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Red Hat OpenShift Virtualization with NetApp ONTAP

Depending on the specific use case, both containers and virtual machines (VMs) can serve as optimal platforms for different types of applications. Therefore, many organizations run some of their workloads on containers and some on VMs. Often, this leads organizations to face additional challenges by having to manage separate platforms: a hypervisor for VMs and a container orchestrator for applications.

To address this challenge, Red Hat introduced OpenShift Virtualization (formerly known as Container Native Virtualization) starting from OpenShift version 4.6. The OpenShift Virtualization feature enables you to run and manage virtual machines alongside containers on the same OpenShift Container Platform installation, providing hybrid management capability to automate deployment and management of VMs through operators. In addition to creating VMs in OpenShift, with OpenShift Virtualization, Red Hat also supports importing VMs from VMware vSphere, Red Hat Virtualization, and Red Hat OpenStack Platform deployments.

Certain features like live VM migration, VM disk cloning, VM snapshots and so on are also supported by OpenShift Virtualization with assistance from Astra Trident when backed by NetApp ONTAP. Examples of each of these workflows are discussed later in this document in their respective sections.

To learn more about Red Hat OpenShift Virtualization, see the documentation here.

Deployment for OpenShift Virtualization

Deploy Red Hat OpenShift Virtualization with NetApp ONTAP

This section details how to deploy Red Hat OpenShift Virtualization with NetApp ONTAP.

Prerequisites

- A Red Hat OpenShift cluster (later than version 4.6) installed on bare-metal infrastructure with RHCOS
worker nodes

• The OpenShift cluster must be installed via installer provisioned infrastructure (IPI)
• Deploy Machine Health Checks to maintain HA for VMs
• A NetApp ONTAP cluster
• Astra Trident installed on the OpenShift cluster
• A Trident backend configured with an SVM on ONTAP cluster
• A StorageClass configured on the OpenShift cluster with Astra Trident as the provisioner
• Cluster-admin access to Red Hat OpenShift cluster
• Admin access to NetApp ONTAP cluster
• An admin workstation with tridentctl and oc tools installed and added to $PATH

Because OpenShift Virtualization is managed by an operator installed on the OpenShift cluster, it imposes additional overhead on memory, CPU, and storage, which must be accounted for while planning the hardware requirements for the cluster. See the documentation here for more details.

Optionally, you can also specify a subset of the OpenShift cluster nodes to host the OpenShift Virtualization operators, controllers, and VMs by configuring node placement rules. To configure node placement rules for OpenShift Virtualization, follow the documentation here.

For the storage backing OpenShift Virtualization, NetApp recommends having a dedicated StorageClass that requests storage from a particular Trident backend, which in turn is backed by a dedicated SVM. This maintains a level of multitenancy with regard to the data being served for VM-based workloads on the OpenShift cluster.

**Deploy Red Hat OpenShift Virtualization with NetApp ONTAP**

To install OpenShift Virtualization, complete the following steps:

1. Log into the Red Hat OpenShift bare-metal cluster with cluster-admin access.
2. Select Administrator from the Perspective drop down.
4. Select the OpenShift Virtualization tile and click Install.

5. On the Install Operator screen, leave all default parameters and click Install.
6. Wait for the operator installation to complete.

**OpenShift Virtualization**

2.6.2 provided by Red Hat

---

**Installing Operator**

The Operator is being installed. This may take a few minutes.

*View installed Operators in Namespace openshift-cnv*

7. After the operator has installed, click Create HyperConverged.
8. On the Create HyperConverged screen, click Create, accepting all default parameters. This step starts the installation of OpenShift Virtualization.
9. After all the pods move to the Running state in the openshift-cnv namespace and the OpenShift Virtualization operator is in the Succeeded state, the operator is ready to use. VMs can now be created on the OpenShift cluster.

**Installed Operators**

Installed Operators are represented by ClusterServiceVersions within this Namespace. For more information, see the Understanding Operators documentation. Or create an Operator and ClusterServiceVersion using the Operator SDK.

<table>
<thead>
<tr>
<th>Name</th>
<th>Managed Namespaces</th>
<th>Status</th>
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<th>Provided APIs</th>
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<td>Succeeded</td>
<td>May 18, 8:02 pm</td>
<td>OpenShift Virtualization Deployment HostPathProvisioner deployment</td>
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</table>

**Workflows**

**Workflows: Red Hat OpenShift Virtualization with NetApp ONTAP**

This section covers the how to create a virtual machine with Red Hat OpenShift Virtualization.
VMs are stateful deployments that require volumes to host the operating system and data. With CNV, because the VMs are run as pods, the VMs are backed by PVs hosted on NetApp ONTAP through Trident. These volumes are attached as disks and store the entire filesystem including the boot source of the VM.

To quickly create a virtual machine on the OpenShift cluster, complete the following steps:

1. Navigate to Virtualization > Virtual Machines and click Create.
2. Select From template.
3. Select the desired operating system for which the boot source is available.
4. Check the checkbox Start the VirtualMachine after creation.
5. Click Quick create VirtualMachine.

The virtual machine is created and started and comes to the **Running** state. It automatically creates a PVC and a corresponding PV for the boot disk using the default storage class. In order to be able to live migrate the VM in the future, you must ensure that the storage class used for the disks can support RWX volumes. This is a requirement for live migration. ontap-nas and ontap-san (volumeMode block for iSCSI and NVMe/TCP protocols) can support RWX access modes for the volumes created using the respective storage classes.

To configure ontap-san storage class on the cluster see the Section for Migrating a VM from VMware to OpenShift Virtualization.
You can set up ontap NAS or iSCSI as the default storage class for the cluster. Clicking on Quick create VirtualMachine will use the default storage class to create the PVC and PV for the bootable root disk for the VM. If your default storage class is not ontap-nas or ontap-san, you can select the storage class for the disk, by selecting Customize VirtualMachine > Customize VirtualMachine parameters > Disks and then editing the disk to use the required storage class.

Typically block access mode is preferred compared to file systems while provisioning the VM disks.

To customize the virtual machine creation after you have selected the OS template, click on Customize VirtualMachine instead of Quick create.

1. If the selected operating system has boot source configured, you can click on Customize VirtualMachine parameters.
2. If the selected operating system has no boot source configured, you must configure it. You can see details about the procedures shown in the documentation.
3. After Configuring the boot disk, you can click on Customize VirtualMachine parameters.
4. You can customize the VM from the tabs on this page. For eg. click on the Disks tab and then click on Add disk to add another disk to the VM.
5. Click Create Virtual Machine to create the virtual machine; this spins up a corresponding pod in the background.

When a boot source is configured for a template or an operating system from an URL or from a registry, it creates a PVC in the openshift-virtualization-os-images project and downloads the KVM guest image to the PVC. You must make sure that template PVCs have enough provisioned space to accommodate the KVM guest image for the corresponding OS. These PVCs are then cloned and attached as rootdisk to virtual machines when they are created using the respective templates in any project.
Workflows: Red Hat OpenShift Virtualization with NetApp ONTAP

This section shows how to migrate a virtual machine in OpenShift Virtualization between nodes in the cluster.

VM Live Migration

Live Migration is a process of migrating a VM instance from one node to another in an OpenShift cluster with no downtime. For live migration to work in an OpenShift cluster, VMs must be bound to PVCs with shared...
ReadWriteMany access mode. Astra Trident backends configured using ontap-nas drivers support RWX access mode for FileSystem protocols nfs and smb. Refer to the documentation here. Astra Trident backends configured using ontap-san drivers support RWX access mode for block volumeMode for iSCSI and NVMe/TCP protocols. Refer to the documentation here.

Therefore, for live migration to succeed, the VMs must be provisioned with disks (boot disks and additional hot plug disks) with PVCs using ontap-nas or ontap-san (volumeMode: Block) storage classes. When the PVCs are created, Trident creates ONTAP volumes in an SVM which is NFS-enabled or iSCSI enabled.

To perform a live migration of a VM that has been created previously and is in a Running state perform the following steps:

1. Select the VM that you want to live-migrate.
2. Click on Configuration tab.
3. Ensure that all the disks of the VM are created using Storage classes that can support RWX access mode.
4. Click on Actions on the right corner and then select Migrate.
5. To look at the progression of the Migration, go to Virtualization > Overview on the left hand side menu and then click on the Migrations tab.

The Migration of the VM will transition from Pending to Scheduling to Succeeded.
A VM instance in an OpenShift cluster automatically migrates to another node when the original node is placed into maintenance mode if the evictionStrategy is set to LiveMigrate.

Workflows: Red Hat OpenShift Virtualization with NetApp ONTAP

This section covers the how to clone a virtual machine with Red Hat OpenShift Virtualization.

VM cloning

Cloning an existing VM in OpenShift is achieved with the support of Astra Trident’s Volume CSI cloning feature. CSI volume cloning allows for creation of a new PVC using an existing PVC as the data source by duplicating its PV. After the new PVC is created, it functions as a separate entity and without any link to or dependency on the source PVC.
There are certain restrictions with CSI volume cloning to consider:

1. Source PVC and destination PVC must be in the same project.
2. Cloning is supported within the same storage class.
3. Cloning can be performed only when source and destination volumes use the same VolumeMode setting; for example, a block volume can only be cloned to another block volume.

VMs in an OpenShift cluster can be cloned in two ways:

1. By shutting down the source VM
2. By keeping the source VM live

**By Shutting down the source VM**

Cloning an existing VM by shutting down the VM is a native OpenShift feature that is implemented with support from Astra Trident. Complete the following steps to clone a VM.

1. Navigate to Workloads > Virtualization > Virtual Machines and click the ellipsis next to the virtual machine you wish to clone.
2. Click Clone Virtual Machine and provide the details for the new VM.
3. Click Clone Virtual Machine; this shuts down the source VM and initiates the creation of the clone VM.

4. After this step is completed, you can access and verify the content of the cloned VM.
By keeping the source VM live

An existing VM can also be cloned by cloning the existing PVC of the source VM and then creating a new VM using the cloned PVC. This method does not require you to shut down the source VM. Complete the following steps to clone a VM without shutting it down.

1. Navigate to Storage > PersistentVolumeClaims and click the ellipsis next to the PVC that is attached to the source VM.
2. Click Clone PVC and furnish the details for the new PVC.

Clone

Name *

rhel8-short-frog-rootdisk-28dvd-clone

Access Mode *
○ Single User (RWO)  ○ Shared Access (RWX)  ○ Read Only (ROX)

Size *

20 GiB

PVC details

Namespace Requested capacity Access mode
NS default 20 GiB Shared Access (RWX)

Storage Class Used capacity Volume mode
Sc basic 2.2 GiB Filesystem

3. Then click Clone. This creates a PVC for the new VM.
4. Navigate to Workloads > Virtualization > Virtual Machines and click Create > With YAML.
5. In the spec > template > spec > volumes section, attach the cloned PVC instead of the container disk. Provide all other details for the new VM according to your requirements.
6. Click Create to create the new VM.
7. After the VM is created successfully, access and verify that the new VM is a clone of the source VM.

Workflows: Red Hat OpenShift Virtualization with NetApp ONTAP

This section shows how to create a virtual machine from a Snapshot with Red Hat OpenShift Virtualization.

Create VM from a Snapshot

With Astra Trident and Red Hat OpenShift, users can take a snapshot of a persistent volume on Storage Classes provisioned by it. With this feature, users can take a point-in-time copy of a volume and use it to create a new volume or restore the same volume back to a previous state. This enables or supports a variety of use-cases, from rollback to clones to data restore.

For Snapshot operations in OpenShift, the resources VolumeSnapshotClass, VolumeSnapshot, and VolumeSnapshotContent must be defined.

- A VolumeSnapshotContent is the actual snapshot taken from a volume in the cluster. It is cluster-wide resource analogous to PersistentVolume for storage.
- A VolumeSnapshot is a request for creating the snapshot of a volume. It is analogous to a PersistentVolumeClaim.
- VolumeSnapshotClass lets the administrator specify different attributes for a VolumeSnapshot. It allows you to have different attributes for different snapshots taken from the same volume.
To create Snapshot of a VM, complete the following steps:

1. Create a VolumeSnapshotClass that can then be used to create a VolumeSnapshot. Navigate to Storage > VolumeSnapshotClasses and click Create VolumeSnapshotClass.

2. Enter the name of the Snapshot Class, enter csi.trident.netapp.io for the driver, and click Create.
3. Identify the PVC that is attached to the source VM and then create a Snapshot of that PVC. Navigate to Storage > VolumeSnapshots and click Create VolumeSnapshots.

4. Select the PVC that you want to create the Snapshot for, enter the name of the Snapshot or accept the default, and select the appropriate VolumeSnapshotClass. Then click Create.

```
apiVersion: snapshot.storage.k8s.io/v1
class: VolumeSnapshot
metadata:
  name: trident-snapshot-class
driver: csi.trident.netapp.io
deletionPolicy: Delete
```

5. This creates the snapshot of the PVC at that point in time.
Create a new VM from the snapshot

1. First, restore the Snapshot into a new PVC. Navigate to Storage > VolumeSnapshots, click the ellipsis next to the Snapshot that you wish to restore, and click Restore as new PVC.

2. Enter the details of the new PVC and click Restore. This creates a new PVC.

3. Next, create a new VM from this PVC. Navigate to Virtualization > Virtual Machines and click Create > With YAML.

4. In the spec > template > spec > volumes section, specify the new PVC created from Snapshot instead of
5. Click Create to create the new VM.

6. After the VM is created successfully, access and verify that the new VM has the same state as that of the VM whose PVC was used to create the snapshot at the time when the snapshot was created.

**Workflows: Red Hat OpenShift Virtualization with NetApp ONTAP**

This section covers the how to migrate a virtual machine between from VMware to an OpenShift Cluster using Red Hat OpenShift Virtualization migration toolkit.

**Migration of VM from VMware to OpenShift Virtualization using Migration Toolkit for Virtualization**

In this section, we will see how to use the Migration Toolkit for Virtualization (MTV) to migrate virtual machines from VMware to OpenShift Virtualization running on OpenShift Container platform and integrated with NetApp ONTAP storage using Astra Trident.

The following video shows a demonstration of the migration of a RHEL VM from VMware to OpenShift Virtualization using ontap-san storage class for persistent storage.

**Using Red Hat MTV to migrate VMs to OpenShift Virtualization with NetApp ONTAP Storage**

The following diagram shows a high level view of the migration of a VM from VMware to Red Hat OpenShift Virtualization.

---

**Migration of VM from VMware to OpenShift Virtualization**

---
Prerequisites for the sample migration

On VMware

- A RHEL 9 VM using rhel 9.3 with the following configurations were installed:
  - CPU: 2, Memory: 20 GB, Hard disk: 20 GB
  - user credentials: root user and an admin user credentials
- After the VM was ready, postgresql server was installed.
  - postgresql server was started and enabled to start on boot

```bash
systemctl start postgresql.service
systemctl enable postgresql.service
```
The above command ensures that the server can start in the VM in OpenShift Virtualization after migration

- Added 2 databases, 1 table and 1 row in the table were added. Refer here for the instructions for installing postgresql server on RHEL and creating database and table entries.

   Ensure that you start the postgresql server and enable the service to start at boot.

On OpenShift Cluster

The following installations were completed before installing MTV:

- OpenShift Cluster 4.13.34
- Astra Trident 23.10
- Multipath on the cluster nodes enabled for iSCSI (for ontap-san storage class). See the provided yaml to create a daemon set that enables iSCSI on each node in the cluster.
- Trident backend and Storage class for ontap SAN using iSCSI. See the provided yaml files for trident backend and storage class.
- OpenShift Virtualization

To install iscsi and multipath on the OpenShift Cluster nodes use the yaml file given below

Preparing the cluster nodes for iSCSI

```
apiVersion: apps/v1
kind: DaemonSet
metadata:
  namespace: trident
name: trident-iscsi-init
labels:
  name: trident-iscsi-init
spec:
  selector:
    matchLabels:
```
name: trident-iscsi-init
template:
  metadata:
    labels:
      name: trident-iscsi-init
  spec:
    hostNetwork: true
    serviceAccount: trident-node-linux
    initContainers:
      - name: init-node
        command:
          - nsenter
          - --mount=/proc/1/ns/mnt
          - --
          - sh
          - -c
        args: ["$(STARTUP_SCRIPT)"]
        image: alpine:3.7
        env:
          - name: STARTUP_SCRIPT
            value: |
              #!/bin/bash
              sudo yum install -y lsscsi iscsi-initiator-utils sg3_utils
device-mapper-multipath
              rpm -q iscsi-initiator-utils
              sudo sed -i 's/^\(node.session.scan\).*/\1 = manual/'
              /etc/iscsi/iscsid.conf
              cat /etc/iscsi/initiatorname.iscsi
              sudo mpathconf --enable --with_multipathd y --find_multipaths
              n
              sudo systemctl enable --now iscsid multipathd
              sudo systemctl enable --now iscsi
    securityContext:
      privileged: true
    hostPID: true
    containers:
      - name: wait
        image: k8s.gcr.io/pause:3.1
    hostNetwork: true
    tolerations:
      - effect: NoSchedule
        key: node-role.kubernetes.io/master
    updateStrategy:
      type: RollingUpdate
Use the following yaml file to create trident backend configuration for using ontap san storage

**Trident backend for iSCSI**

```yaml
apiVersion: v1
kind: Secret
metadata:
  name: backend-tbc-ontap-san-secret
type: Opaque
stringData:
  username: <username>
  password: <password>
---
apiVersion: trident.netapp.io/v1
kind: TridentBackendConfig
metadata:
  name: ontap-san
spec:
  version: 1
  storageDriverName: ontap-san
  managementLIF: <management LIF>
  backendName: ontap-san
  svm: <SVM name>
  credentials:
    name: backend-tbc-ontap-san-secret
```

Use the following yaml file to create trident storage class configuration for using ontap san storage

**Trident storage class for iSCSI**

```yaml
apiVersion: storage.k8s.io/v1
kind: StorageClass
metadata:
  name: ontap-san
provisioner: csi.trident.netapp.io
parameters:
  backendType: "ontap-san"
  media: "ssd"
  provisioningType: "thin"
  snapshots: "true"
  allowVolumeExpansion: true
```

**Install MTV**

Now you can install the Migration Toolkit for virtualization (MTV). Refer to the instructions provided [here](#) for help with the installation.
The Migration Toolkit for Virtualization (MTV) user interface is integrated into the OpenShift web console. You can refer here to start using the user interface for various tasks.

**Create Source Provider**

In order to migrate the RHEL VM from VMware to OpenShift Virtualization, you need to first create the source provider for VMware. Refer to the instructions here to create the source provider.

You need the following to create your VMware source provider:

- VCenter url
- VCenter Credentials
- VCenter server thumbprint
- VDDK image in a repository

Sample source provider creation:

![Source provider creation form](image)
The Migration Toolkit for Virtualization (MTV) uses the VMware Virtual Disk Development Kit (VDDK) SDK to accelerate transferring virtual disks from VMware vSphere. Therefore, creating a VDDK image, although optional, is highly recommended.

To make use of this feature, you download the VMware Virtual Disk Development Kit (VDDK), build a VDDK image, and push the VDDK image to your image registry.

Follow the instructions provided [here](#) to create and push the VDDK image to a registry accessible from the OpenShift Cluster.

**Create Destination provider**

The host cluster is automatically added as the OpenShift virtualization provider is the source provider.

**Create Migration Plan**

Follow the instructions provided [here](#) to create a migration plan.

While creating a plan, you need to create the following if not already created:

- A network mapping to map the source network to the target network.
- A storage mapping to map the source datastore to the target storage class. For this you can choose ontap-san storage class.

Once the migration plan is created, the status of the plan should show **Ready** and you should now be able to **Start** the plan.

Clicking on **Start** will run through a sequence of steps to complete the migration of the VM.
When all steps are completed, you can see the migrated VMs by clicking on the virtual machines under Virtualization in the left-side navigation menu. Instructions to access the virtual machines are provided here.

You can log into the virtual machine and verify the contents of the postgresql databases. The databases, tables and the entries in the table should be the same as what was created on the source VM.

## Data Protection for OpenShift Virtualization

### Data protection for VMs in OpenShift Virtualization using OpenShift API for Data Protection (OADP)

**Author:** Banu Sundhar, NetApp

This section of the reference document provides details for creating backups of VMs using the OpenShift API for Data Protection (OADP) with Velero on NetApp ONTAP S3 or NetApp StorageGRID S3. The backups of Persistent Volumes (PVs) of the VM disks are created using CSI Astra Trident Snapshots.

Virtual machines in the OpenShift Virtualization environment are containerized applications that run in the worker nodes of your OpenShift Container platform. It is important to protect the VM metadata as well as the persistent disks of the VMs, so that when they are lost or corrupted, you can recover them.

The persistent disks of the OpenShift Virtualization VMs can be backed by ONTAP storage integrated to the OpenShift Cluster using Astra Trident CSI. In this section we use OpenShift API for Data Protection (OADP) to perform backup of VMs including its data volumes to

- ONTAP Object Storage
- StorageGrid
We then restore from the backup when needed.

OADP enables backup, restore, and disaster recovery of applications on an OpenShift cluster. Data that can be protected with OADP include Kubernetes resource objects, persistent volumes, and internal images.

Red Hat OpenShift has leveraged the solutions developed by the OpenSource communities for data protection. **Velero** is an open-source tool to safely backup and restore, perform disaster recovery, and migrate Kubernetes cluster resources and persistent volumes. To use Velero easily, OpenShift has developed the OADP operator and the Velero plugin to integrate with the CSI storage drivers. The core of the OADP APIs that are exposed are based on the Velero APIs. After installing the OADP operator and configuring it, the backup/restore operations that can be performed are based on the operations exposed by the Velero API.
OADP 1.3 is available from the operator hub of OpenShift cluster 4.12 and later. It has a built-in Data Mover that can move CSI volume snapshots to a remote object store. This provides portability and durability by moving snapshots to an object storage location during backup. The snapshots are then available for restoration after disasters.

The following are the versions of the various components used for the examples in this section

- OpenShift Cluster 4.14
- OpenShift Virtualization installed via Operator
- OADP Operator 1.13 provided by Red Hat
- Velero CLI 1.13 for Linux
- Astra Trident 24.02
- ONTAP 9.12

Astra Trident CSI
OpenShift API for Data Protection (OADP)
Velero

Installation of OpenShift API for Data Protection (OADP) Operator

This section outlines the installation of OpenShift API for Data Protection (OADP) Operator.

Prerequisites

- A Red Hat OpenShift cluster (later than version 4.12) installed on bare-metal infrastructure with RHCOS worker nodes
- A NetApp ONTAP cluster integrated with the cluster using Astra Trident
• A Trident backend configured with an SVM on ONTAP cluster
• A StorageClass configured on the OpenShift cluster with Astra Trident as the provisioner
• Trident Snapshot class created on the cluster
• Cluster-admin access to Red Hat OpenShift cluster
• Admin access to NetApp ONTAP cluster
• OpenShift Virtualization operator installed and configured
• VMs deployed in a Namespace on OpenShift Virtualization
• An admin workstation with tridentctl and oc tools installed and added to $PATH

If you want to take a backup of a VM when it is in the Running state, then you must install the QEMU guest agent on that virtual machine. If you install the VM using an existing template, then QEMU agent is installed automatically. QEMU allows the guest agent to quiesce in-flight data in the guest OS during the snapshot process, and avoid possible data corruption. If you do not have QEMU installed, you can stop the virtual machine before taking a backup.

Steps to install OADP Operator

1. Go to the Operator Hub of the cluster and select Red Hat OADP operator. In the Install page, use all the default selections and click install. On the next page, again use all the defaults and click Install. The OADP operator will be installed in the namespace openshift-adp.
OADP Operator
1.3.0 provided by Red Hat

**Install**

**Channel**
stable-1.3

**Version**
1.3.0

**Capability level**
- Basic Install
- Seamless Upgrades
  - Full Lifecycle
  - Deep Insights
  - Auto Pilot

**Source**
Red Hat

**Provider**
Red Hat

**Infrastructure features**
Disconnected

OpenShift API for Data Protection (OADP) operator sets up and installs Velero on the OpenShift platform, allowing users to backup and restore applications.

Backup and restore Kubernetes resources and internal images, at the granularity of a namespace, using a version of Velero appropriate for the installed version of OADP.

OADP backs up Kubernetes objects and internal images by saving them as an archive file on object storage. OADP backs up persistent volumes (PVs) by creating snapshots with the native cloud snapshot API or with the Container Storage Interface (CSI). For cloud providers that do not support snapshots, OADP backs up resources and PV data with Restic or Kopia.

- Installing OADP for application backup and restore
- Installing OADP on a ROSA cluster and using STS, please follow the Getting Started Steps 1-3 in order to obtain the role ARN needed for using the standardized STS configuration flow via OLM
- Frequently Asked Questions

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**Installed Operators**

Installed Operators are represented by ClusterServiceVersions within this Namespace. For more information, see the Understanding Operators documentation.

Operator and ClusterServiceVersion using the Operator SDK.

<table>
<thead>
<tr>
<th>Name</th>
<th>Namespace</th>
<th>Managed Namespaces</th>
<th>Status</th>
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<tr>
<td><strong>OpenShift Virtualization</strong></td>
<td>NS openshift-cnv</td>
<td>NS openshift-cnv</td>
<td>Succeeded</td>
</tr>
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<tr>
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<td>NS openshift-adp</td>
<td>Succeeded</td>
</tr>
<tr>
<td>1.3.0 provided by Red Hat</td>
<td></td>
<td></td>
<td>Up to date</td>
</tr>
<tr>
<td><strong>Package Server</strong></td>
<td>NS openshift-operator-lifecycle-manager</td>
<td>NS openshift-operator-lifecycle-manager</td>
<td>Succeeded</td>
</tr>
<tr>
<td>0.0.1-snapshot provided by</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Prerequisites for Velero configuration with Ontap S3 details

After the installation of the operator succeeds, configure the instance of Velero. Velero can be configured to use S3 compatible Object Storage. Configure ONTAP S3 using the procedures shown in the Object Storage Management section of ONTAP documentation. You will need the following information from your ONTAP S3 configuration to integrate with Velero.

- A Logical Interface (LIF) that can be used to access S3
- User credentials to access S3 that includes the access key and the secret access key
- A bucket name in S3 for backups with access permissions for the user
- For secure access to the Object storage, TLS certificate should be installed on the Object Storage server.

Prerequisites for Velero configuration with StorageGrid S3 details

Velero can be configured to use S3 compatible Object Storage. You can configure StorageGrid S3 using the procedures shown in the StorageGrid documentation. You will need the following information from your StorageGrid S3 configuration to integrate with Velero.

- The endpoint that can be used to access S3
- User credentials to access S3 that includes the access key and the secret access key
- A bucket name in S3 for backups with access permissions for the user
- For secure access to the Object storage, TLS certificate should be installed on the Object Storage server.

Steps to configure Velero

- First, create a secret for an ONTAP S3 user credential or StorageGrid Tenant user credentials. This will be used to configure Velero later. You can create a secret from the CLI or from the web console. To create a secret from the web console, select Secrets, then click on Key/Value Secret. Provide the values for the credential name, key and the value as shown. Be sure to use the Access Key Id and Secret Access Key of your S3 user. Name the secret appropriately. In the sample below, a secret with ONTAP S3 user credentials named ontp-s3-credentials is created.
To create a secret named sg-s3-credentials from the CLI you can use the following command.

```
# oc create secret generic sg-s3-credentials --namespace openshift-adp --from-file
cloud=cloud-credentials.txt
```

Where credentials.txt file contains the Access Key Id and the Secret Access Key of the S3 user in the following format:

```
[default]
aws_access_key_id=< Access Key ID of S3 user>
aws_secret_access_key=<Secret Access key of S3 user>
```

• Next, to configure Velero, select Installed Operators from the menu item under Operators, click on OADP operator, and then select the DataProtectionApplication tab.
Click on Create DataProtectionApplication. In the form view, provide a name for the DataProtection Application or use the default name.

Now go to the YAML view and replace the spec information as shown in the yaml file examples below.

Sample yaml file for configuring Velero with ONTAP S3 as the backupLocation
```yaml
spec:
  backupLocations:
    - velero:
      config:
        insecureSkipTLSVerify: 'false' -> use this for https communication with ONTAP S3
        profile: default
        region: us-east-1
        s3ForcePathStyle: 'True' -> This allows use of IP in s3URL
        s3Url: 'https://10.xx.xx.xx' -> LIF to access S3. Ensure TLS certificate for S3 is configured
      credential:
        key: cloud
        name: ontap-s3-credentials -> previously created secret
        default: true
      objectStorage:
        bucket: velero -> Your bucket name previously created in S3 for backups
        prefix: demobackup -> The folder that will be created in the bucket
      provider: aws
    configuration:
      nodeAgent:
        enable: true
        uploaderType: kopia
        # default Data Mover uses Kopia to move snapshots to Object Storage
      velero:
        defaultPlugins:
          - csi -> Add this plugin
          - openshift
          - aws
          - kubevirt -> Add this plugin
```

Sample yml file for configuring Velero with StorageGrid S3 as the backupLocation and snapshotLocation
The spec section in the yaml file should be configured appropriately for the following parameters similar to the example above.

**backupLocations**
ONTAP S3 or StorageGrid S3 (with its credentials and other information as shown in the yaml) is configured as the default BackupLocation for velero.

**snapshotLocations**
If you use Container Storage Interface (CSI) snapshots, you do not need to specify a snapshot location because you will create a VolumeSnapshotClass CR to register the CSI driver. In our example, you use Astra Trident CSI and you have previously created VolumeSnapshotClass CR using the Trident CSI driver.

**Enable CSI plugin**
Add csi to the defaultPlugins for Velero to back up persistent volumes with CSI snapshots. The Velero CSI plugins, to backup CSI backed PVCs, will choose the VolumeSnapshotClass in the cluster that has `velero.io/csi-volumesnapshot-class` label set on it. For this:

- You must have the trident VolumeSnapshotClass created.
- Edit the label of the trident-snapshotclass and set it to
Ensure that the snapshots can persist even if the VolumeSnapshot objects are deleted. This can be done by setting the `deletionPolicy` to Retain. If not, deleting a namespace will completely lose all PVCs ever backed up in it.

```yaml
apiVersion:snapshot.storage.k8s.io/v1
kind:VolumeSnapshotClass
metadata:
  name: trident-snapshotclass
driver: csi.trident.netapp.io
deletionPolicy: Retain
```
Ensure that the DataProtectionApplication is created and is in condition: Reconciled.

The OADP operator will create a corresponding BackupStorageLocation. This will be used when creating a backup.
Creating on-demand backup for VMs in OpenShift Virtualization

This section outlines how to create on-demand backup for VMs in OpenShift Virtualization.

Steps to create a backup of a VM

To create an on-demand backup of the entire VM (VM metadata and VM disks), click on the Backup tab. This creates a Backup Custom Resource (CR). A sample yaml is provided to create the Backup CR. Using this yaml, the VM and its disks in the specified namespace will be backed up. Additional parameters can be set as shown in the documentation.

A snapshot of the persistent volumes backing the disks will be created by the CSI. A backup of the VM along with the snapshot of its disks are created and stored in the backup location specified in the yaml. The backup will remain in the system for 30 days as specified in the ttl.
apiVersion: velero.io/v1
kind: Backup
metadata:
  name: backup1
  namespace: openshift-adp
spec:
  includedNamespaces:
  - virtual-machines-demo
  snapshotVolumes: true
  storageLocation: velero-demo-1 -->this is the backupStorageLocation previously created when Velero is configured.
  ttl: 720h0m0s

Once the backup completes, its Phase will show as completed.

You can inspect the backup in the Object storage with the help of an S3 browser application. The path of the backup shows in the configured bucket with the prefix name (velero/demobackup). You can see the contents of the backup includes the volume snapshots, logs, and other metadata of the virtual machine.

In StorageGrid, you can also use the S3 console that is available from the Tenant Manager to view the backup objects.
Creating scheduled backups for VMs in OpenShift Virtualization

To create backups on a schedule, you need to create a Schedule CR. The schedule is simply a Cron expression allowing you to specify the time at which you want to create the backup. A sample yaml to create a Schedule CR.

```
apiVersion: velero.io/v1
kind: Schedule
metadata:
  name: <schedule>
  namespace: openshift-adp
spec:
  schedule: 0 7 * * *
  template:
    hooks: {}
    includedNamespaces:
    - <namespace>
    storageLocation: velero-demo-1
    defaultVolumesToFsBackup: true
    ttl: 720h0m0s
```

The Cron expression 0 7 * * * means a backup will be created at 7:00 every day. The namespaces to be included in the backup and the storage location for the backup are also specified. So instead of a Backup CR, Schedule CR is used to create a backup at the specified time and frequency.

Once the schedule is created, it will be Enabled.
Backups will be created according to this schedule, and can be viewed from the Backup tab.

```
<table>
<thead>
<tr>
<th>Name</th>
<th>Kind</th>
<th>Status</th>
<th>Labels</th>
</tr>
</thead>
<tbody>
<tr>
<td>schedule</td>
<td>Schedule</td>
<td>Enabled</td>
<td>No labels</td>
</tr>
</tbody>
</table>
```

**Restore a VM from a backup**

This section describes how to restore virtual machine(s) from a backup.

**Prerequisites**

To restore from a backup, let us assume that the namespace where the virtual machine existed got accidentally deleted.
**Restore to the same namespace**

To restore from the backup that we just created, we need to create a Restore Custom Resource (CR). We need to provide it a name, provide the name of the backup that we want to restore from and set the restorePVs to true. Additional parameters can be set as shown in the [documentation](#). Click on Create button.

```yaml
apiVersion: velero.io/v1
kind: Restore
metadata:
  name: restore1
  namespace: openshift-adp
spec:
  backupName: backup1
  restorePVs: true
```

When the phase shows completed, you can see that the virtual machines have been restored to the state when the snapshot was taken. (If the backup was created when the VM was running, restoring the VM from the backup will start the restored VM and bring it to a running state). The VM is restored to the same namespace.
Restore to a different namespace

To restore the VM to a different namespace, you can provide a namespaceMapping in the yaml definition of the Restore CR.

The following sample yaml file creates a Restore CR to restore a VM and its disks in the virtual-machines-demo namespace when the backup was taken to the virtual-machines namespace.

```yaml
apiVersion: velero.io/v1
kind: Restore
metadata:
  name: restore-to-different-ns
  namespace: openshift-adp
spec:
  backupName: backup
  restorePVs: true
  includedNamespaces:
  - virtual-machines-demo
  namespaceMapping:
    virtual-machines-demo: virtual-machines
```

When the phase shows completed, you can see that the virtual machines have been restored to the state when the snapshot was taken. (If the backup was created when the VM was running, restoring the VM from the backup will start the restored VM and bring it to a running state). The VM is restored to a different namespace as specified in the yaml.

![Virtual Machines](image-url)
Restore to a different storage class

Velero provides a generic ability to modify the resources during restore by specifying json patches. The json patches are applied to the resources before they are restored. The json patches are specified in a configmap and the configmap is referenced in the restore command. This feature enables you to restore using different storage class.

In the example below, the virtual machine, during creation uses ontap-nas as the storage class for its disks. A backup of the virtual machine named backup1 is created.

![Virtual machine details](image)

Simulate a loss of the VM by deleting the VM.

To restore the VM using a different storage class, for example, ontap-nas-eco storage class, you need to do the following two steps:

**Step 1**

Create a config map (console) in the openshift-adp namespace as follows:
Fill in the details as shown in the screenshot:
Select namespace : openshift-adp
Name: change-storage-class-config (can be any name)
Key: change-storage-class-config.yaml:
Value:

```yaml
version: v1
resourceModifierRules:
  - conditions:
    groupResource: persistentvolumeclaims
    resourceNameRegex: "^rhel*"
    namespaces:
    - virtual-machines-demo
  patches:
  - operation: replace
    path: "/spec/storageClassName"
    value: "ontap-nas-eco"
```

The resulting config map object should look like this (CLI):
This config map will apply the resource modifier rule when the restore is created. A patch will be applied to replace the storage class name to `ontap-nas-eco` for all persistent volume claims starting with `rhel`.

**Step 2**

To restore the VM use the following command from the Velero CLI:

```
# velero restore create restore1 --from-backup backup1 --resource
-modifier-configmap change-storage-class-config -n openshift-adp
```

The VM is restored in the same namespace with the disks created using the storage class `ontap-nas-eco`. 
Deleting backups and restores in using Velero

This section outlines how to delete backups and restores for VMs in OpenShift Virtualization using Velero.

Deleting a backup

You can delete a Backup CR without deleting the Object Storage data by using the OC CLI tool.

```
oc delete backup <backup_CR_name> -n <velero_namespace>
```

If you want the delete the Backup CR and delete the associated object storage data, you can do so by using the Velero CLI tool.

Download the CLI as given in the instructions in the Velero documentation.

Execute the following delete command using the Velero CLI

```
velero backup delete <backup_CR_name> -n <velero_namespace>
```

Deleting a Restore

You can delete the Restore CR using the Velero CLI

```
velero restore delete restore --namespace openshift-adp
```

You can use oc command as well as the UI to delete the restore CR
Monitoring using Cloud Insights

Monitoring using Cloud Insights for VMs in Red Hat OpenShift Virtualization

Author: Banu Sundhar, NetApp

This section of the reference document provides details for integrating NetApp Cloud Insights with a Red Hat OpenShift Cluster to monitor OpenShift Virtualization VMs.

NetApp Cloud Insights is a cloud infrastructure monitoring tool that gives you visibility into your complete infrastructure. With Cloud Insights, you can monitor, troubleshoot, and optimize all your resources including your public clouds and your private data centers. For more information about NetApp Cloud Insights, refer to the Cloud Insights documentation.

To start using Cloud Insights, you must sign up on the NetApp BlueXP portal. For details, refer to the Cloud Insights Onboarding

Cloud Insights has several features that enable you to quickly and easily find data, troubleshoot issues, and provide insights into your environment. You can find data easily with powerful queries, you can visualize data in dashboards, and send email alerts for data thresholds you set. Refer to the video tutorials to help you understand these features.

For Cloud Insights to start collecting data you need the following

Data Collectors
There are 3 types of Data Collectors:
* Infrastructure (storage devices, network switches, compute infrastructure)
* Operating Systems (such as VMware or Windows)
* Services (such as Kafka)

Data Collectors discover information from the data sources, such as ONTAP storage device (infrastructure data collector). The information gathered is used for analysis, validation, monitoring, and troubleshooting.

Acquisition Unit
If you are using an infrastructure Data Collector, you also need an Acquisition Unit to inject data into Cloud Insights. An Acquisition Unit is a computer dedicated to hosting data collectors, typically a Virtual Machine. This computer is typically located in the same data center/VPC as the monitored items.

Telegraf Agents
Cloud Insights also supports Telegraf as its agent for collection of integration data. Telegraf is a plugin-driven server agent that can be used to collect and report metrics, events, and logs.

Cloud Insights Architecture
Integration with Cloud Insights for VMs in Red Hat OpenShift Virtualization

To start collecting data for VMs in OpenShift Virtualization you will need to install:

1. A Kubernetes monitoring operator and data collector to collect Kubernetes data
   For complete instructions, refer to the documentation.
2. An acquisition unit to collect data from ONTAP storage that provides persistent storage for the VM disks
   For complete instructions, refer to the documentation.
3. A data collector for ONTAP
   For complete instructions, refer to the documentation

Additionally, if you are using StorageGrid for VM backups, you need a data collector for the StorageGRID as well.

Sample Monitoring capabilities for VMs in Red Hat OpenShift Virtualization

This section discusses monitoring using Cloud Insights for VMs in Red Hat OpenShift Virtualization.

Monitoring based on events and creating Alerts

Here is a sample where the namespace that contains a VM in OpenShift Virtualization is monitored based on events. In this example, a monitor is created based on `logs.kubernetes.event` for the specified namespace in the cluster.
This query provides all the events for the virtual machine in the namespace. (There is only one virtual machine in the namespace). An advanced query can also be constructed to filter based on the event where the reason is “failed” or “FailedMount.” These events are typically created when there is an issue in creating a PV or mounting the PV to a pod indicating issues in the dynamic provisioner for creating persistent volumes for the VM.

While creating the Alert Monitor as shown above, you can also configure notification to recipients. You can also provide corrective actions or additional information that can be useful to resolve the error. In the above example, additional information could be to look into the Trident backend configuration and storage class definitions for resolving the issue.

**Change Analytics**

With Change Analytics, you can get a view of what changed in the state of your cluster including who made that change which can help in troubleshooting issues.
In the above example, Change Analysis is configured on the OpenShift cluster for the namespace that contains an OpenShift Virtualization VM. The dashboard shows changes against the timeline. You can drill down to see what changed and the click on All Changes Diff to see the diff of the manifests. From the manifest, you can see that a new backup of the persistent disks was created.
Backend Storage Mapping

With Cloud Insights, you can easily see the backend storage of the VM disks and several statistics about the PVCs.

You can click on the links under the backend column, which will pull data directly from the backend ONTAP storage.
Another way to look at all the pod to storage mapping is creating an All Metrics query From Observability menu under Explore.

Clicking on any of the links will give you the corresponding details from ONTP storage. For example, clicking on an SVM name in the storageVirtualMachine column will pull details about the SVM from ONTAP. Clicking on an internal volume name will pull details about the volume in ONTAP.
| zoneb | ntpachi-a300e9u25:zoneb:trident_p |
| zoneb | ntpachi-a300e9u25:zoneb:trident_p |
| demo  | ntpachi-a300e9u25:zoneb:trident_p |
| zoneb | ntpachi-a300e9u25:zoneb:trident_p |
| zoneb | ntpachi-a300e9u25:zoneb:trident_p |
| zoneb | ntpachi-a300e9u25:zoneb:trident_p |
| zoneb | ntpachi-a300e9u25:zoneb:trident_p |
| zoneb | ntpachi-a300e9u25:zoneb:trident_p |
| zoneb | ntpachi-a300e9u25:zoneb:trident_p |

The image shows a screenshot of a software interface, likely related to virtual machines or storage management. The interface includes various tables and graphs, indicating the status and statistics of the virtual machines. The tables list different zones and their corresponding identifiers, while the graphs provide visual data representations.
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