on AMD EPYC 7601 processors
More VMs per server equaled more operations per second.



AMD EPYC 7601 processors delivered more for Apache Cassandra distributed databases in our tests

Private clouds require an investment in hardware that can often be costly—a cost that grows along with the size of distributed database workloads a business deploys. The new AMD EPYC processor architecture can help ease that burden by increasing the available number of cores per socket, which could let businesses get more distributed database work done per server compared to a previous generation Intel Xeon E5-2699 v4 processor architecture. In our tests, we found that a cluster based on 32-core AMD EPYC 7601 processors increased the operations per second an Apache Cassandra distributed database could process by 50 percent over a same-sized cluster based on 22-core Intel Xeon processors E5-2699 v4.[3] This means that businesses seeking to run these reliable, elastic databases on a private cloud setup could do so on an AMD EPYC 7601 processor-based server platform and experience faster updates and shorter data load times.

1 Processor specifications, accessed December 19, 2017, http://www.amd.com/en/products/epyc-7000-series-2-socket-models and https://ark.intel.com/products/91317/Intel-Xeon-Processor-E5-2699-v4-55M-Cache-2_20-GHz.

2 To learn more, see "What is Cassandra?," accessed October 18, 2017, http://cassandra.apache.org.

3 Outputs will vary based on your specific application and configuration.

On October 23, 2017, we finalized the hardware and software configurations we tested. Updates for current and recently released hardware and software appear often, so unavoidably these configurations may not represent the latest versions available when this report appears. For older systems, we chose configurations representative of typical purchases of those systems. We concluded hands-on testing on October 30, 2017.

Appendix A: System configuration information

Server configuration information	**AMD Speedway**	**Lenovo System x3650 M5**
BIOS name and version	AMD RSW1002E	LENOVO TCE130L-2.41
Non-default BIOS settings	SR-IOV Support Enabled PCIe ARI Support Enabled	N/A
Operating system name and version/ build number	Ubuntu Server 16.04.3 LTS kernel 4.13.9-041309-generic x86_64	Ubuntu Server 16.04.3 LTS kernel 4.13.9-041309-generic x86_64
Date of last OS updates/patches applied	10/23/2017	10/23/2017
Power management policy	High Performance	High Performance
Processor		
Number of processors	2	2
Vendor and model	AMD EPYC 7601	Intel® Xeon® CPU E5-2699 v4
Core count (per processor)	32	22
Core frequency (GHz)	2.20	2.20
Stepping	1	1
Memory module(s)		
Total memory in system (GB)	512	384
Number of memory modules	16	12
Vendor and model	Micron 36ASF4G72PZ-2G6D1	Micron 36ASF4G72PZ-2G6D1
Size (GB)	32	32
Type	PC4-2666	PC4-2666
Speed (MHz)	2667	2666
Speed running in the server (MHz)	2400	2133
Storage controller 1		
Vendor and model	AMD FCH SATA Controller (x3)	LSI Logic MegaRAID SAS-3 3108
Driver version	ahci 3.0	megaraid_sas 07.701.17.00-rc1
Storage controller 2		
Vendor and model	N/A	LSI Logic SAS3224 PCIe Fusion-MPT SAS-3
Driver version	N/A	mpt3sas 15.100.00.00

Server configuration information	AMD Speedway	Lenovo System x3650 M5
Local storage		
Number of drives	17	11
Drive vendor and model	Samsung PM863a	Samsung PM863a
Drive size (GB)	960	960
Drive information (speed, interface, type)	6Gb, SATA, SSD	6Gb, SATA, SSD
Network adapter		
Vendor and model	Mellanox ConnectX-4 Lx	Mellanox ConnectX-4 Lx
Number and type of ports	2 x 25GbE	2 x 25GbE
Driver version	mlx5_core 5.0-0	mlx5_core 5.0-0
Cooling fans		
Vendor and model	Delta Electronics GFC0812DS	AVC DBTC0638B2U
Number of cooling fans	4	6
Power Supplies		
Vendor and model	LITEON PS-2112-5Q	Delta Electronics DPS-900DB A
Number of power supplies	2	2
Wattage of each (W)	1200	900

Appendix B: How we tested

We performed the following steps to install and configure the testbed for Ubuntu Server 16.04.3 KVM and Apache Cassandra. Your environment may differ slightly, so keep that in mind when setting IPs and naming hosts.

Installing the operating system

1. Insert the Ubuntu Server 16.04.3 LTS installation media, and power on the system.
2. Select Boot and Install with the HWE kernel, and press Enter.
3. Select your language, location, and keyboard layout.
4. Select Configure network manually, and press Enter.
5. Type your IP address, netmask, gateway, nameserver addresses, hostname, domain name, and press Enter at each screen.
6. Type `ubuntu` as the full name and username of your new user.
7. Choose a password for your new user.
8. When prompted to Encrypt your home directory, select No, and press Enter.
9. Select or confirm your timezone.
10. Select the partitioning method Guided – use entire disk, and press Enter.
11. Select the disk to partition, and press Enter.
12. Review the partitioning layout, select Yes to write the changes to disk, and press Enter. Installation will now begin.
13. During installation, if prompted for HTTP proxy information, leave the field blank for none, and press Enter.
14. Select No automatic updates, and press Enter.
15. At the Software selection screen, use the cursor keys and press the spacebar to select or unselect software to install. Choose the Standard system utilities, Virtual Machine host, and OpenSSH server software collections to install, and press Enter.
16. When installation is complete, press Enter to reboot.
17. Repeat steps 1–16 for the remaining servers in the test bed.

Configuring the operating system

1. Log into the Ubuntu console.
2. Update the system by typing the following commands:
```
sudo apt update
sudo apt -y upgrade
```
3. Reboot the system.
4. Install the prerequisites for Ambari and HDP by typing the following command:
```
sudo apt install -y numactl sysstat curl wget vim bc cpufrequtils iftop ntp
```
5. Enable NTP by typing the following commands:
```
sed -i '/^server [^ ]* iburst/d' /etc/ntp.conf
echo "server [your NTP server IP address] iburst" >> /etc/ntp.conf
systemctl enable ntpd
systemctl start ntpd
```
6. Reboot the system.
7. Download the latest version of the Mellanox OFED from the Mellanox website.
8. Install the Mellanox OFED by typing the following commands:
```
tar -xf MLNX_OFED_LINUX-4.1-1.0.2.0-ubuntu16.04-x86_64.tgz
cd MLNX_OFED_LINUX-4.1-1.0.2.0-ubuntu16.04-x86_64
./mlnxofedinstall --hypervisor --force-fw-update --enable-mlnx_tune –force
```
9. Reboot the system.
10. Configure SR-IOV in the Mellanox card firmware:
```
mlxconfig -d /dev/mst/mt4117_pciconf0 set SRIOV_EN=1 NUM_OF_VFS=10
```
11. Clear the SSH settings by typing the following commands:
```
rm -rf ~/.ssh
mkdir -p ~/.ssh
chmod 700 ~/.ssh
cd ~/.ssh
```
12. Create an SSH private key for all hosts by typing the following commands:
```
ssh-keygen -t rsa -q
cp id_rsa.pub authorized_keys
```

```
echo "StrictHostKeyChecking=no" > config
echo > known_hosts
cp -rp ~/.ssh ~/clean_ssh
cd ~/clean_ssh
```

13. Copy keys to the root user by typing the following commands:

```
sudo su

rm -rf /root/.ssh
cp -rp ../clean_ssh /root/.ssh
chown -R root:root /root/.ssh
exit
```

14. Copy the key to the other hosts by typing the following commands (replacing ${remotehost} with the host you want to copy to):

```
scp -rp ~/clean_ssh ${remotehost}:~/.ssh
ssh ${remotehost}
cd ~
sudo su

rm -rf /root/.ssh
cp -rp .ssh /root/.ssh
chown -R root:root /root/.ssh
exit
exit
```

15. Create a hosts file containing a FQDN, nickname, and IP address of every host you plan to use in the cluster. Copy the file out to all of your hosts.
16. On the AMD servers, run `vim /etc/default/grub` and modify the GRUB_CMDLINE_LINUX setting by adding `iommu=pt` to the end of the line.
17. Configure the servers to run in performance mode by typing the following commands:

```
sudo systemctl disable ondemand
echo "GOVERNOR=\"performance\"" > /etc/default/cpufrequtils
```

Configuring KVM on a host machine

1. Configure the host networking for SR-IOV by adding the following lines to the beginning of the /etc/rc.local file:

```
echo 7 > /sys/class/net/enp49s0f0/device/sriov_numvfs
echo 8 > /sys/class/net/enp49s0f1/device/sriov_numvfs
virsh net-start net1
virsh net-start net2
```

2. Create the following template files for both net1.xml and net2.xml:

```
==> net1.xml <==
<network>
  <name>net1</name>
  <forward mode='hostdev' managed='yes'>
    <pf dev='enp49s0f0'/>
  </forward>
</network>

==> net2.xml <==
<network>
  <name>net2</name>
  <forward mode='hostdev' managed='yes'>
    <pf dev='enp49s0f1'/>
  </forward>
</network>
```

3. Imprort the virtual network configuration using the following commands:

```
virsh net-define net1.xml
virsh net-define net2.xml
```

4. Create symbolic links to each SSD device using a unique identifier (such as WWN) to keep consistent pairing between block storage and VM virtual machine. Keep in mind NUMA locality when picking the SSD and in later steps, the VM CPU binding. Example command:

```
ln -s /dev/disk/by-id/wwn-0x5002538c40522a8e /vmdisk/amdc1n1
```

Building a Cassandra VM

1. Create KVM virtual machine using the XML libvirt template (see Appendix C: vm_template.xml).
2. Attach the Ubuntu Server 16.04.3 LTS installation ISO image to the virtual machine, and power on the VM.
3. Select Boot and Install with the HWE kernel, and press Enter.
4. Select your language, location, and keyboard layout.
5. Select Configure network manually, and press Enter.
6. Type your IP address, netmask, gateway, nameserver addresses, hostname, domain name, and press Enter at each screen.
7. Type `ubuntu` as the full name and username of your new user.
8. Choose a password for your new user.
9. When prompted to "Encrypt your home directory, select No, and press Enter.
10. Select or confirm your timezone.
11. Select the partitioning method Guided – use entire disk, and press Enter.
12. Select the disk to partition, and press Enter.
13. Review the partitioning layout, remove the swap partition, select Yes to write the changes to disk, and press Enter. Installation will now begin.
14. During installation, if prompted for HTTP proxy information, leave the field blank for none, and press Enter.
15. Select No automatic updates, and press Enter.
16. At the Software selection screen, use the cursor keys and press spacebar to select or unselect software to install. Choose the Standard system utilities and OpenSSH server software collections to install, and press Enter.
17. When installation is complete, press Enter.

Configuring the Cassandra VM template

1. Log into the Ubuntu console.
2. Update the system by typing the following commands:
```
sudo apt update
sudo apt -y upgrade
```
3. Reboot the VM.
4. Install the prerequisites for Cassandra and other system utilities by typing the following command:
```
sudo apt install -y numactl sysstat curl wget vim bc iftop ntp qemu-guest-tools
```
5. Enable NTP by typing the following commands:
```
sed -i '/^server [^ ]* iburst/d' /etc/ntp.conf
echo "server [Cassandra driver IP address] iburst" >> /etc/ntp.conf
systemctl enable ntpd
systemctl start ntpd
```
6. Reboot the VM.
7. Clear the SSH settings by typing the following commands:
```
rm -rf ~/.ssh
mkdir -p ~/.ssh
chmod 700 ~/.ssh
cd ~/.ssh
```
8. Copy the SSH keys created on the KVM host to the Cassandra VM by typing the following commands on the KVM host (replacing ${remoteVM} with the VM IP address):
```
scp -rp ~/clean_ssh ${remoteVM}:~/.ssh
ssh ${remoteVM}
cd ~
sudo su

rm -rf /root/.ssh
cp -rp .ssh /root/.ssh
chown -R root:root /root/.ssh
exit
exit
```
9. Copy the SSH keys created on the KVM host to the Cassandra VM by typing the following commands on the KVM host (replacing ${remoteVM} with the VM IP address):
```
scp -rp ~/clean_ssh ${remoteVM}:~/.ssh
```

Installing Cassandra on the VM templates

1. Log into the Ubuntu console.
2. Install Java 8 using the following commands:

```
sudo add-apt-repository ppa:webupd8team/java
sudo apt update
sudo apt -y install oracle-java8-installer
```

3. Install the Cassandra packages by typing the following commands:

```
echo "deb http://www.apache.org/dist/cassandra/debian 311x main" | sudo tee -a /etc/apt/sources.
list.d/cassandra.sources.list
curl https://www.apache.org/dist/cassandra/KEYS | sudo apt-key add -
sudo apt update
sudo apt install cassandra cassandra-tools
sudo systemctl stop cassandra
sudo systemctl disable cassandra
sudo rm -rf /var/lib/cassandra/*
```

4. Reboot the VM.

Configuring Cassandra on the VM template

1. Log in as root to the Ubuntu console on the VM template.
2. Edit the /etc/cassandra/cassandra.yaml file with the following property changes:

```
seeds: "cass1,cass2,cass3,cass4,cass5,cass6"
memtable_allocation_type: offheap_objects
# listen_address: localhost
listen_interface: ens3
endpoint_snitch: GossipingPropertyFileSnitch
```

3. Replace the /etc/rc.local file with the contents of Appendix C.
4. Copy the hosts_template file from Appendix C to the /etc folder.
5. Copy the interfaces_template file from Appendix C to the /etc/network folder.
6. Trim all unused space for VM image compaction:

```
sudo fstrim -v /
```

7. Power off the VM.

Cloning the VM template

1. Log in as root to the Ubuntu console on the KVM host where the VM template was created.
2. Create a qcow2 format VM disk image for copying to other KVM hosts and target drives:

```
qemu-img convert -O qcow2 /var/lib/libvirt/images/vm_template.img vm_template.qcow2
```

3. Copy the qcow2 image to all KVM hosts.
4. Extract the qcow2 VM disk image onto each SSD being used by the VMs. For example:

```
qemu-img convert -O raw vm_template.qcow2 /vmdisk/amdc1n1
```

5. Make copies of the vm_template.xml for each VM and edit the name, disk device, and virtual NIC mac address.
6. Import each VM XML file definition into libvirt on the appropriate host. For example:

```
virsh define amdc1n1.xml
```

7. Start each VM, one at a time, with at least a 5-second pause between each one so there is time for it to restart and initialize the hostname, IP address, and cassandra.yaml config file.
8. After all VMs have been started, verify the cluster status is up using the following command on one of the six VMs in the cluster:

```
nodetool status
```

9. Verify the output is similar to the following:

```
Datacenter: dc1
===============
Status=Up/Down
|/ State=Normal/Leaving/Joining/Moving
--  Address    Load        Tokens      Owns (effective)  Host ID                               Rack
UN  10.12.1.1  253.65 KiB  256         32.9%             1938fb50-d564-4ba4-89a5-f098808bfee2  rack1
UN  10.12.1.2  306.91 KiB  256         33.1%             a49993c8-e953-4578-84b1-706d68bcdb5f  rack1
UN  10.12.1.3  290.67 KiB  256         35.4%             40ab41c3-7f3a-46c9-860b-f91a75a49c91  rack1
UN  10.12.1.4  273.85 KiB  256         33.2%             68bba61c-2cd7-4c89-be1f-bef4400f63e5  rack1
UN  10.12.1.5  287.11 KiB  256         33.0%             fa93af12-69b2-452d-8c82-4c114507bc0c  rack1
UN  10.12.1.6  256.47 KiB  256         32.4%             9f002909-c973-43b4-84c6-9a4b68bbaab9  rack1
```

Setting up the cassandra-stress client driver system

1. Install Ubuntu using the same steps as the KVM host.
2. Log in as root to the Ubuntu console on the client driver system.
3. Update the system by typing the following commands:
```
sudo apt update
sudo apt -y upgrade
```
4. Reboot the client driver.
5. Install the prerequisites for Apache Cassandra and the cassandra-stress tool by typing the following command:
```
sudo apt install -y numactl sysstat curl wget vim bc cpufrequtils iftop ntp
```
6. Enable the client to act as an NTP server by typing the following commands:
```
echo “server 127.127.1.0” >> /etc/ntp.conf
echo “fudge 127.127.1.0 stratum 10” >> /etc/ntp.conf
systemctl enable ntpd
systemctl start ntpd
```
7. Download the latest version of the Mellanox OFED from the Mellanox website.
8. Install the Mellanox OFED by typing the following commands:
```
tar -xf MLNX_OFED_LINUX-4.1-1.0.2.0-ubuntu16.04-x86_64.tgz
cd MLNX_OFED_LINUX-4.1-1.0.2.0-ubuntu16.04-x86_64
./mlnxofedinstall --hypervisor --force-fw-update --enable-mlnx_tune –force
```
9. Reboot the client driver.
10. Clear the SSH settings by typing the following commands:
```
rm -rf ~/.ssh
mkdir -p ~/.ssh
chmod 700 ~/.ssh
cd ~/.ssh
```
11. Copy the SSH keys created on the KVM host to the cassandra-stress client driver by typing the following commands on the KVM host (replacing ${clientDriver} with the client driver hostname):
```
scp -rp ~/clean_ssh ${clientDriver}:~/.ssh
ssh ${clientDriver}
cd ~
sudo su

rm -rf /root/.ssh
cp -rp .ssh /root/.ssh
chown -R root:root /root/.ssh
exit
exit
```
12. Copy the SSH keys created on the KVM host to the Cassandra VM by typing the following commands on the KVM host (replacing ${`clientDriver`} with the client driver hostname):
```
scp -rp ~/clean_ssh ${clientDriver}:~/.ssh
```

Installing cassandra-stress on the client driver system

1. Log in as root to the Ubuntu console on the client driver system.
2. Install Java 8 using the following commands:
```
sudo add-apt-repository ppa:webupd8team/java
sudo apt update
sudo apt -y install oracle-java8-installer
```
3. Install the Cassandra packages by typing the following commands:
```
echo “deb http://www.apache.org/dist/cassandra/debian 311x main” | sudo tee -a /etc/apt/sources.
list.d/cassandra.sources.list
curl https://www.apache.org/dist/cassandra/KEYS | sudo apt-key add -
sudo apt update
sudo apt install cassandra cassandra-tools
sudo systemctl stop cassandra
sudo systemctl disable cassandra
```
4. Reboot the client driver.

Running cassandra-stress

1. Log in as root to the Ubuntu console on the client driver system or any linux system with SSH access to all systems and VMs in the testbed.
2. Create a folder to hold the test scripts and results, then copy to the casstest.sh (Appendix C) and run_script.sh (Appendix C) scripts to that folder.
3. Update the casstest.sh script with the appropriate test parameters.
4. Create two files, clusters-amd.txt and clusters-intel.txt, which include the host names of each cassandra client, separated by commas for VMs of the same cluster and each cluster on a separate line. For example:

   ```
   amdc1n1,amdc1n2,amdc1n3,amdc1n4,amdc1n5,amdc1n6
   amdc2n1,amdc2n2,amdc2n3,amdc2n4,amdc2n5,amdc2n6
   amdc3n1,amdc3n2,amdc3n3,amdc3n4,amdc3n5,amdc3n6
   ```
5. Run the benchmark using the following command:

   ```
   ./run_script.sh
   ```

Appendix C: Scripts

vm_template.xml

```
<domain type='kvm'>
  <name>amdc1n1</name>
  <memory unit='KiB'>31457280</memory>
  <currentMemory unit='KiB'>31457280</currentMemory>
  <memoryBacking>
    <hugepages/>
    <nosharepages/>
  </memoryBacking>
  <vcpu placement='static' cpuset='0-3,64-67'>8</vcpu>
  <numatune>
    <memory mode='strict' nodeset='0'/>
  </numatune>
  <os>
    <type arch='x86_64' machine='pc-i440fx-xenial'>hvm</type>
    <boot dev='hd'/>
  </os>
  <features>
    <acpi/>
    <apic/>
  </features>
  <cpu mode='host-passthrough'>
    <topology sockets='1' cores='8' threads='1'/>
  </cpu>
  <clock offset='utc'/>
  <on_poweroff>destroy</on_poweroff>
  <on_reboot>restart</on_reboot>
  <on_crash>restart</on_crash>
  <pm>
    <suspend-to-mem enabled='no'/>
    <suspend-to-disk enabled='no'/>
  </pm>
  <devices>
    <emulator>/usr/bin/kvm</emulator>
    <disk type='block' device='disk'>
      <driver name='qemu' type='raw' cache='none' discard='unmap'/>
      <source dev='/vmdisk/amdc1n1'/>
      <target dev='sda' bus='scsi'/>
      <address type='drive' controller='0' bus='0' target='0' unit='0'/>
    </disk>
    <controller type='usb' index='0' model='ich9-ehci1'>
      <address type='pci' domain='0x0000' bus='0x00' slot='0x05' function='0x7'/>
    </controller>
    <controller type='usb' index='0' model='ich9-uhci1'>
      <master startport='0'/>
      <address type='pci' domain='0x0000' bus='0x00' slot='0x05' function='0x0' multifunction='on'/>
    </controller>
    <controller type='usb' index='0' model='ich9-uhci2'>
      <master startport='2'/>
      <address type='pci' domain='0x0000' bus='0x00' slot='0x05' function='0x1'/>
    </controller>
    <controller type='usb' index='0' model='ich9-uhci3'>
      <master startport='4'/>
      <address type='pci' domain='0x0000' bus='0x00' slot='0x05' function='0x2'/>
    </controller>
    <controller type='scsi' index='0' model='virtio-scsi'>
      <address type='pci' domain='0x0000' bus='0x00' slot='0x04' function='0x0'/>
    </controller>
    <controller type='pci' index='0' model='pci-root'/>
    <controller type='virtio-serial' index='0'>
      <address type='pci' domain='0x0000' bus='0x00' slot='0x02' function='0x0'/>
    </controller>
    <interface type='network'>
```

```
        <mac address='12:01:01:61:6d:64'/>
        <source network='net1'/>
        <model type='virtio'/>
        <address type='pci' domain='0x0000' bus='0x00' slot='0x03' function='0x0'/>
      </interface>
      <serial type='pty'>
        <target port='0'/>
      </serial>
      <console type='pty'>
        <target type='serial' port='0'/>
      </console>
      <channel type='unix'>
        <source mode='bind'/>
        <target type='virtio' name='org.qemu.guest_agent.0'/>
        <address type='virtio-serial' controller='0' bus='0' port='1'/>
      </channel>
      <memballoon model='virtio'>
        <address type='pci' domain='0x0000' bus='0x00' slot='0x07' function='0x0'/>
      </memballoon>
    </devices>
  </domain>
```

rc.local

```
#!/bin/sh -e
DOMAIN="cass.local"
IFNAME="ens3"
SWAPDEV="/dev/sda2"
ROOTDEV="/dev/sda1"
ETHER=`ip addr show dev ${IFNAME} | awk '/ether/{print $2;exit}'`
echo $ETHER > /var/run/ether
SUBNETVAR=`awk -F':' '{printf("%d",$1)}' /run/ether`
CLUSTER=`awk -F':' '{printf("%d",$2)}' /run/ether`
NODE=`awk -F':' '{printf("%d",$3)}' /run/ether`
HOSTPREFIX=`awk -F':' '{print $4$5$6}' /run/ether | xxd -r -p`
export DOMAIN ETHER HOSTPREFIX SUBNETVAR CLUSTER NODE
echo $DOMAIN > /run/domain
echo $SUBNETVAR > /run/subnetvar
echo $CLUSTER > /run/cluster
echo $NODE > /run/node
echo $HOSTPREFIX > /run/hostprefix
HOSTNAME="${HOSTPREFIX}c${CLUSTER}n${NODE}"
export HOSTNAME
hostnamectl set-hostname $HOSTNAME
cp -pf /etc/hosts /etc/hosts_backup
cp -pf /etc/network/interfaces /etc/network/interfaces_backup
cp -pf /etc/blkid /etc/blkid_backup
envsubst < /etc/hosts_template > /etc/hosts
envsubst < /etc/network/interfaces_template > /etc/network/interfaces
blkid > /etc/blkid
REBOOT=0
if [ "$(diff -q /etc/hosts /etc/hosts_backup)" != "" ]; then
    REBOOT=1
elif [ "$(diff -q /etc/network/interfaces /etc/network/interfaces_backup)" != "" ]; then
    REBOOT=1
elif [ "$(diff -q /etc/blkid /etc/blkid_backup)" != "" ]; then
    REBOOT=1
fi
if [ 0$REBOOT -ne 0 ]; then
    if [ ! -e /noreboot ]; then
        rm -rf /var/lib/cassandra/*
        rm -rf /var/log/cassandra/*
#       swapoff ${SWAPDEV}
#       mkswap -L ${HOSTNAME}-swap ${SWAPDEV}
        tune2fs -L ${HOSTNAME}-root ${ROOTDEV}
        blkid > /etc/blkid
        update-grub
        echo REBOOT REQUIRED!
        sleep 5
        reboot
    fi
fi
cp -pf /etc/cassandra/cassandra.yaml /etc/cassandra/cassandra.yaml_backup
sed -i "s/cluster_name:.*/cluster_name: '${HOSTPREFIX}-cluster${CLUSTER}'/" /etc/cassandra/cassandra.
yaml
if [ "$(diff -q /etc/cassandra/cassandra.yaml /etc/cassandra/cassandra.yaml_backup)" != "" ]; then
    rm -rf /var/lib/cassandra/*
    rm -rf /var/log/cassandra/*
fi
exit 0
```

hosts_template

```
127.0.0.1   localhost
# The following lines are desirable for IPv6 capable hosts
::1     localhost ip6-localhost ip6-loopback
ff02::1 ip6-allnodes
ff02::2 ip6-allrouters
10.${SUBNETVAR}.${CLUSTER}.1    ${HOSTPREFIX}c${CLUSTER}n1.${DOMAIN} ${HOSTPREFIX}c${CLUSTER}n1 cass1
10.${SUBNETVAR}.${CLUSTER}.2    ${HOSTPREFIX}c${CLUSTER}n2.${DOMAIN} ${HOSTPREFIX}c${CLUSTER}n2 cass2
10.${SUBNETVAR}.${CLUSTER}.3    ${HOSTPREFIX}c${CLUSTER}n3.${DOMAIN} ${HOSTPREFIX}c${CLUSTER}n3 cass3
10.${SUBNETVAR}.${CLUSTER}.4    ${HOSTPREFIX}c${CLUSTER}n4.${DOMAIN} ${HOSTPREFIX}c${CLUSTER}n4 cass4
10.${SUBNETVAR}.${CLUSTER}.5    ${HOSTPREFIX}c${CLUSTER}n5.${DOMAIN} ${HOSTPREFIX}c${CLUSTER}n5 cass5
10.${SUBNETVAR}.${CLUSTER}.6    ${HOSTPREFIX}c${CLUSTER}n6.${DOMAIN} ${HOSTPREFIX}c${CLUSTER}n6 cass6
10.${SUBNETVAR}.0.21    driver1-${SUBNETVAR}.${DOMAIN} driver1-${SUBNETVAR} driver1.${DOMAIN} driver1
10.${SUBNETVAR}.0.22    driver2-${SUBNETVAR}.${DOMAIN} driver2-${SUBNETVAR} driver2.${DOMAIN} driver2
10.${SUBNETVAR}.0.23    driver3-${SUBNETVAR}.${DOMAIN} driver3-${SUBNETVAR} driver3.${DOMAIN} driver3
10.${SUBNETVAR}.0.24    driver4-${SUBNETVAR}.${DOMAIN} driver4-${SUBNETVAR} driver4.${DOMAIN} driver4
10.${SUBNETVAR}.0.25    driver5-${SUBNETVAR}.${DOMAIN} driver5-${SUBNETVAR} driver5.${DOMAIN} driver5
10.${SUBNETVAR}.0.26    driver6-${SUBNETVAR}.${DOMAIN} driver6-${SUBNETVAR} driver6.${DOMAIN} driver6
10.${SUBNETVAR}.0.27    driver7-${SUBNETVAR}.${DOMAIN} driver7-${SUBNETVAR} driver7.${DOMAIN} driver7
10.${SUBNETVAR}.0.28    driver8-${SUBNETVAR}.${DOMAIN} driver8-${SUBNETVAR} driver8.${DOMAIN} driver8
10.${SUBNETVAR}.0.29    driver9-${SUBNETVAR}.${DOMAIN} driver9-${SUBNETVAR} driver9.${DOMAIN} driver9
```

interfaces_template

```
# This file describes the network interfaces available on your system
# and how to activate them. For more information, see interfaces(5).
source /etc/network/interfaces.d/*
# The loopback network interface
auto lo
iface lo inet loopback
# The primary network interface
auto ens3
iface ens3 inet static
    address 10.${SUBNETVAR}.${CLUSTER}.${NODE}
    netmask 255.255.0.0
    gateway 10.${SUBNETVAR}.0.1
    dns-search 10.${SUBNETVAR}.0.1
    dns-nameservers 10.${SUBNETVAR}.0.1
```

casstest.sh

```
#!/bin/bash
NAME=${1-amd}
#NAME=${1-intel}
TIMESTAMP="`date +%Y%m%d%H%M%S`"
CLUSTER_FILE="clusters-${NAME}.txt"
```

```
CLUSTERS="$(cat $CLUSTER_FILE)"
CLIENT_CORES=7
CLIENT_CORE_START=1
CLIENT_HTSKIP=44
CLIENT_COUNT=3
HOST_COUNT=6
HOST_LIST="$(for i in `seq 1 $HOST_COUNT`; do echo ${NAME}00${i}; done) $(for i in `seq 1 $CLIENT_
COUNT`; do echo driver${i}; done)"
RESULT_DIR="${NAME}_results_${TIMESTAMP}"
RESULT_FILE="$RESULT_DIR/${NAME}_results.txt"
LOG_FILE="$RESULT_DIR/script.log"
TIMING_FILE="$RESULT_DIR/script.log"
THREADS=1000
DURATION=300
STAT_INTERVAL=10
STAT_COUNT=$((DURATION/STAT_INTERVAL))

STRESS_CMD="cassandra-stress write no-warmup duration=${DURATION}s cl=one -rate threads=${THREADS}
-schema \"replication(factor=3)\" -pop seq=1..100000000 no-wrap"

echo "Contacting all hosts:"
for HOST in ${HOST_LIST};
do
  ssh ${HOST} 'echo $(uname -nr)'
done
wait
echo "Contacting all VMs:"
for CLUSTER in ${CLUSTERS}; do
  for NODE in $(echo $CLUSTER | sed 's/,/ /g'); do
    ssh ${NODE} 'echo $(uname -nr) : $(java -version 2>&1 | tail -n 1) : cassandra $(dpkg -s
cassandra | awk "/Version/{print \$2;exit}")'
    ssh ${NODE} "nodetool flush ; nodetool cleanup ; sync" &
  done
done
wait
sleep 1
for CLUSTER in ${CLUSTERS}; do
  NODE1="$(echo ${CLUSTER} | awk -F',' '{print $1}')"
  ssh ${NODE1} "nodetool status"
  cqlsh --request-timeout=120 -e "drop keyspace keyspace1" ${NODE1} &
  sleep 0.1
done
wait
sleep 1
for CLUSTER in ${CLUSTERS}; do
  for NODE in $(echo $CLUSTER | sed 's/,/ /g'); do
    ssh ${NODE} "nodetool flush ; sleep 10 ; nodetool cleanup ; nodetool clearsnapshot ; nodetool flush
; nodetool cleanup ; sync" &
    sleep 0.01
  done
  sleep 0.1
done
wait
echo "Cleanup done...sleeping 60 seconds..."
sleep 60
for CLUSTER in ${CLUSTERS}; do
  NODE1="$(echo ${CLUSTER} | awk -F',' '{print $1}')"
  ssh ${NODE1} "nodetool status" &
  sleep 0.1
done
wait
echo "Starting perf capture on hosts"
for HOST in ${HOST_LIST};
do
  SAR_FILE="/tmp/sar_${HOST}.bin"
  VMSTAT_FILE="/tmp/vmstat_${HOST}.txt"
  ssh ${HOST} "killall -w sar > /dev/null ; sync ; rm -f ${SAR_FILE} ; sync ; nohup sar ${STAT_
INTERVAL} $((STAT_COUNT+10)) -o ${SAR_FILE} > /dev/null 2>&1 &” &
  ssh ${HOST} “pkill vmstat ; sync ; rm -f ${VMSTAT_FILE} ; sync ; nohup vmstat ${STAT_INTERVAL}
$((STAT_COUNT+10)) > ${VMSTAT_FILE} 2>&1 &” &
done
wait
echo “Starting perf capture on VMs”
for CLUSTER in ${CLUSTERS}; do
  for NODE in $(echo $CLUSTER | sed ‘s/,/ /g’); do
    VMSTAT_FILE=”/tmp/vmstat_${NODE}.txt”
    ssh ${NODE} “pkill vmstat ; sync ; rm -f ${VMSTAT_FILE} ; sync ; nohup vmstat ${STAT_INTERVAL}
$((STAT_COUNT+10)) > ${VMSTAT_FILE} 2>&1 &” &
  done
done
wait

sleep ${STAT_INTERVAL}

mkdir -p ${RESULT_DIR}
rm -f latest_results
ln -s ${RESULT_DIR} latest_results
COUNT=${CLIENT_CORE_START}
CLUSTER_COUNT=1
for CLUSTER in ${CLUSTERS}; do
  CLUSTER_NAME=${NAME}_cluster${CLUSTER_COUNT}
  CLUSTER_NODES=$CLUSTER
  ssh root@driver$(((CLUSTER_COUNT%CLIENT_COUNT)+1)) “numactl --physcpubind=$((COUNT+0))-
$((COUNT+CLIENT_CORES-1)),$((COUNT+CLIENT_HTSKIP))-$((COUNT+CLIENT_HTSKIP+CLIENT_CORES-1))
--localalloc ${STRESS_CMD} -node ${CLUSTER_NODES} -log interval=1” | while read -r line; do echo
-e “${CLUSTER_NAME}\t$(date ‘+%Y-%m-%d %T.%3N’) $line”; done | tee ${RESULT_DIR}/${CLUSTER_NAME}_
driver$(((CLUSTER_COUNT%CLIENT_COUNT)+1)).txt | grep -v “replica were required but only” &
  sleep 0.01
  if [ $((CLUSTER_COUNT%CLIENT_COUNT)) = 0 ]; then
    COUNT=$((COUNT+CLIENT_CORES))
  fi
  ((CLUSTER_COUNT++))
done
wait
sync

grep “Op rate” ${RESULT_DIR}/*_cluster*_driver*.txt | tee ${RESULT_FILE}
sed ‘s/,//’ ${RESULT_FILE} | awk ‘{sum=sum+$7}END{print “Total op/s: “sum}’ | tee -a ${RESULT_FILE}
sync

echo “Stopping perf capture on hosts”
sleep ${STAT_INTERVAL}
for HOST in ${HOST_LIST};
do
  ssh ${HOST} “killall -w sar ; pkill vmstat ; sync” &
done
wait

echo “Stopping perf capture on VMs”
for CLUSTER in ${CLUSTERS}; do
  for NODE in $(echo $CLUSTER | sed ‘s/,/ /g’); do
    ssh ${NODE} “pkill vmstat ; sync” &
  done
done
wait

echo “Copying host perf logs”
for HOST in ${HOST_LIST};
do
  SAR_FILE=”/tmp/sar_${HOST}.bin”
  VMSTAT_FILE=”/tmp/vmstat_${HOST}.txt”
  scp ${HOST}:${SAR_FILE} ${RESULT_DIR}/
  scp ${HOST}:${VMSTAT_FILE} ${RESULT_DIR}/
done
wait
```

```
echo “Copying VM perf logs”
for CLUSTER in ${CLUSTERS}; do
  for NODE in $(echo $CLUSTER | sed ‘s/,/ /g’); do
    VMSTAT_FILE=”/tmp/vmstat_${NODE}.txt”
    scp ${NODE}:${VMSTAT_FILE} ${RESULT_DIR}/
  done
done
wait

cp $0 ${RESULT_DIR}/
```

run_script.sh

```
#!/bin/bash
OUTPUT_FILE=”script_output.log”
TIMING_FILE=”script_timing.txt”
REPLAY_FILE=”script_replay.sh”
rm -f ${OUTPUT_FILE}
rm -f ${TIMING_FILE}
sync
script --timing=${TIMING_FILE} ${OUTPUT_FILE} -c ./casstest.sh
echo “scriptreplay --timing=${TIMING_FILE} ${OUTPUT_FILE}” > ${REPLAY_FILE}
chmod +x ${REPLAY_FILE}
sync
cp -f ${OUTPUT_FILE} latest_results/
cp -f ${TIMING_FILE} latest_results/
cp -f ${REPLAY_FILE} latest_results/
cp -f $0 latest_results/
sync
```

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