Red Hat Enterprise Linux 9 Building, running, and managing containers

Using Podman, Buildah, and Skopeo on Red Hat Enterprise Linux 9
Abstract

Red Hat Enterprise Linux 9 provides a number of command-line tools for working with container images. You can manage pods and container images using Podman. To build, update, and manage container images you can use Buildah. To copy and inspect images in remote repositories, you can use Skopeo.
Table of Contents

MAKING OPEN SOURCE MORE INCLUSIVE ................................................................. 7

PROVIDING FEEDBACK ON RED HAT DOCUMENTATION ........................................ 8

CHAPTER 1. STARTING WITH CONTAINERS ............................................................... 9
  1.1. CHARACTERISTICS OF PODMAN, BUILDAH, AND SKOPEO .............................. 9
  1.2. COMMON PODMAN COMMANDS ...................................................................... 10
  1.3. RUNNING CONTAINERS WITHOUT DOCKER ............................................... 12
  1.4. CHOOSING A RHEL ARCHITECTURE FOR CONTAINERS ................................. 13
  1.5. GETTING CONTAINER TOOLS ....................................................................... 13
  1.6. SETTING UP ROOTLESS CONTAINERS ......................................................... 14
  1.7. UPGRADING TO ROOTLESS CONTAINERS ................................................. 15
  1.8. SPECIAL CONSIDERATIONS FOR ROOTLESS CONTAINERS ......................... 16
  1.9. ADDITIONAL RESOURCES ........................................................................... 17

CHAPTER 2. TYPES OF CONTAINER IMAGES ............................................................ 18
  2.1. GENERAL CHARACTERISTICS OF RHEL CONTAINER IMAGES ..................... 18
  2.2. CHARACTERISTICS OF UBI IMAGES ................................................................ 18
  2.3. UNDERSTANDING THE UBI STANDARD IMAGES ........................................... 19
  2.4. UNDERSTANDING THE UBI INIT IMAGES ...................................................... 20
  2.5. UNDERSTANDING THE UBI MINIMAL IMAGES ............................................. 20
  2.6. UNDERSTANDING THE UBI MICRO IMAGES .............................................. 21

CHAPTER 3. WORKING WITH CONTAINER REGISTRIES .......................................... 22
  3.1. CONTAINER REGISTRIES .............................................................................. 22
  3.2. CONFIGURING CONTAINER REGISTRIES ..................................................... 23
  3.3. SEARCHING FOR CONTAINER IMAGES ....................................................... 24
  3.4. PULLING IMAGES FROM REGISTRIES ......................................................... 25
  3.5. CONFIGURING SHORT-NAME ALIASES ....................................................... 26

CHAPTER 4. WORKING WITH CONTAINER IMAGES ............................................... 28
  4.1. PULLING CONTAINER IMAGES USING SHORT-NAME ALIASES ....................... 28
  4.2. LISTING IMAGES .......................................................................................... 29
  4.3. INSPECTING LOCAL IMAGES ....................................................................... 29
  4.4. INSPECTING REMOTE IMAGES .................................................................. 30
  4.5. COPYING CONTAINER IMAGES ................................................................... 31
  4.6. COPYING IMAGE LAYERS TO A LOCAL DIRECTORY ..................................... 31
  4.7. TAGGING IMAGES ........................................................................................ 32
  4.8. SAVING AND LOADING IMAGES .................................................................. 33
  4.9. REDISTRIBUTING UBI IMAGES ................................................................... 34
  4.10. REMOVING IMAGES ................................................................................... 35

CHAPTER 5. WORKING WITH CONTAINERS ............................................................. 37
  5.1. PODMAN RUN COMMAND ............................................................................ 37
  5.2. RUNNING COMMANDS IN A CONTAINER FROM THE HOST ......................... 37
  5.3. RUNNING COMMANDS INSIDE THE CONTAINER ......................................... 38
  5.4. LISTING CONTAINERS .................................................................................. 39
  5.5. STARTING CONTAINERS ............................................................................... 40
  5.6. INSPECTING CONTAINERS FROM THE HOST ............................................. 40
  5.7. MOUNTING DIRECTORY ON LOCALHOST TO THE CONTAINER ............... 41
  5.8. MOUNTING A CONTAINER FILESYSTEM ..................................................... 42
  5.9. RUNNING A SERVICE AS A DAEMON WITH A STATIC IP .............................. 43
  5.10. EXECUTING COMMANDS INSIDE A RUNNING CONTAINER ....................... 43
<table>
<thead>
<tr>
<th>Chapter</th>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.11</td>
<td>SHARING FILES BETWEEN TWO CONTAINERS</td>
<td>45</td>
</tr>
<tr>
<td>5.12</td>
<td>EXPORTING AND IMPORTING CONTAINERS</td>
<td>47</td>
</tr>
<tr>
<td>5.13</td>
<td>STOPPING CONTAINERS</td>
<td>49</td>
</tr>
<tr>
<td>5.14</td>
<td>REMOVING CONTAINERS</td>
<td>49</td>
</tr>
<tr>
<td>5.15</td>
<td>CREATING SELINUX POLICIES FOR CONTAINERS</td>
<td>50</td>
</tr>
<tr>
<td>5.16</td>
<td>CONFIGURING PRE-EXECUTION HOOKS IN PODMAN</td>
<td>51</td>
</tr>
<tr>
<td>6.1</td>
<td>SELECTING A CONTAINER RUNTIME</td>
<td>53</td>
</tr>
<tr>
<td>6.2</td>
<td>THE RUNC CONTAINER RUNTIME</td>
<td>53</td>
</tr>
<tr>
<td>6.3</td>
<td>THE CRUN CONTAINER RUNTIME</td>
<td>53</td>
</tr>
<tr>
<td>6.4</td>
<td>RUNNING CONTAINERS WITH RUNC AND CRUN</td>
<td>53</td>
</tr>
<tr>
<td>6.5</td>
<td>TEMPORARILY CHANGING THE CONTAINER RUNTIME</td>
<td>55</td>
</tr>
<tr>
<td>6.6</td>
<td>PERMANENTLY CHANGING THE CONTAINER RUNTIME</td>
<td>55</td>
</tr>
<tr>
<td>7.1</td>
<td>ADDING SOFTWARE TO A UBI CONTAINER</td>
<td>57</td>
</tr>
<tr>
<td>7.2</td>
<td>USING THE UBI INIT IMAGES</td>
<td>57</td>
</tr>
<tr>
<td>7.3</td>
<td>USING THE UBI MICRO IMAGES</td>
<td>58</td>
</tr>
<tr>
<td>7.4</td>
<td>ADDING SOFTWARE TO A UBI CONTAINER ON A SUBSCRIBED HOST</td>
<td>59</td>
</tr>
<tr>
<td>7.5</td>
<td>ADDING SOFTWARE IN A STANDARD UBI CONTAINER</td>
<td>60</td>
</tr>
<tr>
<td>7.6</td>
<td>ADDING SOFTWARE IN A MINIMAL UBI CONTAINER</td>
<td>61</td>
</tr>
<tr>
<td>7.7</td>
<td>BUILDING UBI-BASED IMAGES</td>
<td>62</td>
</tr>
<tr>
<td>7.8</td>
<td>USING APPLICATION STREAM RUNTIME IMAGES</td>
<td>64</td>
</tr>
<tr>
<td>7.9</td>
<td>GETTING UBI CONTAINER IMAGE SOURCE CODE</td>
<td>64</td>
</tr>
<tr>
<td>8.1</td>
<td>SIGNING CONTAINER IMAGES</td>
<td>66</td>
</tr>
<tr>
<td>8.2</td>
<td>SIGNING CONTAINER IMAGES WITH GPG SIGNATURES</td>
<td>66</td>
</tr>
<tr>
<td>8.3</td>
<td>VERIFYING GPG IMAGE SIGNATURES</td>
<td>67</td>
</tr>
<tr>
<td>8.4</td>
<td>SIGNING CONTAINER IMAGES WITH SIGSTORE SIGNATURES USING A PRIVATE KEY</td>
<td>69</td>
</tr>
<tr>
<td>8.5</td>
<td>VERIFYING SIGSTORE IMAGE SIGNATURES USING A PUBLIC KEY</td>
<td>70</td>
</tr>
<tr>
<td>8.6</td>
<td>SIGNING CONTAINER IMAGES WITH SIGSTORE SIGNATURES USING FULCIO AND REKOR</td>
<td>72</td>
</tr>
<tr>
<td>8.7</td>
<td>VERIFYING CONTAINER IMAGES WITH SIGSTORE SIGNATURES USING FULCIO AND REKOR</td>
<td>73</td>
</tr>
<tr>
<td>9.1</td>
<td>MANAGING A CONTAINER NETWORK</td>
<td>77</td>
</tr>
<tr>
<td>9.2</td>
<td>LISTING CONTAINER NETWORKS</td>
<td>77</td>
</tr>
<tr>
<td>9.3</td>
<td>INSPECTING A NETWORK</td>
<td>77</td>
</tr>
<tr>
<td>9.4</td>
<td>CREATING A NETWORK</td>
<td>79</td>
</tr>
<tr>
<td>9.5</td>
<td>CONNECTING A CONTAINER TO A NETWORK</td>
<td>79</td>
</tr>
<tr>
<td>9.6</td>
<td>DISCONNECTING A CONTAINER FROM A NETWORK</td>
<td>80</td>
</tr>
<tr>
<td>9.7</td>
<td>REMOVING A NETWORK</td>
<td>80</td>
</tr>
<tr>
<td>10.1</td>
<td>WORKING WITH PODS</td>
<td>83</td>
</tr>
<tr>
<td>10.2</td>
<td>CREATING PODS</td>
<td>83</td>
</tr>
<tr>
<td>10.3</td>
<td>DISPLAYING POD INFORMATION</td>
<td>84</td>
</tr>
<tr>
<td>10.4</td>
<td>STOPPING PODS</td>
<td>85</td>
</tr>
<tr>
<td>10.5</td>
<td>REMOVING PODS</td>
<td>86</td>
</tr>
<tr>
<td>11.1</td>
<td>COMMUNICATING AMONG CONTAINERS</td>
<td>88</td>
</tr>
<tr>
<td>11.2</td>
<td>THE NETWORK MODES AND LAYERS</td>
<td>88</td>
</tr>
<tr>
<td>11.3</td>
<td>INSPECTING A NETWORK SETTINGS OF A CONTAINER</td>
<td>88</td>
</tr>
<tr>
<td>11.4</td>
<td>COMMUNICATING BETWEEN A CONTAINER AND AN APPLICATION</td>
<td>89</td>
</tr>
<tr>
<td>11.5</td>
<td>COMMUNICATING BETWEEN CONTAINERS USING PORT MAPPING</td>
<td>90</td>
</tr>
</tbody>
</table>

Red Hat Enterprise Linux 9 Building, running, and managing containers
17.10. CREATING CONTAINERS IN THE POD IN THE WEB CONSOLE 144
17.11. CHANGING THE STATE OF PODS IN THE WEB CONSOLE 144
17.12. DELETING PODS IN THE WEB CONSOLE 145

CHAPTER 18. RUNNING SKOPEO, BUILDAH, AND PODMAN IN A CONTAINER 145
18.1. RUNNING SKOPEO IN A CONTAINER 145
18.2. RUNNING SKOPEO IN A CONTAINER USING CREDENTIALS 146
18.3. RUNNING SKOPEO IN A CONTAINER USING AUTHFILES 147
18.4. COPYING CONTAINER IMAGES TO OR FROM THE HOST 148
18.5. RUNNING BUILDAH IN A CONTAINER 148
18.6. PRIVILEGED AND UNPRIVILEGED PODMAN CONTAINERS 150
18.7. RUNNING PODMAN WITH EXTENDED PRIVILEGES 150
18.8. RUNNING PODMAN WITH LESS PRIVILEGES 151
18.9. BUILDING A CONTAINER INSIDE A PODMAN CONTAINER 152

CHAPTER 19. BUILDING CONTAINER IMAGES WITH BUILDAH 154
19.1. THE BUILDAH TOOL 154
19.2. INSTALLING BUILDAH 154
19.3. GETTING IMAGES WITH BUILDAH 155
19.4. BUILDING AN IMAGE FROM A CONTAINERFILE WITH BUILDAH 156
19.5. CREATING IMAGES FROM SCRATCH WITH BUILDAH 157
19.6. REMOVING IMAGES WITH BUILDAH 159

CHAPTER 20. WORKING WITH CONTAINERS USING BUILDAH 160
20.1. RUNNING COMMANDS INSIDE OF THE CONTAINER 160
20.2. INSPECTING CONTAINERS AND IMAGES WITH BUILDAH 160
20.3. MODIFYING A CONTAINER USING BUILDAH MOUNT 161
20.4. MODIFYING A CONTAINER USING BUILDAH COPY AND BUILDAH CONFIG 162
20.5. PUSHING CONTAINERS TO A PRIVATE REGISTRY 164
20.6. PUSHING CONTAINERS TO THE DOCKER HUB 165
20.7. REMOVING CONTAINERS WITH BUILDAH 166

CHAPTER 21. MONITORING CONTAINERS 167
21.1. USING A HEALTH CHECK ON A CONTAINER 167
21.2. PERFORMING A HEALTH CHECK USING THE COMMAND LINE 168
21.3. PERFORMING A HEALTH CHECK USING A CONTAINERFILE 169
21.4. DISPLAYING PODMAN SYSTEM INFORMATION 171
21.5. PODMAN EVENT TYPES 174
21.6. MONITORING PODMAN EVENTS 176
21.7. USING PODMAN EVENTS FOR AUDITING 178

CHAPTER 22. CREATING AND RESTORING CONTAINER CHECKPOINTS 180
22.1. CREATING AND RESTORING A CONTAINER CHECKPOINT LOCALLY 180
22.2. REDUCING STARTUP TIME USING CONTAINER RESTORE 182
22.3. MIGRATING CONTAINERS AMONG SYSTEMS 183

CHAPTER 23. USING PODMAN IN HPC ENVIRONMENT 186
23.1. USING PODMAN WITH MPI 186
23.2. THE MPRUN OPTIONS 187

CHAPTER 24. RUNNING SPECIAL CONTAINER IMAGES 189
24.1. OPENING PRIVILEGES TO THE HOST 189
24.2. CONTAINER IMAGES WITH RUNLABELS 189
24.3. RUNNING RSYSLOG WITH RUNLABELS 189
Red Hat is committed to replacing problematic language in our code, documentation, and web properties. We are beginning with these four terms: master, slave, blacklist, and whitelist. Because of the enormity of this endeavor, these changes will be implemented gradually over several upcoming releases. For more details, see our CTO Chris Wright’s message.
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CHAPTER 1. STARTING WITH CONTAINERS

Linux containers have emerged as a key open source application packaging and delivery technology, combining lightweight application isolation with the flexibility of image-based deployment methods. Red Hat Enterprise Linux implements Linux containers using core technologies such as:

- Control groups (cgroups) for resource management
- Namespaces for process isolation
- SELinux for security
- Secure multi-tenancy

These technologies reduce the potential for security exploits and provide you with an environment for producing and running enterprise-quality containers.

Red Hat OpenShift provides powerful command-line and Web UI tools for building, managing, and running containers in units referred to as pods. Red Hat allows you to build and manage individual containers and container images outside of OpenShift. This guide describes the tools provided to perform those tasks that run directly on RHEL systems.

Unlike other container tools implementations, the tools described here do not center around the monolithic Docker container engine and `docker` command. Instead, Red Hat provides a set of command-line tools that can operate without a container engine. These include:

- **podman** - for directly managing pods and container images (run, stop, start, ps, attach, exec, and so on)
- **buildah** - for building, pushing, and signing container images
- **skopeo** - for copying, inspecting, deleting, and signing images
- **runc** - for providing container run and build features to podman and buildah
- **crun** - an optional runtime that can be configured and gives greater flexibility, control, and security for rootless containers

Because these tools are compatible with the Open Container Initiative (OCI), they can be used to manage the same Linux containers that are produced and managed by Docker and other OCI-compatible container engines. However, they are especially suited to run directly on Red Hat Enterprise Linux, in single-node use cases.

For a multi-node container platform, see OpenShift and Using the CRI-O Container Engine for details.

1.1. CHARACTERISTICS OF PODMAN, BUILDAH, AND SKOPEO

The Podman, Skopeo, and Buildah tools were developed to replace Docker command features. Each tool in this scenario is more lightweight and focused on a subset of features.

The main advantages of Podman, Skopeo and Buildah tools include:

- Running in rootless mode - rootless containers are much more secure, as they run without any added privileges
- No daemon required - these tools have much lower resource requirements at idle, because if you are not running containers, Podman is not running. Docker, conversely, have a daemon always running.

- Native `systemd` integration - Podman allows you to create `systemd` unit files and run containers as system services.

The characteristics of Podman, Skopeo, and Buildah include:

- Podman, Buildah, and the CRI-O container engine all use the same back-end store directory, `/var/lib/containers`, instead of using the Docker storage location `/var/lib/docker`, by default.

- Although Podman, Buildah, and CRI-O share the same storage directory, they cannot interact with each other’s containers. Those tools can share images.

- To interact programmatically with Podman, you can use the Podman v2.0 RESTful API, it works in both a rootful and a rootless environment. For more information, see Using the container-tools API chapter.

Additional resources

- Say "Hello" to Buildah, Podman, and Skopeo
- Podman and Buildah for Docker users
- Buildah: A tool for building OCI container images
- Podman: A tool for managing OCI containers and pods
- Skopeo: A tool for copying and inspecting container images

1.2. COMMON PODMAN COMMANDS

You can manage images, containers, and container resources with the `podman` utility by using the following basic commands. To display a full list of all Podman commands, use `podman -h`.

- **attach**
  Attach to a running container.

- **commit**
  Create new image from changed container.

- **container checkpoint**
  Checkpoint one or more running containers.

- **container restore**
  Restore one or more containers from a checkpoint.

- **build**
  Build an image using Containerfile instructions.

- **create**
  Create, but do not start, a container.

- **diff**
  Inspect changes on container’s filesystems.

- **exec**
Run a process in a running container.

**export**
Export container’s filesystem contents as a tar archive.

**help, h**
Show a list of commands or help for one command.

**healthcheck**
Run a container healthcheck.

**history**
Show history of a specified image.

**images**
List images in local storage.

**import**
Import a tarball to create a filesystem image.

**info**
Display system information.

**inspect**
Display the configuration of a container or image.

**kill**
Send a specific signal to one or more running containers.

**kube generate**
Generate Kubernetes YAML based on containers, pods or volumes.

**kube play**
Create containers, pods and volumes based on Kubernetes YAML.

**load**
Load an image from an archive.

**login**
Login to a container registry.

**logout**
Logout of a container registry.

**logs**
Fetch the logs of a container.

**mount**
Mount a working container’s root filesystem.

**pause**
Pause all the processes in one or more containers.

**ps**
List containers.

**port**
List port mappings or a specific mapping for the container.

**pull**
Pull an image from a registry.
push
 Push an image to a specified destination.

restart
 Restart one or more containers.

rm
 Remove one or more containers from the host. Add -f if running.

rmi
 Remove one or more images from local storage.

run
 Run a command in a new container.

save
 Save image to an archive.

search
 Search registry for image.

start
 Start one or more containers.

stats
 Display percentage of CPU, memory, network I/O, block I/O and PIDs for one or more containers.

stop
 Stop one or more containers.

tag
 Add an additional name to a local image.

top
 Display the running processes of a container.

unmount, unmount
 Unmount a working container’s root filesystem.

unpause
 Unpause the processes in one or more containers.

version
 Display podman version information.

wait
 Block on one or more containers.

Additional resources

- Podman Basics Cheat Sheet
- 5 Podman features to try now

1.3. RUNNING CONTAINERS WITHOUT DOCKER

Red Hat removed the Docker container engine and the docker command from RHEL 9.
If you still want to use Docker in RHEL, you can get Docker from different upstream projects, but it is unsupported in RHEL 9.

- You can install the podman-docker package, every time you run a docker command, it actually runs a podman command.

- Podman also supports the Docker Socket API, so the podman-docker package also sets up a link between /var/run/docker.sock and /var/run/podman/podman.sock. As a result, you can continue to run your Docker API commands with docker-py and docker-compose tools without requiring the Docker daemon. Podman will service the requests.

- The podman command, like the docker command, can build container images from a Containerfile or Dockerfile. The available commands that are usable inside a Containerfile and a Dockerfile are equivalent.

- Options to the docker command that are not supported by podman include network, node, plugin (podman does not support plugins), rename (use rm and create to rename containers with podman), secret, service, stack, and swarm (podman does not support Docker Swarm). The container and image options are used to run subcommands that are used directly in podman.

Additional resources

- Podman and Buildah for Docker users

1.4. CHOOSING A RHEL ARCHITECTURE FOR CONTAINERS

Red Hat provides container images and container-related software for the following computer architectures:

- AMD64 and Intel 64 (base and layered images; no support for 32-bit architectures)
- PowerPC 8 and 9 64-bit (base image and most layered images)
- 64-bit IBM Z (base image and most layered images)
- ARM 64-bit (base image only)

Although not all Red Hat images were supported across all architectures at first, nearly all are now available on all listed architectures.

Additional resources

- Universal Base Images (UBI): Images, repositories, and packages

1.5. GETTING CONTAINER TOOLS

This procedure shows how you can install the container-tools meta-package which contains the Podman, Buildah, Skopeo, CRIU, Udica, and all required libraries.

NOTE

The stable streams are not available on RHEL 9. To receive stable access to Podman, Buildah, Skopeo, and others, use the RHEL EUS subscription.
Procedure

1. Install RHEL.

2. Register RHEL: Enter your user name and password. The user name and password are the same as your login credentials for Red Hat Customer Portal:

   ```sh
   # subscription-manager register
   Registering to: subscription.rhsm.redhat.com:443/subscription
   Username: <username>
   Password: <password>
   ```

3. Subscribe to RHEL.
   - To auto-subscribe to RHEL:
     ```sh
     # subscription-manager attach --auto
     ```
   - To subscribe to RHEL by Pool ID:
     ```sh
     # subscription-manager attach --pool <PoolID>
     ```

4. Install the `container-tools` meta-package:
   ```sh
   # dnf install container-tools
   ```

5. Optional: Install the `podman-docker` package:
   ```sh
   # dnf install podman-docker
   ```
   The `podman-docker` package replaces the Docker command-line interface and `docker-api` with the matching Podman commands instead.

1.6. SETTING UP ROOTLESS CONTAINERS

Running the container tools such as Podman, Skopeo, or Buildah as a user with superuser privileges (root user) is the best way to ensure that your containers have full access to any feature available on your system. However, with the feature called “Rootless Containers” generally available as of Red Hat Enterprise Linux 8.1, you can work with containers as a regular user.

Although container engines, such as Docker, let you run Docker commands as a regular (non-root) user, the Docker daemon that carries out those requests runs as root. As a result, regular users can make requests through their containers that can harm the system. By setting up rootless container users, system administrators prevent potentially damaging container activities from regular users, while still allowing those users to safely run most container features under their own accounts.

This procedure describes how to set up your system to use Podman, Skopeo, and Buildah tools to work with containers as a non-root user (rootless). It also describes some of the limitations you will encounter, because regular user accounts do not have full access to all operating system features that their containers might need to run.

Prerequisites
You need to become a root user to set up your RHEL system to allow non-root user accounts to use container tools.

Procedure

1. Install RHEL.
2. Install the podman package:
   
   ```
   # dnf install podman -y
   ```
3. Create a new user account:
   
   ```
   # useradd -c "Joe Jones" joe
   # passwd joe
   ```
   - The user is automatically configured to be able to use rootless Podman.
   - The `useradd` command automatically sets the range of accessible user and group IDs automatically in the `/etc/subuid` and `/etc/subgid` files.
   - If you change the `/etc/subuid` or `/etc/subgid` manually, you have to run the `podman system migrate` command to allow the new changes to be applied.
4. Connect to the user:
   
   ```
   $ ssh joe@server.example.com
   ```
   **NOTE**
   Do not use `su` or `su -` commands because these commands do not set the correct environment variables.
5. Pull the `registry.access.redhat.com/ubi9/ubi` container image:
   
   ```
   $ podman pull registry.access.redhat.com/ubi9/ubi
   ```
6. Run the container named `myubi` and display the OS version:
   
   ```
   $ podman run --rm --name=myubi registry.access.redhat.com/ubi9/ubi \
   cat /etc/os-release
   NAME="Red Hat Enterprise Linux"
   VERSION="9 (Plow)"
   ```

Additional resources

- Rootless containers with Podman: The basics
- podman-system-migrate man page

1.7. UPGRADING TO ROOTLESS CONTAINERS
To upgrade to rootless containers from Red Hat Enterprise Linux 7, you must configure user and group IDs manually.

Here are some things to consider when upgrading to rootless containers from Red Hat Enterprise Linux 7:

- If you set up multiple rootless container users, use unique ranges for each user.
- Use 65536 UIDs and GIDs for maximum compatibility with existing container images, but the number can be reduced.
- Never use UIDs or GIDs under 1000 or reuse UIDs or GIDs from existing user accounts (which, by default, start at 1000).

Prerequisites

- The user account has been created.

Procedure

- Run the `usermod` command to assign UIDs and GIDs to a user:
  
  ```
  # usermod --add-subuids 200000-201000 --add-subgids 200000-201000 <username>
  ```

  - The `usermod --add-subuid` command manually adds a range of accessible user IDs to the user’s account.
  - The `usermod --add-subgids` command manually adds a range of accessible user GIDs and group IDs to the user’s account.

Verification steps

- Check that the UIDs and GIDs are set properly:
  
  ```
  # grep <username> /etc/subuid /etc/subgid
  /etc/subuid:<username>:200000:1001
  /etc/subgid:<username>:200000:1001
  ```

1.8. SPECIAL CONSIDERATIONS FOR ROOTLESS CONTAINERS

There are several considerations when running containers as a non-root user:

- The path to the host container storage is different for root users (`/var/lib/containers/storage`) and non-root users (`$HOME/.local/share/containers/storage`).
- Users running rootless containers are given special permission to run as a range of user and group IDs on the host system. However, they have no root privileges to the operating system on the host.
- If you change the `/etc/subuid` or `/etc/subgid` manually, you have to run the `podman system migrate` command to allow the new changes to be applied.
- If you need to configure your rootless container environment, create configuration files in your home directory (`$HOME/.config/containers`). Configuration files include `storage.conf` (for configuring storage) and `containers.conf` (for a variety of container settings). You could also
create a `registries.conf` file to identify container registries that are available when you use Podman to pull, search, or run images.

- There are some system features you cannot change without root privileges. For example, you cannot change the system clock by setting a `SYS_TIME` capability inside a container and running the network time service (`ntpd`). You have to run that container as root, bypassing your rootless container environment and using the root user’s environment. For example:

```
# podman run -d --cap-add SYS_TIME ntpd
```

Note that this example allows `ntpd` to adjust time for the entire system, and not just within the container.

- A rootless container cannot access a port numbered less than 1024. Inside the rootless container namespace it can, for example, start a service that exposes port 80 from an `httpd` service from the container, but it is not accessible outside of the namespace:

```
$ podman run -d httpd
```

However, a container would need root privileges, using the root user’s container environment, to expose that port to the host system:

```
# podman run -d -p 80:80 httpd
```

- The administrator of a workstation can allow users to expose services on ports numbered lower than 1024, but they should understand the security implications. A regular user could, for example, run a web server on the official port 80 and make external users believe that it was configured by the administrator. This is acceptable on a workstation for testing, but might not be a good idea on a network-accessible development server, and definitely should not be done on production servers. To allow users to bind to ports down to port 80 run the following command:

```
# echo 80 > /proc/sys/net/ipv4/ip_unprivileged_port_start
```

Additional resources

- Shortcomings of Rootless Podman

1.9. ADDITIONAL RESOURCES

- A Practical Introduction to Container Terminology
CHAPTER 2. TYPES OF CONTAINER IMAGES

The container image is a binary that includes all of the requirements for running a single container, and metadata describing its needs and capabilities.

There are two types of container images:

- Red Hat Enterprise Linux Base Images (RHEL base images)
- Red Hat Universal Base Images (UBI images)

Both types of container images are built from portions of Red Hat Enterprise Linux. By using these containers, users can benefit from great reliability, security, performance and life cycles.

The main difference between the two types of container images is that the UBI images allow you to share container images with others. You can build a containerized application using UBI, push it to your choice of registry server, easily share it with others, and even deploy it on non-Red Hat platforms. The UBI images are designed to be a foundation for cloud-native and web applications use cases developed in containers.

2.1. GENERAL CHARACTERISTICS OF RHEL CONTAINER IMAGES

Following characteristics apply to both RHEL base images and UBI images.

In general, RHEL container images are:

- **Supported**: Supported by Red Hat for use with containerized applications. They contain the same secured, tested, and certified software packages found in Red Hat Enterprise Linux.
- **Cataloged**: Listed in the [Red Hat Container Catalog](#), with descriptions, technical details, and a health index for each image.
- **Updated**: Offered with a well-defined update schedule, to get the latest software, see [Red Hat Container Image Updates](#) article.
- **Tracked**: Tracked by Red Hat Product Errata to help understand the changes that are added into each update.
- **Reusable**: The container images need to be downloaded and cached in your production environment once. Each container image can be reused by all containers that include it as their foundation.

2.2. CHARACTERISTICS OF UBI IMAGES

The UBI images allow you to share container images with others. Four UBI images are offered: micro, minimal, standard, and init. Pre-build language runtime images and DNF repositories are available to build your applications.

Following characteristics apply to UBI images:

- **Built from a subset of RHEL content**: Red Hat Universal Base images are built from a subset of normal Red Hat Enterprise Linux content.
- **Redistributable**: UBI images allow standardization for Red Hat customers, partners, ISVs, and others. With UBI images, you can build your container images on a foundation of official Red Hat software that can be freely shared and deployed.
• **Provide a set of four base images** micro, minimal, standard, and init.

• **Provide a set of pre-built language runtime container images** The runtime images based on Application Streams provide a foundation for applications that can benefit from standard, supported runtimes such as python, perl, php, dotnet, nodejs, and ruby.

• **Provide a set of associated DNF repositories** DNF repositories include RPM packages and updates that allow you to add application dependencies and rebuild UBI container images.
  - The **ubi-9-baseos** repository holds the redistributable subset of RHEL packages you can include in your container.
  - The **ubi-9-appstream** repository holds Application streams packages that you can add to a UBI image to help you standardize the environments you use with applications that require particular runtimes.
  - **Adding UBI RPMs**: You can add RPM packages to UBI images from preconfigured UBI repositories. If you happen to be in a disconnected environment, you must allowlist the UBI Content Delivery Network (https://cdn-ubi.redhat.com) to use that feature. See the Connect to https://cdn-ubi.redhat.com solution for details.

• **Licensing**: You are free to use and redistribute UBI images, provided you adhere to the Red Hat Universal Base Image End User Licensing Agreement.

---

**NOTE**

All of the layered images are based on UBI images. To check on which UBI image is your image based, display the Containerfile in the Red Hat Container Catalog and ensure that the UBI image contains all required content.

Additional resources

- Introducing the Red Hat Universal Base Image
- Universal Base Images (UBI): Images, repositories, and packages
- All You Need to Know About Red Hat Universal Base Image
- FAQ - Universal Base Images

**2.3. UNDERSTANDING THE UBI STANDARD IMAGES**

The standard images (named **ubi**) are designed for any application that runs on RHEL. The key features of UBI standard images include:

- **init system**: All the features of the systemd initialization system you need to manage systemd services are available in the standard base images. These init systems let you install RPM packages that are pre-configured to start up services automatically, such as a Web server (httpd) or FTP server (vsftpd).

- **dnf**: You have access to free dnf repositories for adding and updating software. You can use the standard set of dnf commands (**dnf**, **dnf-config-manager**, **dnfdownloader**, and so on).

- **utilities**: Utilities include **tar**, **dmidecode**, **gzip**, **getfacl** and further acl commands, **dmsetup** and further device mapper commands, between other utilities not mentioned here.
2.4. UNDERSTANDING THE UBI INIT IMAGES

The UBI init images, named ubi-init, contain the systemd initialization system, making them useful for building images in which you want to run systemd services, such as a web server or file server. The init image contents are less than what you get with the standard images, but more than what is in the minimal images.

NOTE

Because the ubi9-init image builds on top of the ubi9 image, their contents are mostly the same. However, there are a few critical differences:

- ubi9-init:
  - CMD is set to /sbin/init to start the systemd Init service by default
  - includes ps and process related commands (procps-ng package)
  - sets SIGRTMIN+3 as the StopSignal, as systemd in ubi9-init ignores normal signals to exit (SIGTERM and SIGKILL), but will terminate if it receives SIGRTMIN+3

- ubi9:
  - CMD is set to /bin/bash
  - does not include ps and process related commands (procps-ng package)
  - does not ignore normal signals to exit (SIGTERM and SIGKILL)

2.5. UNDERSTANDING THE UBI MINIMAL IMAGES

The UBI minimal images, named ubi-minimal offer a minimized pre-installed content set and a package manager (microdnf). As a result, you can use a Containerfile while minimizing the dependencies included in the image.

The key features of UBI minimal images include:

- **Small size**: Minimal images are about 92M on disk and 32M, when compressed. This makes it less than half the size of the standard images.

- **Software installation (microdnf)**: Instead of including the fully-developed dnf facility for working with software repositories and RPM software packages, the minimal images includes the microdnf utility. The microdnf is a scaled-down version of dnf allowing you to enable and disable repositories, remove and update packages, and clean out cache after packages have been installed.

- **Based on RHEL packaging**: Minimal images incorporate regular RHEL software RPM packages, with a few features removed. Minimal images do not include initialization and service management system, such as systemd or System V init, Python run-time environment, and some shell utilities. You can rely on RHEL repositories for building your images, while carrying the smallest possible amount of overhead.

- **Modules for microdnf are supported**: Modules used with microdnf command let you install multiple versions of the same software, when available. You can use microdnf module enable, microdnf module disable, and microdnf module reset to enable, disable, and reset a module.
stream, respectively.

- For example, to enable the `nodejs:14` module stream inside the UBI minimal container, enter:

```bash
# microdnf module enable nodejs:14
Downloading metadata...
...
Enabling module streams:
  nodejs:14

Running transaction test...
```

Red Hat only supports the latest version of UBI and does not support parking on a dot release. If you need to park on a specific dot release, please take a look at Extended Update Support.

### 2.6. UNDERSTANDING THE UBI MICRO IMAGES

The **ubi-micro** is the smallest possible UBI image, obtained by excluding a package manager and all of its dependencies which are normally included in a container image. This minimizes the attack surface of container images based on the **ubi-micro** image and is suitable for minimal applications, even if you use UBI Standard, Minimal, or Init for other applications. The container image without the Linux distribution packaging is called a Distroless container image.
CHAPTER 3. WORKING WITH CONTAINER REGISTRIES

A container image registry is a repository or collection of repositories for storing container images and container-based application artifacts. The 
/etc/containers/registries.conf file is a system-wide configuration file containing the container image registries that can be used by the various container tools such as Podman, Buildah, and Skopeo.

If the container image given to a container tool is not fully qualified, then the container tool references the registries.conf file. Within the registries.conf file, you can specify aliases for short names, granting administrators full control over where images are pulled from when not fully qualified. For example, the podman pull example.com/example_image command pulls a container image from the example.com registry to your local system as specified in the registries.conf file.

3.1. CONTAINER REGISTRIES

A container registry is a repository or collection of repositories for storing container images and container-based application artifacts. The registries that Red Hat provides are:

- registry.redhat.io (requires authentication)
- registry.access.redhat.com (requires no authentication)
- registry.connect.redhat.com (holds Red Hat Partner Connect program images)

To get container images from a remote registry, such as Red Hat’s own container registry, and add them to your local system, use the podman pull command:

```
# podman pull <registry>[:<port>]/[<namespace>/]<name>:<tag>
```

where `<registry>[:<port>]/[<namespace>/]<name>:<tag>` is the name of the container image.

For example, the registry.redhat.io/ubi9/ubi container image is identified by:

- Registry server (registry.redhat.io)
- Namespace (ubi9)
- Image name (ubi)

If there are multiple versions of the same image, add a tag to explicitly specify the image name. By default, Podman uses the :latest tag, for example ubi9/ubi:latest.

Some registries also use `<namespace>` to distinguish between images with the same `<name>` owned by different users or organizations. For example:

<table>
<thead>
<tr>
<th>Namespace</th>
<th>Examples (&lt;namespace&gt;/&lt;name&gt;)</th>
</tr>
</thead>
<tbody>
<tr>
<td>organization</td>
<td>redhat/kubernetes, google/kubernetes</td>
</tr>
<tr>
<td>login (user name)</td>
<td>alice/application, bob/application</td>
</tr>
<tr>
<td>role</td>
<td>devel/database, test/database, prod/database</td>
</tr>
</tbody>
</table>
For details on the transition to registry.redhat.io, see Red Hat Container Registry Authentication. Before you can pull containers from registry.redhat.io, you need to authenticate using your RHEL Subscription credentials.

### 3.2. CONFIGURING CONTAINER REGISTRIES

You can display the container registries using the `podman info --format` command:

```
$ podman info -f json | jq '.registries["search"]'
[
  "registry.access.redhat.com",
  "registry.redhat.io",
  "docker.io"
]
```

**NOTE**

The `podman info` command is available in Podman 4.0.0 or later.

You can edit the list of container registries in the `registries.conf` configuration file. As a root user, edit the `/etc/containers/registries.conf` file to change the default system-wide search settings.

As a user, create the `$HOME/.config/containers/registries.conf` file to override the system-wide settings.

```
unqualified-search-registries = ["registry.access.redhat.com", "registry.redhat.io", "docker.io"]
short-name-mode = "enforcing"
```

By default, the `podman pull` and `podman search` commands search for container images from registries listed in the `unqualified-search-registries` list in the given order.

#### Configuring a local container registry

You can configure a local container registry without the TLS verification. You have two options on how to disable TLS verification. First, you can use the `--tls-verify=false` option in Podman. Second, you can set `insecure=true` in the `registries.conf` file:

```
[[registry]]
location="localhost:5000"
insecure=true
```

#### Blocking a registry, namespace, or image

You can define registries the local system is not allowed to access. You can block a specific registry by setting `blocked=true`.

```
[[registry]]
location = "registry.example.org"
bloked = true
```

You can also block a namespace by setting the prefix to `prefix=":registry.example.org/namespace"`. For example, pulling the image using the `podman pull registry.example.org/example/image:latest` command will be blocked, because the specified prefix is matched.
NOTE

prefix is optional, default value is the same as the location value.

You can block a specific image by setting prefix="registry.example.org/namespace/image".

Mirroring registries

You can set a registry mirror in cases you cannot access the original registry. For example, you cannot connect to the internet, because you work in a highly-sensitive environment. You can specify multiple mirrors that are contacted in the specified order. For example, when you run podman pull registry.example.com/myimage:latest command, the mirror-1.com is tried first, then mirror-2.com.

Additional resources

- How to manage Linux container registries
- podman-pull man page
- podman-info man page

3.3. SEARCHING FOR CONTAINER IMAGES

Using the podman search command you can search selected container registries for images. You can also search for images in the Red Hat Container Catalog. The Red Hat Container Registry includes the image description, contents, health index, and other information.

NOTE

The podman search command is not a reliable way to determine the presence or existence of an image. The podman search behavior of the v1 and v2 Docker distribution API is specific to the implementation of each registry. Some registries may not support searching at all. Searching without a search term only works for registries that implement the v2 API. The same holds for the docker search command.
To search for the `postgresql-10` images in the quay.io registry, follow the steps.

**Prerequisites**

- The `containers-tool` meta-package is installed.
- The registry is configured.

**Procedure**

1. Authenticate to the registry:
   ```
   # podman login quay.io
   ```

2. Search for the image:
   - To search for a particular image on a specific registry, enter:
     ```
     # podman search quay.io/postgresql-10
     INDEX       NAME                                           DESCRIPTION           STARS   OFFICIAL
     AUTOMATED
     redhat.io   registry.redhat.io/rhel8/postgresql-10         This container image ... 0
     redhat.io   registry.redhat.io/rhscl/postgresql-10-rhel7   PostgreSQL is an ... 0
     ```
   - Alternatively, to display all images provided by a particular registry, enter:
     ```
     # podman search quay.io/
     ```
   - To search for the image name in all registries, enter:
     ```
     # podman search postgresql-10
     ```

     To display the full descriptions, pass the `--no-trunc` option to the command.

**Additional resources**

- `podman-search` man page

### 3.4. PULLING IMAGES FROM REGISTRIES

Use the `podman pull` command to get the image to your local system.

**Prerequisites**

- The `containers-tool` meta-package is installed.

**Procedure**

1. Log in to the registry.redhat.io registry:
   ```
   $ podman login registry.redhat.io
   Username: <username>
   Password: <password>
   ```
Login Succeeded!

2. Pull the registry.redhat.io/ubi9/ubi container image:

$ podman pull registry.redhat.io/ubi9/ubi

Verification steps

- List all images pulled to your local system:

$ podman images

REPOSITORY TAG IMAGE ID CREATED SIZE
registry.redhat.io/ubi9/ubi latest 3269c37eae33 7 weeks ago 208 MB

Additional resources

- podman-pull man page

3.5. CONFIGURING SHORT-NAME ALIASES

Red Hat recommends always to pull an image by its fully-qualified name. However, it is customary to pull images by short names. For example, you can use ubi9 instead of registry.access.redhat.com/ubi9:latest.

The registries.conf file allows to specify aliases for short names, giving administrators full control over where images are pulled from. Aliases are specified in the [aliases] table in the form "name" = "value". You can see the lists of aliases in the /etc/containers/registries.conf.d directory. Red Hat ships a set of aliases in this directory. For example, podman pull ubi9 directly resolves to the right image, that is registry.access.redhat.com/ubi9:latest.

For example:

unqualified-search-registries= ["registry.fedoraproject.org", "quay.io"]

[aliases]
"fedora"="registry.fedoraproject.org/fedora"

The short-names modes are:

- **enforcing**: If no matching alias is found during the image pull, Podman prompts the user to choose one of the unqualified-search registries. If the selected image is pulled successfully, Podman automatically records a new short-name alias in the $HOME/.cache/containers/short-name-aliases.conf file (rootless user) or in the /var/cache/containers/short-name-aliases.conf (root user). If the user cannot be prompted (for example, stdin or stdout are not a TTY), Podman fails. Note that the short-name-aliases.conf file has precedence over the registries.conf file if both specify the same alias.

- **permissive**: Similar to enforcing mode, but Podman does not fail if the user cannot be prompted. Instead, Podman searches in all unqualified-search registries in the given order. Note that no alias is recorded.

- **disabled**: All unqualified-search registries are tried in a given order, no alias is recorded.
NOTE

Red Hat recommends using fully qualified image names including registry, namespace, image name, and tag. When using short names, there is always an inherent risk of spoofing. Add registries that are trusted, that is, registries that do not allow unknown or anonymous users to create accounts with arbitrary names. For example, a user wants to pull the example container image from example.registry.com registry. If example.registry.com is not first in the search list, an attacker could place a different example image at a registry earlier in the search list. The user would accidentally pull and run the attacker image rather than the intended content.

Additional resources

- Container image short names in Podman
CHAPTER 4. WORKING WITH CONTAINER IMAGES

The Podman tool is designed to work with container images. You can use this tool to pull the image, inspect, tag, save, load, redistribute, and define the image signature.

4.1. PULLING CONTAINER IMAGES USING SHORT-NAME ALIASES

You can use secure short names to get the image to your local system. The following procedure describes how to pull a fedora or nginx container image.

Prerequisites

- The containers-tool meta-package is installed.

Procedure

- Pull the container image:
  - Pull the fedora image:

    $ podman pull fedora
    Resolved “fedora” as an alias (/etc/containers/registries.conf.d/000-shortnames.conf)
    Trying to pull registry.fedoraproject.org/fedora:latest...
    ...Storing signatures
    ...

    Alias is found and the registry.fedoraproject.org/fedora image is securely pulled. The unqualified-search-registries list is not used to resolve fedora image name.

  - Pull the nginx image:

    $ podman pull nginx
    ? Please select an image:
    registry.access.redhat.com/nginx:latest
    registry.redhat.io/nginx:latest
    docker.io/library/nginx:latest
    docker.io/library/nginx:latest
    Trying to pull docker.io/library/nginx:latest...
    ...Storing signatures
    ...

    If no matching alias is found, you are prompted to choose one of the unqualified-search-registries list. If the selected image is pulled successfully, a new short-name alias is recorded locally, otherwise an error occurs.

Verification

- List all images pulled to your local system:

  $ podman images
  REPOSITORY TAG IMAGE ID CREATED SIZE
  registry.fedoraproject.org/fedora latest 28317703decd 12 days ago 184 MB
4.2. LISTING IMAGES

Use the `podman images` command to list images in your local storage.

**Prerequisites**

- The `containers-tool` meta-package is installed.
- A pulled image is available on the local system.

**Procedure**

- List all images in the local storage:

  ```
  $ podman images
  REPOSITORY                           TAG     IMAGE ID      CREATED      SIZE
  registry.access.redhat.com/ubi9/ubi   latest  3269c37eae33  6 weeks ago  208 MB
  ```

**Additional resources**

- `podman-images` man page

4.3. INSPECTING LOCAL IMAGES

After you pull an image to your local system and run it, you can use the `podman inspect` command to investigate the image. For example, use it to understand what the image does and check what software is inside the image. The `podman inspect` command displays information about containers and images identified by name or ID.

**Prerequisites**

- The `containers-tool` meta-package is installed.
- A pulled image is available on the local system.

**Procedure**

- Inspect the `registry.redhat.io/ubi9/ubi` image:

  ```
  $ podman inspect registry.redhat.io/ubi9/ubi
  ...
  "Cmd": [
    "/bin/bash"
  ],
  "Labels": {
    "architecture": "x86_64",
    "build-date": "2020-12-10T01:59:40.343735",
  
```
The "Cmd" key specifies a default command to run within a container. You can override this command by specifying a command as an argument to the `podman run` command. This ubi9/ubi container will execute the bash shell if no other argument is given when you start it with `podman run`. If an "Entrypoint" key was set, its value would be used instead of the "Cmd" value, and the value of "Cmd" is used as an argument to the Entrypoint command.

Additional resources

- `podman-inspect` man page

### 4.4. INSPECTING REMOTE IMAGES

Use the `skopeo inspect` command to display information about an image from a remote container registry before you pull the image to your system.

**Prerequisites**

- The `containers-tool` meta-package is installed.

**Procedure**

- The `containers-tool` meta-package is installed.

- Inspect the `registry.redhat.io/ubi9/ubi-init` image:

  ```
  # skopeo inspect docker://registry.redhat.io/ubi9/ubi-init
  {
  "Name": "registry.redhat.io/ubi9/ubi9-init",
  "Digest": "sha256:c6d1e50ab...",
  "RepoTags": [
      ...
      "latest"
    ],
  "Created": "2020-12-10T07:16:37.250312Z",
  "DockerVersion": "1.13.1",
  "Labels": {
    "architecture": "x86_64",
    "build-date": "2020-12-10T07:16:11.378348",
    "com.redhat.build-host": "cpt-1007.osbs.prod.upshift.rdu2.redhat.com",
    "com.redhat.component": "ubi9-init-container",
    "com.redhat.license_terms": "https://www.redhat.com/en/about/red-hat-end-user-license-agreements#UBI",
    "description": "The Universal Base Image Init is designed to run an init system as PID 1 for running multi-services inside a container
    ...
  }
  ```
4.5. COPYING CONTAINER IMAGES

You can use the `skopeo copy` command to copy a container image from one registry to another. For example, you can populate an internal repository with images from external registries, or sync image registries in two different locations.

**Prerequisites**

- The `containers-tool` meta-package is installed.

**Procedure**

- Copy the `skopeo` container image from `docker://quay.io` to `docker://registry.example.com`:

  ```bash
  $ skopeo copy docker://quay.io/skopeo/stable:latest
docker://registry.example.com/skopeo:latest
  ```

**Additional resources**

- `skopeo-copy` man page

4.6. COPYING IMAGE LAYERS TO A LOCAL DIRECTORY

You can use the `skopeo copy` command to copy the layers of a container image to a local directory.

**Prerequisites**

- The `containers-tool` meta-package is installed.

**Procedure**

1. Create the `/var/lib/images/nginx` directory:

   ```bash
   $ mkdir -p /var/lib/images/nginx
   ```

2. Copy the layers of the `docker://docker.io/nginx:latest` image to the newly created directory:

   ```bash
   $ skopeo copy docker://docker.io/nginx:latest dir:/var/lib/images/nginx
   ```

**Verification**

- Display the content of the `/var/lib/images/nginx` directory:

  ```bash
  $ ls /var/lib/images/nginx
  08b11a3d692c1a2e15ae840f2c15c18308dcb079aa5320e15d46b62015c0f6f3
  ...
  4fcb23e29ba19bf305d0d4b35412625fefa51e82292ec7312f9be724cb6e31f8d  manifest.json
  version
  ```
Additional resources

- skopeo-copy man page

4.7. TAGGING IMAGES

Use the podman tag command to add an additional name to a local image. This additional name can consist of several parts: `<registryhost>/<username>/<name>:<tag>.

Prerequisites

- The containers-tool meta-package is installed.
- A pulled image is available on the local system.

Procedure

1. List all images:

   ```bash
   $ podman images
   REPOSITORY                           TAG     IMAGE ID      CREATED      SIZE
   registry.redhat.io/ubi9/ubi          latest  3269c37eae33  7 weeks ago  208 MB
   ```

2. Assign the myubi name to the registry.redhat.io/ubi9/ubi image using one of the following options:

   - The image name:

     ```bash
     $ podman tag registry.redhat.io/ubi9/ubi myubi
     ```

   - The image ID:

     ```bash
     $ podman tag 3269c37eae33 myubi
     ```

   Both commands give you the same result.

3. List all images:

   ```bash
   $ podman images
   REPOSITORY                           TAG     IMAGE ID      CREATED       SIZE
   registry.redhat.io/ubi9/ubi          latest  3269c37eae33  2 months ago  208 MB
   localhost/myubi                      latest  3269c37eae33  2 months ago  208 MB
   ```

   Notice that the default tag is latest for both images. You can see all the image names are assigned to the single image ID 3269c37eae33.

4. Add the 9 tag to the registry.redhat.io/ubi9/ubi image using either:

   - The image name:

     ```bash
     $ podman tag registry.redhat.io/ubi9/ubi myubi:9
     ```

   - The image ID:
Both commands give you the same result.

5. List all images:

```sh
$ podman images

REPOSITORY                           TAG     IMAGE ID      CREATED       SIZE
registry.redhat.io/ubi9/ubi          latest  3269c37eae33  2 months ago  208 MB
localhost/myubi                      latest  3269c37eae33  2 months ago  208 MB
localhost/myubi                      9     3269c37eae33  2 months ago  208 MB
```

Notice that the default tag is `latest` for both images. You can see all the image names are assigned to the single image ID 3269c37eae33.

After tagging the `registry.redhat.io/ubi9/ubi` image, you have three options to run the container:

- by ID (`3269c37eae33`)
- by name (`localhost/myubi:latest`)
- by name (`localhost/myubi:9`)

Additional resources

- `podman-tag` man page

### 4.8. SAVING AND LOADING IMAGES

Use the `podman save` command to save an image to a container archive. You can restore it later to another container environment or send it to someone else. You can use `--format` option to specify the archive format. The supported formats are:

- `docker-archive`
- `oci-archive`
- `oci-dir` (directory with oci manifest type)
- `docker-dir` (directory with v2s2 manifest type)

The default format is the `docker-dir` format.

Use the `podman load` command to load an image from the container image archive into the container storage.

Prerequisites

- The `containers-tool` meta-package is installed.
- A pulled image is available on the local system.

Procedure

1. Save the `registry.redhat.io/rhel9/rsyslog` image as a tarball:
• In the default `docker-dir` format:
  
  ```
  $ podman save -o myrsyslog.tar registry.redhat.io/rhel9/rsyslog:latest
  ```

• In the `oci-archive` format, using the `--format` option:
  
  ```
  $ podman save -o myrsyslog-oci.tar --format=oci-archive
  registry.redhat.io/rhel9/rsyslog
  ```

  The `myrsyslog.tar` and `myrsyslog-oci.tar` archives are stored in your current directory. The next steps are performed with the `myrsyslog.tar` tarball.

2. Check the file type of `myrsyslog.tar`:

  ```
  $ file myrsyslog.tar
  myrsyslog.tar: POSIX tar archive
  ```

3. To load the `registry.redhat.io/rhel9/rsyslog:latest` image from the `myrsyslog.tar`:

  ```
  $ podman load -i myrsyslog.tar
  ...
  Loaded image(s): registry.redhat.io/rhel9/rsyslog:latest
  ```

Additional resources

• `podman-save` man page

4.9. REDISTRIBUTING UBI IMAGES

Use `podman push` command to push a UBI image to your own, or a third party, registry and share it with others. You can upgrade or add to that image from UBI dnf repositories as you like.

Prerequisites

• The `containers-tool` meta-package is installed.

• A pulled image is available on the local system.

Procedure

1. Optional: Add an additional name to the `ubi` image:

   ```
   # podman tag registry.redhat.io/ubi9/ubi registry.example.com:5000/ubi9/ubi
   ```

2. Push the `registry.example.com:5000/ubi9/ubi` image from your local storage to a registry:

   ```
   # podman push registry.example.com:5000/ubi9/ubi
   ```

IMPORTANT

While there are few restrictions on how you use these images, there are some restrictions about how you can refer to them. For example, you cannot call those images Red Hat certified or Red Hat supported unless you certify it through the Red Hat Partner Connect.
Program, either with Red Hat Container Certification or Red Hat OpenShift Operator Certification.

### 4.10. REMOVING IMAGES

Use the `podman rmi` command to remove locally stored container images. You can remove an image by its ID or name.

**Prerequisites**

- The `containers-tool` meta-package is installed.

**Procedure**

1. List all images on your local system:

   ```bash
   $ podman images
   REPOSITORY                             TAG     IMAGE ID      CREATED      SIZE
   registry.redhat.io/rhel8/rsyslog     latest  4b32d14201de  7 weeks ago  228 MB
   registry.redhat.io/ubi8/ubi          latest  3269c37eae33  7 weeks ago  208 MB
   localhost/myubi                      X.Y     3269c37eae33  7 weeks ago  208 MB
   ```

2. List all containers:

   ```bash
   $ podman ps -a
   CONTAINER ID  IMAGE                                    COMMAND          CREATED        STATUS
   PORTS   NAMES
   7ccd6001166e  registry.redhat.io/rhel8/rsyslog:latest  /bin/rsyslog.sh  6 seconds ago  Up 5 seconds ago mysyslog
   ```

   To remove the `registry.redhat.io/rhel8/rsyslog` image, you have to stop all containers running from this image using the `podman stop` command. You can stop a container by its ID or name.

3. Stop the `mysyslog` container:

   ```bash
   $ podman stop mysyslog
   7ccd6001166e9720c47fbeb077e0af0bb635e74a1b0ede3fd34d09eaf5af52e9
   ```

4. Remove the `registry.redhat.io/rhel8/rsyslog` image:

   ```bash
   $ podman rmi registry.redhat.io/rhel8/rsyslog
   ```

   - To remove multiple images:

     ```bash
     $ podman rmi registry.redhat.io/rhel8/rsyslog registry.redhat.io/ubi8/ubi
     ```

   - To remove all images from your system:

     ```bash
     $ podman rmi -a
     ```

   - To remove images that have multiple names (tags) associated with them, add the `-f` option to remove them:
$ podman rmi -f 1de7d7b3f531
1de7d7b3f531...

Additional resources

- podman-rmi man page
CHAPTER 5. WORKING WITH CONTAINERS

Containers represent a running or stopped process created from the files located in a decompressed container image. You can use the Podman tool to work with containers.

5.1. PODMAN RUN COMMAND

The **podman run** command runs a process in a new container based on the container image. If the container image is not already loaded then **podman run** pulls the image, and all image dependencies, from the repository in the same way running **podman pull image**, before it starts the container from that image. The container process has its own file system, its own networking, and its own isolated process tree.

The **podman run** command has the form:

```
podman run [options] image [command [arg ...]]
```

Basic options are:

- **--detach (-d)**: Runs the container in the background and prints the new container ID.
- **--attach (-a)**: Runs the container in the foreground mode.
- **--name (-n)**: Assigns a name to the container. If a name is not assigned to the container with **--name** then it generates a random string name. This works for both background and foreground containers.
- **--rm**: Automatically remove the container when it exits. Note that the container will not be removed when it could not be created or started successfully.
- **--tty (-t)**: Allocates and attaches the pseudo-terminal to the standard input of the container.
- **--interactive (-i)**: For interactive processes, use **-i** and **-t** together to allocate a terminal for the container process. The **-i -t** is often written as **-it**.

5.2. RUNNING COMMANDS IN A CONTAINER FROM THE HOST

This procedure shows how to use the **podman run** command to display the type of operating system of the container.

**Prerequisites**

- The **containers-tool** meta-package is installed.

**Procedure**

1. Display the type of operating system of the container based on the **registry.access.redhat.com/ubi9/ubi** container image using the **cat /etc/os-release** command:

```
$ podman run --rm registry.access.redhat.com/ubi9/ubi cat /etc/os-release
NAME="Red Hat Enterprise Linux"
...
ID="rhel"
...
```
2. Optional: List all containers.

```
$ podman ps
CONTAINER ID  IMAGE   COMMAND  CREATED  STATUS  PORTS   NAMES

```

Because of the `--rm` option you should not see any container. The container was removed.

### Additional resources
- podman-run man page

### 5.3. RUNNING COMMANDS INSIDE THE CONTAINER

This procedure shows how you can use the `podman run` command to run a container interactively.

#### Prerequisites
- The `containers-tool` meta-package is installed.

#### Procedure

1. Run the container named `myubi` based on the `registry.redhat.io/ubi9/ubi` image:

   ```
   $ podman run --name=myubi -it registry.access.redhat.com/ubi9/ubi /bin/bash
   [root@6ccffd0f6421 /]#
   
   - The `-i` option creates an interactive session. Without the `-t` option, the shell stays open, but you cannot type anything to the shell.
   - The `-t` option opens a terminal session. Without the `-i` option, the shell opens and then exits.
   
2. Install the `procps-ng` package containing a set of system utilities (for example `ps`, `top`, `uptime`, and so on):

   ```
   [root@6ccffd0f6421 /]# dnf install procps-ng
   
   3. Use the `ps -ef` command to list current processes:

   ```
   # ps -ef
   UID   PID  PPID  C  STIME TTY      TIME CMD
   root  1     0      0 12:55 pts/0   00:00:00 /bin/bash
   root  31    1     0 13:07 pts/0   00:00:00 ps -ef
   
   4. Enter `exit` to exit the container and return to the host:

   ```
   # exit
5. Optional: List all containers:

```
$ podman ps
CONTAINER ID IMAGE COMMAND CREATED STATUS
PORTS NAMES
198455a2c27 registry.redhat.io/ubi9/ubi:latest /bin/bash 21 minutes ago Exited (0) 21
minutes ago   myubi
```

You can see that the container is in Exited status.

Additional resources

- podman-run man page

### 5.4. LISTING CONTAINERS

Use the `podman ps` command to list the running containers on the system.

**Prerequisites**

- The `containers-tool` meta-package is installed.

**Procedure**

1. Run the container based on `registry.redhat.io/rhel9/rsyslog` image:

```
$ podman run -d registry.redhat.io/rhel9/rsyslog
```

2. List all containers:

   - To list all running containers:

```
$ podman ps
CONTAINER ID IMAGE COMMAND CREATED STATUS
PORTS NAMES
74b1da000a11 rhel9/rsyslog /bin/rsyslog.sh 2 minutes ago Up About a minute
musing_brown
```

   - To list all containers, running or stopped:

```
$ podman ps -a
CONTAINER ID IMAGE COMMAND CREATED STATUS PORTS NAMES IS INFRA
d65aecc325a4 ubi9/ubi /bin/bash 3 secs ago Exited (0) 5 secs ago peaceful_hopper
false
74b1da000a11 rhel9/rsyslog rsyslog.sh 2 mins ago Up About a minute musing_brown
false
```

If there are containers that are not running, but were not removed (`--rm` option), the containers are present and can be restarted.

Additional resources
5.5. STARTING CONTAINERS

If you run the container and then stop it, and not remove it, the container is stored on your local system ready to run again. You can use the `podman start` command to re-run the containers. You can specify the containers by their container ID or name.

Prerequisites

- The `containers-tool` meta-package is installed.
- At least one container has been stopped.

Procedure

1. Start the `myubi` container:
   - In the non interactive mode:
     ```
     $ podman start myubi
     ```
     Alternatively, you can use `podman start 1984555a2c27`.
   - In the interactive mode, use `-a` (**attach**) and `-i` (**interactive**) options to work with container bash shell:
     ```
     $ podman start -a -i myubi
     ```
     Alternatively, you can use `podman start -a -i 1984555a2c27`.

2. Enter `exit` to exit the container and return to the host:
   ```
   [root@6ccf0f6421 /]# exit
   ```

Additional resources

- `podman-start` man page

5.6. INSPECTING CONTAINERS FROM THE HOST

Use the `podman inspect` command to inspect the metadata of an existing container in a JSON format. You can specify the containers by their container ID or name.

Prerequisites

- The `containers-tool` meta-package is installed.

Procedure

- Inspect the container defined by ID 64ad95327c74:
  - To get all metadata:
To get particular items from the JSON file, for example, the `StartedAt` timestamp:

```bash
podman inspect --format='{{.State.StartedAt}}' 64ad95327c74
```

2021-03-02 11:23:54.945071961 +0100 CET

The information is stored in a hierarchy. To see the container `StartedAt` timestamp (`StartedAt` is under `State`), use the `--format` option and the container ID or name.

Examples of other items you might want to inspect include:

- **.Path** to see the command run with the container
- **.Args** arguments to the command
- **.Config.ExposedPorts** TCP or UDP ports exposed from the container
- **.State.Pid** to see the process id of the container
- **.HostConfig.PortBindings** port mapping from container to host

Additional resources

- **podman-inspect** man page

### 5.7. MOUNTING DIRECTORY ON LOCALHOST TO THE CONTAINER

This procedure shows how you can make log messages from inside a container available to the host system by mounting the host `/dev/log` device inside the container.

**Prerequisites**

- The **containers-tool** meta-package is installed.

**Procedure**

1. Run the container named `log_test` and mount the host `/dev/log` device inside the container:

```bash
podman run --name="log_test" -v /dev/log:/dev/log --rm \
registry.redhat.io/ubi9/ubi logger "Testing logging to the host"
```
2. Use the `journalctl` utility to display logs:

```
# journalctl -b | grep Testing
Dec 09 16:55:00 localhost.localdomain root[14634]: Testing logging to the host
```

The `--rm` option removes the container when it exits.

Additional resources

- `podman-run` man page

### 5.8. MOUNTING A CONTAINER FILESYSTEM

Use the `podman mount` command to mount a working container root filesystem in a location accessible from the host.

**Prerequisites**

- The `containers-tool` meta-package is installed.

**Procedure**

1. Run the container named `mysyslog`:

   ```
   # podman run -d --name=mysyslog registry.redhat.io/rhel9/rsyslog
   ```

2. Optional: List all containers:

   ```
   # podman ps -a
   CONTAINER ID  IMAGE                                    COMMAND          CREATED         STATUS
   PORTS   NAMES
   c56ef6a256f8  registry.redhat.io/rhel9/rsyslog:latest  /bin/rsyslog.sh  20 minutes ago  Up 20
   minutes ago                  mysyslog
   ```

3. Mount the `mysyslog` container:

   ```
   # podman mount mysyslog
   /var/lib/containers/storage/overlay/990b5c6ddcdeed4bde7b245885ce4544c553d108310e2b797
d7be46750894719/merged
   ```

4. Display the content of the mount point using `ls` command:

   ```
   # ls
   /var/lib/containers/storage/overlay/990b5c6ddcdeed4bde7b245885ce4544c553d108310e2b797d7be46750894719/merged
   bin boot dev etc home lib lib64 lost+found media mnt opt proc root run sbin srv sys
   tmp usr var
   ```

5. Display the OS version:

   ```
   # cat
   /var/lib/containers/storage/overlay/990b5c6ddcdeed4bde7b245885ce4544c553d108310e2b797d7be46750894719/merged/etc/os-release
   ```
NAME="Red Hat Enterprise Linux"
VERSION="9 (Ootpa)"
ID="rhel"
ID_LIKE="fedora"
...

Additional resources

- podman-mount man page

5.9. RUNNING A SERVICE AS A DAEMON WITH A STATIC IP

The following example runs the rsyslog service as a daemon process in the background. The --ip option sets the container network interface to a particular IP address (for example, 10.88.0.44). After that, you can run the podman inspect command to check that you set the IP address properly.

Prerequisites

- The containers-tool meta-package is installed.

Procedure

1. Set the container network interface to the IP address 10.88.0.44:

   ```bash
   # podman run -d --ip=10.88.0.44 registry.access.redhat.com/rhel9/rsyslog efde5f0a8c72f70dd5cb5dc3d5039df3b962fae65575b08662e0d5b5f9fbe85
   ```

2. Check that the IP address is set properly:

   ```bash
   # podman inspect efde5f0a8c72f70dd5cb5dc3d5039df3b962fae65575b08662e0d5b5f9fbe85 | grep 10.88.0.44
   "IPAddress": "10.88.0.44",
   ```

Additional resources

- podman-inspect man page
- podman-run man page

5.10. EXECUTING COMMANDS INSIDE A RUNNING CONTAINER

Use the podman exec command to execute a command in a running container and investigate that container. The reason for using the podman exec command instead of podman run command is that you can investigate the running container without interrupting the container activity.

Prerequisites

- The containers-tool meta-package is installed.
- The container is running.

Procedure

1. Execute the rpm -qa command inside the myrsyslog container to list all installed packages:
2. Execute a `/bin/bash` command in the `myrsyslog` container:

```
$ podman exec -it myrsyslog /bin/bash
```

3. Install the `procps-ng` package containing a set of system utilities (for example `ps`, `top`, `uptime`, and so on):

```
# dnf install procps-ng
```

4. Inspect the container:

   - To list every process on the system:

```
# ps -ef
UID     PID    PPID  C   STIME TTY     TIME CMD
root    1       0      0 10:23 ?      00:00:01 /usr/sbin/rsyslogd -n
root    8       0      0 11:07 pts/0    00:00:00 /bin/bash
root   47      8      0 11:13 pts/0    00:00:00 ps -ef
```

   - To display file system disk space usage:

```
# df -h
Filesystem   Size  Used  Avail  Use%  Mounted on
fuse-overlayfs 27G    7.1G   20G    27% /
tmpfs           64M     0    64M    0% /dev
tmpfs          269M 936K  268M    1% /etc/hosts
shm             63M     0    63M    0% /dev/shm
...             ...
```

   - To display system information:

```
# uname -r
4.18.0-240.10.1.el8_3.x86_64
```

   - To display amount of free and used memory in megabytes:

```
# free --mega
          total       used       free     shared    buff/cache   available
Mem:     2818       615      1183        12        1020       1957
Swap:    3124        0      3124
```

Additional resources

- `podman-exec man page`
5.11. SHARING FILES BETWEEN TWO CONTAINERS

You can use volumes to persist data in containers even when a container is deleted. Volumes can be used for sharing data among multiple containers. The volume is a folder which is stored on the host machine. The volume can be shared between the container and the host.

Main advantages are:

- Volumes can be shared among the containers.
- Volumes are easier to back up or migrate.
- Volumes do not increase the size of the containers.

Prerequisites

- The containers-tool meta-package is installed.

Procedure

1. Create a volume:

   ```bash
   $ podman volume create hostvolume
   ```

2. Display information about the volume:

   ```bash
   $ podman volume inspect hostvolume
   {
   "name": "hostvolume",
   "labels": {},
   "mountpoint":
   "/home/username/.local/share/containers/storage/volumes/hostvolume/_data",
   "driver": "local",
   "options": {},
   "scope": "local"
   }
   ```

   Notice that it creates a volume in the volumes directory. You can save the mount point path to the variable for easier manipulation: `mntPoint=$(podman volume inspect hostvolume --format {{.Mountpoint}})`.

   Notice that if you run `sudo podman volume create hostvolume`, then the mount point changes to `/var/lib/containers/storage/volumes/hostvolume/_data`.

3. Create a text file inside the directory using the path that is stored in the mntPoint variable:

   ```bash
   $ echo "Hello from host" >> $mntPoint/host.txt
   ```

4. List all files in the directory defined by the mntPoint variable:

   ```bash
   $ ls $mntPoint/ host.txt
   ```
5. Run the container named myubi1 and map the directory defined by the hostvolume volume name on the host to the /containervolume1 directory on the container:

```
$ podman run -it --name myubi1 -v hostvolume:/containervolume1
registry.access.redhat.com/ubi9/ubi /bin/bash
```

Note that if you use the volume path defined by the mntPoint variable (-v $mntPoint:/containervolume1), data can be lost when running podman volume prune command, which removes unused volumes. Always use -v hostvolume_name:/containervolume_name.

6. List the files in the shared volume on the container:

```
# ls /containervolume1
host.txt
```

You can see the host.txt file which you created on the host.

7. Create a text file inside the /containervolume1 directory:

```
# echo "Hello from container 1" >> /containervolume1/container1.txt
```

8. Detach from the container with CTRL+p and CTRL+q.

9. List the files in the shared volume on the host, you should see two files:

```
$ ls $mntPoint
container1.txt host.txt
```

At this point, you are sharing files between the container and host. To share files between two containers, run another container named myubi2.

10. Run the container named myubi2 and map the directory defined by the hostvolume volume name on the host to the /containervolume2 directory on the container:

```
$ podman run -it --name myubi2 -v hostvolume:/containervolume2
registry.access.redhat.com/ubi9/ubi /bin/bash
```

11. List the files in the shared volume on the container:

```
# ls /containervolume2
container1.txt host.txt
```

You can see the host.txt file which you created on the host and container1.txt which you created inside the myubi1 container.

12. Create a text file inside the /containervolume2 directory:

```
# echo "Hello from container 2" >> /containervolume2/container2.txt
```

13. Detach from the container with CTRL+p and CTRL+q.

14. List the files in the shared volume on the host, you should see three files:
5.12. EXPORTING AND IMPORTING CONTAINERS

You can use the podman export command to export the file system of a running container to a tarball on your local machine. For example, if you have a large container that you use infrequently or one that you want to save a snapshot of in order to revert back to it later, you can use the podman export command to export a current snapshot of your running container into a tarball.

You can use the podman import command to import a tarball and save it as a filesystem image. Then you can run this filesystem image or you can use it as a layer for other images.

Prerequisites

- The containers-tool meta-package is installed.

Procedure

1. Run the myubi container based on the registry.access.redhat.com/ubi9/ubi image:

   $ podman run -dt --name=myubi registry.access.redhat.com/9/ubi

2. Optional: List all containers:

   $ podman ps -a

   CONTAINER ID   IMAGE                                    COMMAND          CREATED     STATUS          PORTS   NAMES
   a6a6d4896142  registry.access.redhat.com/9:latest   /bin/bash        7 seconds ago Up 7 seconds ago   myubi

3. Attach to the myubi container:

   $ podman attach myubi

4. Create a file named testfile:

   [root@a6a6d4896142 ]# echo "hello" > testfile

5. Detach from the container with CTRL+p and CTRL+q.

6. Export the file system of the myubi as a myubi-container.tar on the local machine:

   $ podman export -o myubi.tar a6a6d4896142

7. Optional: List the current directory content:
8. Optional: Create a `myubi-container` directory, extract all files from the `myubi-container.tar` archive. List a content of the `myubi-directory` in a tree-like format:

```
$ ls -l
-rw-r--r--. 1 user user 210885120 Apr  6 10:50 myubi-container.tar
...
```

```
$ mkdir myubi-container
$ tar -xf myubi-container.tar -C myubi-container
$ tree -L 1 myubi-container
  └── testfile

20 directories, 1 file
```

You can see that the `myubi-container.tar` contains the container file system.

9. Import the `myubi.tar` and saves it as a filesystem image:

```
$ podman import myubi.tar myubi-imported
Getting image source signatures
Copying blob 277cab30fe96 done
Copying config c296689a17 done
Writing manifest to image destination
Storing signatures
c296689a17da2f33bf9d16071911636d7ce4d63f329741db679c3f41537e7cbf
```

10. List all images:

```
$ podman images
REPOSITORY                              TAG     IMAGE ID      CREATED         SIZE
docker.io/library/myubi-imported       latest  c296689a17da  51 seconds ago  211 MB
```

11. Display the content of the `testfile` file:

Red Hat Enterprise Linux 9 Building, running, and managing containers
$ podman run -it --name=myubi-imported docker.io/library/myubi-imported cat testfile
hello

Additional resources

- `podman-export` man page
- `podman-import` man page

### 5.13. STOPPING CONTAINERS

Use the `podman stop` command to stop a running container. You can specify the containers by their container ID or name.

**Prerequisites**

- The `containers-tool` meta-package is installed.
- At least one container is running.

**Procedure**

- Stop the `myubi` container:
  - Using the container name:
    ```bash
    $ podman stop myubi
    ```
  - Using the container ID:
    ```bash
    $ podman stop 1984555a2c27
    ```

To stop a running container that is attached to a terminal session, you can enter the `exit` command inside the container.

The `podman stop` command sends a SIGTERM signal to terminate a running container. If the container does not stop after a defined period (10 seconds by default), Podman sends a SIGKILL signal.

You can also use the `podman kill` command to kill a container (SIGKILL) or send a different signal to a container. Here is an example of sending a SIGHUP signal to a container (if supported by the application, a SIGHUP causes the application to re-read its configuration files):

```
# *podman kill --signal="SIGHUP" 74b1da000a11*
74b1da000a114015886c557deec8bed9dfb80c888097aa83f30ca4074ff55fb2
```

Additional resources

- `podman-stop` man page
- `podman-kill` man page

### 5.14. REMOVING CONTAINERS
Use the `podman rm` command to remove containers. You can specify containers with the container ID or name.

**Prerequisites**

- The `containers-tool` meta-package is installed.
- At least one container has been stopped.

**Procedure**

1. List all containers, running or stopped:

   ```bash
   $ podman ps -a
   CONTAINER ID    IMAGE            COMMAND   CREATED     STATUS              PORTS NAMES
   IS INFRA  
   d65aecc325a4  ubi9/ubi        /bin/bash  3 seconds ago Exited (0) 5 seconds ago peaceful_hopper false  
   74b1da000a11  rhel9/rsyslog     rsyslog.sh 2 minutes ago Up About a minute musing_brown false
   
   2. Remove the containers:

   - To remove the `peaceful_hopper` container:
     ```bash
     $ podman rm peaceful_hopper
     Notice that the `peaceful_hopper` container was in Exited status, which means it was stopped and it can be removed immediately.
     ```
   - To remove the `musing_brown` container, first stop the container and then remove it:
     ```bash
     $ podman stop musing_brown
     $ podman rm musing_brown
     ```

   **NOTE**

   - To remove multiple containers:
     ```bash
     $ podman rm clever_yonath furious_shockley
     ```
   - To remove all containers from your local system:
     ```bash
     $ podman rm -a
     ```

**Additional resources**

- `podman-rm` man page

**5.15. CREATING SELINUX POLICIES FOR CONTAINERS**

To generate SELinux policies for containers, use the UDICA tool. For more information, see [Introduction to the udica SELinux policy generator](#).
5.16. CONFIGURING PRE-EXECUTION HOOKS IN PODMAN

You can create plugin scripts to define a fine-control over container operations, especially blocking unauthorized actions, for example pulling, running, or listing container images.

**NOTE**

The file `/etc/containers/podman_preexec_hooks.txt` must be created by an administrator and can be empty. If the `/etc/containers/podman_preexec_hooks.txt` does not exist, the plugin scripts will not be executed.

The following rules apply to the plugin scripts:

- Have to be root-owned and not writable.
- Have to be located in the `/usr/libexec/podman/pre-exec-hooks` and `/etc/containers/pre-exec-hooks` directories.
- Execute in sequentially and alphanumeric order.
- If all plugin scripts return zero value, then the `podman` command is executed.
- If any of the plugin scripts return a non-zero value, it indicates a failure. The `podman` command exits and returns the non-zero value of the first-failed script.
- Red Hat recommends using the following naming convention to execute the scripts in the correct order: `DDD_name.lang`, where:
  - The `DDD` is the decimal number indicating the order of script execution. Use one or two leading zeros if necessary.
  - The `name` is the name of the plugin script.
  - The `lang` (optional) is the file extension for the given programming language. For example, the name of the plugin script can be: `001-check-groups.sh`.

**NOTE**

The plugin scripts are valid at the time of creation. Containers created before plugin scripts are not affected.

Prerequisites

- The `containers-tool` meta-package is installed.

Procedure

- Create the script plugin named `001-check-groups.sh`. For example:

  ```bash
  #!/bin/bash
  if id -nG "$USER" 2> /dev/null | grep -qw "$GROUP" 2> /dev/null ; then
    exit 0
  else
    exit 1
  fi
  ```
The script checks if a user is in a specified group.

The `USER` and `GROUP` are environment variables set by Podman.

Exit code provided by the `001-check-groups.sh` script would be provided to the `podman` binary.

The `podman` command exits and returns the non-zero value of the first-failed script.

**Verification**

- Check if the `001-check-groups.sh` script works correctly:

  ```bash
  $ podman run image
  ...
  
  If the user is not in the correct group, the following error appears:

  ```bash
  external preexec hook /etc/containers/pre-exec-hooks/001-check-groups.sh failed
  ```
CHAPTER 6. SELECTING A CONTAINER RUNTIME

The runc and crun are container runtimes and can be used interchangeably as both implement the OCI runtime specification. The crun container runtime has a couple of advantages over runc, as it is faster and requires less memory. Due to that, the crun container runtime is the recommended container runtime for use.

6.1. THE RUNC CONTAINER RUNTIME

The runc container runtime is a lightweight, portable implementation of the Open Container Initiative (OCI) container runtime specification. The runc runtime shares a lot of low-level code with Docker but it is not dependent on any of the components of the Docker platform. The runc supports Linux namespaces, live migration, and has portable performance profiles.

It also provides full support for Linux security features such as SELinux, control groups (cgroups), seccomp, and others. You can build and run images with runc, or you can run OCI-compatible images with runc.

6.2. THE CRUN CONTAINER RUNTIME

The crun is a fast and low-memory footprint OCI container runtime written in C. The crun binary is up to 50 times smaller and up to twice as fast as the runc binary. Using crun, you can also set a minimal number of processes when running your container. The crun runtime also supports OCI hooks.

Additional features of crun include:

- Sharing files by group for rootless containers
- Controlling the stdout and stderr of OCI hooks
- Running older versions of systemd on cgroup v2
- A C library that is used by other programs
- Extensibility
- Portability

Additional resources

- An introduction to crun, a fast and low-memory footprint container runtime

6.3. RUNNING CONTAINERS WITH RUNC AND CRUN

With runc or crun, containers are configured using bundles. A bundle for a container is a directory that includes a specification file named config.json and a root filesystem. The root filesystem contains the contents of the container.

**NOTE**

The <runtime> can be crun or runc.

Prerequisites
• The **containers-tool** meta-package is installed.

**Procedure**

1. Pull the `registry.access.redhat.com/ubi9/ubi` container image:

   ```
   # podman pull registry.access.redhat.com/ubi9/ubi
   ```

2. Export the `registry.access.redhat.com/ubi9/ubi` image to the `rhel.tar` archive:

   ```
   # podman export $(podman create registry.access.redhat.com/ubi9/ubi) > rhel.tar
   ```

3. Create the `bundle/rootfs` directory:

   ```
   # mkdir -p bundle/rootfs
   ```

4. Extract the `rhel.tar` archive into the `bundle/rootfs` directory:

   ```
   # tar -C bundle/rootfs -xf rhel.tar
   ```

5. Create a new specification file named `config.json` for the bundle:

   ```
   # <runtime> spec -b bundle
   ```
   - The `-b` option specifies the bundle directory. The default value is the current directory.

6. Optional: Change the settings:

   ```
   # vi bundle/config.json
   ```

7. Create an instance of a container named `myubi` for a bundle:

   ```
   # <runtime> create -b bundle/ myubi
   ```

8. Start a `myubi` container:

   ```
   # <runtime> start myubi
   ```

   **NOTE**
   
   The name of a container instance must be unique to the host. To start a new instance of a container: `# <runtime> start <container_name>`

**Verification**

• List containers started by `<runtime>`:

   ```
   # <runtime> list
   ```

<table>
<thead>
<tr>
<th>ID</th>
<th>PID</th>
<th>STATUS</th>
<th>BUNDLE</th>
<th>CREATED</th>
<th>OWNER</th>
</tr>
</thead>
<tbody>
<tr>
<td>myubi</td>
<td>0</td>
<td>stopped</td>
<td>/root/bundle</td>
<td>2021-09-14T09:52:26.659714605Z</td>
<td>root</td>
</tr>
</tbody>
</table>

**Additional resources**
6.4. TEMPORARILY CHANGING THE CONTAINER RUNTIME

You can use the `podman run` command with the `--runtime` option to change the container runtime.

**NOTE**

The `<runtime>` can be crun or runc.

Prerequisites

- The containers-tool meta-package is installed.

Procedure

- Pull the `registry.access.redhat.com/ubi9/ubi` container image:

  ```
  $ podman pull registry.access.redhat.com/ubi9/ubi
  ```

1. Change the container runtime using the `--runtime` option:

  ```
  $ podman run --name=myubi -dt --runtime=<runtime> ubi9
  bashe4654eb4df12ac031f1d0f2657dc4ae6ff8eb0085bf114623b66cc664072e69b
  ```

2. Optional: List all images:

  ```
  $ podman ps -a
  CONTAINER ID  IMAGE                                   COMMAND  CREATED        STATUS
  PORTS   NAMES
  e4654eb4df12  registry.access.redhat.com/ubi9:latest  bash     4 seconds ago  Up 4
  seconds ago          myubi
  ```

Verification

- Ensure that the OCI runtime is set to `<runtime>` in the myubi container:

  ```
  $ podman inspect myubi --format "{.OCIRuntime}" <runtime>
  ```

Additional resources

- An introduction to crun, a fast and low-memory footprint container runtime

6.5. PERMANENTLY CHANGING THE CONTAINER RUNTIME
You can set the container runtime and its options in the `/etc/containers/containers.conf` configuration file as a root user or in the `$HOME/.config/containers/containers.conf` configuration file as a non-root user.

**NOTE**

The `<runtime>` can be crun or runc runtime.

**Prerequisites**

- The `containers-tool` meta-package is installed.

**Procedure**

- Change the runtime in the `/etc/containers/containers.conf` file:

```
# vim /etc/containers/containers.conf
[engine]
runtime = "<runtime>"
```

- Run the container named myubi:

```
# podman run --name=myubi -dt ubi9 bash
Resolved "ubi9" as an alias (/etc/containers/registries.conf.d/001-rhel-shortnames.conf)
Trying to pull registry.access.redhat.com/ubi9:latest…
... Storing signatures
```

**Verification**

- Ensure that the OCI runtime is set to `<runtime>` in the `myubi` container:

```
# podman inspect myubi --format "{{.OCIRuntime}}"
<runtime>
```

**Additional resources**

- An introduction to crun, a fast and low-memory footprint container runtime

- `containers.conf` man page
CHAPTER 7. ADDING SOFTWARE TO A UBI CONTAINER

Red Hat Universal Base Images (UBIs) are built from a subset of the RHEL content. UBIs also provide a subset of RHEL packages that are freely available to install for use with UBI. To add or update software to a running container, you can use the dnf repositories that include RPM packages and updates. UBIs provide a set of pre-built language runtime container images such as Python, Perl, Node.js, Ruby, and so on.

To add packages from UBI repositories to running UBI containers:

- On UBI init and UBI standard images, use the `dnf` command
- On UBI minimal images, use the `microdnf` command

**NOTE**

Installing and working with software packages directly in running containers adds packages temporarily. The changes are not saved in the container image. To make package changes persistent, see section Building an image from a Containerfile with Buildah.

**NOTE**

When you add software to a UBI container, procedures differ for updating UBIs on a subscribed RHEL host or on an unsubscribed (or non-RHEL) system.

7.1. USING THE UBI INIT IMAGES

This procedure shows how to build a container using a `Containerfile` that installs and configures a Web server (httpd) to start automatically by the systemd service (/sbin/init) when the container is run on a host system. The `podman build` command builds an image using instructions in one or more `Containerfiles` and a specified build context directory. The context directory can be specified as the URL of an archive, Git repository or `Containerfile`. If no context directory is specified, then the current working directory is considered as the build context, and must contain the `Containerfile`. You can also specify a `Containerfile` with the `--file` option.

**Prerequisites**

- The `containers-tool` meta-package is installed.

**Procedure**

1. Create a `Containerfile` with the following contents to a new directory:

```
FROM registry.access.redhat.com/ubi9/ubi-init
RUN dnf -y install httpd; dnf clean all; systemctl enable httpd;
RUN echo "Successful Web Server Test" > /var/www/html/index.html
RUN mkdir /etc/systemd/system/httpd.service.d/; echo -e '[Service]
    Restart=always' > /etc/systemd/system/httpd.service.d/httpd.conf
EXPOSE 80
CMD [ "/sbin/init" ]
```
The `Containerfile` installs the `httpd` package, enables the `httpd` service to start at boot time, creates a test file (`index.html`), exposes the Web server to the host (port 80), and starts the `systemd` init service (`/sbin/init`) when the container starts.

2. Build the container:
   
   ```bash
   # podman build --format=docker -t mysysd .
   ```

3. Optional: If you want to run containers with `systemd` and SELinux is enabled on your system, you must set the `container_manage_cgroup` boolean variable:
   
   ```bash
   # setsebool -P container_manage_cgroup 1
   ```

4. Run the container named `mysysd_run`:
   
   ```bash
   # podman run -d --name=mysysd_run -p 80:80 mysysd
   ```

   The `mysysd` image runs as the `mysysd_run` container as a daemon process, with port 80 from the container exposed to port 80 on the host system.

   **NOTE**
   
   In rootless mode, you have to choose host port number \( \geq 1024 \). For example:
   
   ```bash
   $ podman run -d --name=mysysd -p 8081:80 mysysd
   ```

   To use port numbers \(< 1024\), you have to modify the `net.ipv4.ip_unprivileged_port_start` variable:
   
   ```bash
   # sysctl net.ipv4.ip_unprivileged_port_start=80
   ```

5. Check that the container is running:
   
   ```bash
   # podman ps
   a282b0c2ad3d  localhost/mysysd:latest  /sbin/init  15 seconds ago  Up 14 seconds ago 0.0.0.0:80->80/tcp  mysysd_run
   ```

6. Test the web server:
   
   ```bash
   # curl localhost/index.html
   Successful Web Server Test
   ```

Additional resources

- Shortcomings of Rootless Podman

7.2. USING THE UBI MICRO IMAGES

This procedure shows how to build a `ubi-micro` container image using the Buildah tool.

Prerequisites
• The **containers-tool** meta-package is installed.

Prerequisites

• The **podman** tool, provided by the **containers-tool** meta-package, is installed.

Procedure

1. Pull and build the `registry.access.redhat.com/ubi8/ubi-micro` image:

   ```
   # microcontainer=$(buildah from registry.access.redhat.com/ubi9/ubi-micro)
   ```

2. Mount a working container root filesystem:

   ```
   # micromount=$(buildah mount $microcontainer)
   ```

3. Install the **httpd** service to the **micromount** directory:

   ```
   # dnf install \
   --installroot $micromount \
   --releasever=/ \
   --setopt install_weak_deps=false \
   --setopt=reposdir=/etc/yum.repos.d/ \
   --nodocs -y \ 
   httpd 
   
   # dnf clean all \
   --installroot $micromount
   ```

4. Unmount the root file system on the working container:

   ```
   # buildah umount $microcontainer
   ```

5. Create the **ubi-micro-httpd** image from a working container:

   ```
   # buildah commit $microcontainer ubi-micro-httpd
   ```

Verification steps

1. Display details about the **ubi-micro-httpd** image:

   ```
   # podman images ubi-micro-httpd
   localhost/ubi-micro-httpd latest 7c557e7fbe9f 22 minutes ago 151 MB
   ```

7.3. ADDING SOFTWARE TO A UBI CONTAINER ON A SUBSCRIBED HOST

If you are running a UBI container on a registered and subscribed RHEL host, the RHEL Base and AppStream repositories are enabled inside the standard UBI container, along with all the UBI repositories.

Additional resources
7.4. ADDING SOFTWARE IN A STANDARD UBI CONTAINER

To add software inside the standard UBI container, disable non-UBI dnf repositories to ensure the containers you build can be redistributed.

Prerequisites

- The containers-tool meta-package is installed.

Procedure

1. Pull and run the registry.access.redhat.com/ubi9/ubi image:

   $ podman run -it --name myubi registry.access.redhat.com/ubi9/ubi

2. Add a package to the myubi container.
   - To add a package that is in the UBI repository, disable all dnf repositories except for UBI repositories. For example, to add the bzip2 package:

     # dnf install --disablerepo=* --enablerepo=ubi-8-appstream-rpms --enablerepo=ubi-8-baseos-rpms bzip2

   - To add a package that is not in the UBI repository, do not disable any repositories. For example, to add the zsh package:

     # dnf install zsh

   - To add a package that is in a different host repository, explicitly enable the repository you need. For example, to install the python38-devel package from the codeready-builder-for-rhel-8-x86_64-rpms repository:

     # dnf install --enablerepo=codeready-builder-for-rhel-8-x86_64-rpms python38-devel

Verification steps

1. List all enabled repositories inside the container:

   # dnf repolist

2. Ensure that the required repositories are listed.

3. List all installed packages:

   # rpm -qa

4. Ensure that the required packages are listed.
7.5. ADDING SOFTWARE IN A MINIMAL UBI CONTAINER

UBI dnf repositories are enabled inside UBI Minimal images by default.

**Prerequisites**

- The **containers-tool** meta-package is installed.

**Procedure**

1. Pull and run the `registry.access.redhat.com/ubi9/ubi-minimal` image:

   ```bash
   $ podman run -it --name myubimin registry.access.redhat.com/ubi9/ubi-minimal
   ```

2. Add a package to the `myubimin` container:

   - To add a package that is in the UBI repository, do not disable any repositories. For example, to add the `bzip2` package:
     ```bash
     # microdnf install bzip2
     ```

   - To add a package that is in a different host repository, explicitly enable the repository you need. For example, to install the `python38-devel` package from the `codeready-builder-for-rhel-8-x86_64-rpms` repository:
     ```bash
     # microdnf install --enablerepo=codeready-builder-for-rhel-8-x86_64-rpms python38-devel
     ```

**Verification steps**

1. List all enabled repositories inside the container:

   ```bash
   # microdnf repolist
   ```

2. Ensure that the required repositories are listed.

3. List all installed packages:

   ```bash
   # rpm -qa
   ```

4. Ensure that the required packages are listed.

**NOTE**

Installing Red Hat packages that are not inside the Red Hat UBI repositories can limit the ability to distribute the container outside of subscribed RHEL systems.
7.6. ADDING SOFTWARE TO A UBI CONTAINER ON A UNSUBSCRIBED HOST

You do not have to disable any repositories when adding software packages on unsubscribed RHEL systems.

Prerequisites

- The `containers-tool` meta-package is installed.

Procedure

- Add a package to a running container based on the UBI standard or UBI init images. Do not disable any repositories. Use the `podman run` command to run the container, then use the `dnf install` command inside a container.

  - For example, to add the `bzip2` package to the UBI standard based container:

    ```
    $ podman run -it --name myubi registry.access.redhat.com/ubi9/ubi
    # dnf install bzip2
    ```

  - For example, to add the `bzip2` package to the UBI init based container:

    ```
    $ podman run -it --name myubimin registry.access.redhat.com/ubi9/ubi-minimal
    # microdnf install bzip2
    ```

Verification steps

1. List all enabled repositories:
   - To list all enabled repositories inside the containers based on UBI standard or UBI init images:

     ```
     # dnf repolist
     ```

   - To list all enabled repositories inside the containers based on UBI minimal containers:

     ```
     # microdnf repolist
     ```

2. Ensure that the required repositories are listed.

3. List all installed packages:

   ```
   # rpm -qa
   ```

4. Ensure that the required packages are listed.

7.7. BUILDING UBI-BASED IMAGES

You can create a UBI-based web server container from a `Containerfile` using the Buildah utility. You have to disable all non-UBI dnf repositories to ensure that your image contains only Red Hat software that you can redistribute.
NOTE

For UBI minimal images, use **microdnf** instead of **dnf**: 

```bash
RUN microdnf update -y && rm -rf /var/cache/yum
```

and

```bash
RUN microdnf install httpd -y && microdnf clean all
```

Prerequisites

- The **containers-tool** meta-package is installed.

Procedure

1. Create a **Containerfile**:

   ```bash
   FROM registry.access.redhat.com/ubi9/ubi
   USER root
   LABEL maintainer="John Doe"
   # Update image
   RUN dnf update --disablerepo=* --enablerepo=ubi-8-appstream-rpms --enablerepo=ubi-8-baseos-rpms -y && rm -rf /var/cache/yum
   RUN dnf install --disablerepo=* --enablerepo=ubi-8-appstream-rpms --enablerepo=ubi-8-baseos-rpms httpd -y && rm -rf /var/cache/yum
   # Add default Web page and expose port
   RUN echo "The Web Server is Running" > /var/www/html/index.html
   EXPOSE 80
   # Start the service
   CMD ["-D", "FOREGROUND"]
   ENTRYPOINT ["/usr/sbin/httpd"]
   ```

2. Build the container image:

   ```bash
   # buildah bud -t johndoe/webserver .
   STEP 1: FROM registry.access.redhat.com/ubi9/ubi:latest
   STEP 2: USER root
   STEP 3: LABEL maintainer="John Doe"
   STEP 4: RUN dnf update --disablerepo=* --enablerepo=ubi-8-appstream-rpms --enablerepo=ubi-8-baseos-rpms -y
   ...
   Writing manifest to image destination
   Storing signatures
   --> f9874f27050
   f9874f270500c255b950e751e53d37c6f8f6dba13425d42f30c2a8ef26b769f2
   ```

Verification steps

1. Run the web server:

   ```bash
   # podman run -d --name=myweb -p 80:80 johndoe/webserver
   bbe98c71d18720d66e4567949888dc4f86eecc7d304e785d5177168a5965f64
   ```

2. Test the web server:

   ```bash
   # curl http://localhost/index.html
   The Web Server is Running
   ```
7.8. USING APPLICATION STREAM RUNTIME IMAGES

Runtime images based on Application Streams offer a set of container images that you can use as the basis for your container builds.

Supported runtime images are Python, Ruby, s2-core, s2i-base, .NET Core, PHP. The runtime images are available in the Red Hat Container Catalog.

NOTE

Because these UBI images contain the same basic software as their legacy image counterparts, you can learn about those images from the Using Red Hat Software Collections Container Images guide.

Additional resources

- Red Hat Container Catalog
- Red Hat Container Image Updates

7.9. GETTING UBI CONTAINER IMAGE SOURCE CODE

Source code is available for all Red Hat UBI-based images in the form of downloadable container images. Source container images cannot be run, despite being packaged as containers. To install Red Hat source container images on your system, use the skopeo command, not the podman pull command.

Source container images are named based on the binary containers they represent. For example, for a particular standard RHEL UBI 9 container registry.access.redhat.com/ubi9:8.1-397 append -source to get the source container image (registry.access.redhat.com/ubi9:8.1-397-source).

Prerequisites

- The containers-tool meta-package is installed.

Procedure

1. Use the skopeo copy command to copy the source container image to a local directory:

   ```
   $ skopeo copy \\
   docker://registry.access.redhat.com/ubi9:8.1-397-source \\
   dir:$HOME/TEST \
   ...
   Copying blob 477bc8106765 done
   Copying blob c438818481d3 done
   ...
   Writing manifest to image destination
   Storing signatures
   ```

2. Use the skopeo inspect command to inspect the source container image:

   ```
   $ skopeo inspect dir:$HOME/TEST
   {
   "Digest":
   ```
"sha256:7ab721ef3305271bb629a6db065c59bbeb87bc53e7cbf88e2953a1217ba7322",
"RepoTags": [],
"Created": "2020-02-11T12:14:18.612461174Z",
"DockerVersion": "",
"Labels": null,
"Architecture": "amd64",
"Os": "linux",
"Layers": [
  "sha256:1ae73d938ab9f11718d0f6a4148eb07d38ac1c0a70b1d03e751de8bf3c2c87fa",
  "sha256:9fe966885cb8712c47e5e5ec2eaa0797a0d5ff6b8b119c4b4b400cc9e255421",
  "sha256:61b2527a4b836a4efbb82dfd449c0556c0f769570a6c02e112f88f8bbcd90166",
  ...
  "sha256:cc56c782b513e2b2d2cc2af77b69e13df4ab624dd8b56c4d086206b46b9b9e5f",
  "sha256:dcf9396fada4e6c1ce667b306b7f08a83c9e6b39d0955c481b8ea5b2a465b32",
  ...
  "sha256:feb6d2ae252402ea6a6fca8a158a7d32c7e4572db0e6e5a5eab15d4e0777951e"
],
"Env": null
}

3. Unpack all the content:

```bash
$ cd $HOME/TEST
$ for f in $(ls); do tar xvf $f; done
```

4. Check the results:

```bash
$ find blobs/ rpm_dir/
blobs/
blobs/sha256
blobs/sha256/10914f1fff060ce31388f5ab963871870535aaa551629f5ad182384d60fd82
rpm_dir/
rpm_dir/gzip-1.9-4.el8.src.rpm
```

If the results are correct, the image is ready to be used.

**NOTE**

It could take several hours after a container image is released for its associated source container to become available.

Additional resources

- `skopeo-copy` man page
- `skopeo-inspect` man page
CHAPTER 8. SIGNING CONTAINER IMAGES

You can use a GNU Privacy Guard (GPG) signature or a sigstore signature to sign your container image. Both signing techniques are generally compatible with any OCI compliant container registries. You can use Podman to sign the image before pushing it into a remote registry and configure consumers so that any unsigned image is rejected. Signing container images helps to prevent supply chain attacks.

Signing using GPG keys requires deploying a separate lookaside server to distribute signatures. The lookaside server can be any HTTP server. Starting with Podman version 4.2, you can use the sigstore format of container signatures. Compared to the GPG keys, the separate lookaside server is not required because the sigstore signatures are stored in the container registry.

8.1. SIGNING CONTAINER IMAGES WITH GPG SIGNATURES

You can sign images using a GNU Privacy Guard (GPG) key.

Prerequisites

- The `containers-tool` meta-package is installed.
- The GPG tool is installed.
- The lookaside web server is set up and you can publish files on it.
  - You can check the system-wide registries configuration in the `/etc/containers/registries.d/default.yaml` file. The `lookaside-staging` option references a file path for signature writing and is typically set on hosts publishing signatures.

```
# cat /etc/containers/registries.d/default.yaml
docker:
  <registry>:
    lookaside: https://registry-lookaside.example.com
    lookaside-staging: file:///var/lib/containers/sigstore
...
```

Procedure

1. Generate a GPG key:

   ```
   # gpg --full-gen-key
   ```

2. Export the public key:

   ```
   # gpg --output <path>/key.gpg --armor --export <username@domain.com>
   ```

3. Build the container image using `Containerfile` in the current directory:

   ```
   $ podman build -t <registry>/<namespace>/<image>
   ```

   Replace `<registry>`, `<namespace>`, and `<image>` with the container image identifiers. For more details, see Container registries.

4. Sign the image and push it to the registry:
$ podman push \
  --sign-by <username@domain.com> \
  <registry>/<namespace>/<image>

**NOTE**

If you need to sign existing images while moving them across container registries, you can use the `skopeo copy` command.

5. Optional: Display the new image signature:

```
# (cd /var/lib/containers/sigstore/; find . -type f) 
./<image>@sha256=<digest>/signature-1
```

6. Copy your local signatures to the lookaside web server:

```
# rsync -a /var/lib/containers/sigstore <user@registry-lookaside.example.com>:/registry-lookaside/webroot/sigstore
```

The signatures are stored in the location determined by the `lookaside-staging` option, in this case, `/var/lib/containers/sigstore` directory.

**Verification**

- For more details, see Verifying GPG image signatures.

**Additional resources**

- `podman-image-trust` man page
- `podman-push` man page
- `podman-build` man page
- How to generate GPG key pairs

### 8.2. VERIFYING GPG IMAGE SIGNATURES

You can verify that a container image is correctly signed with a GPG key using the following procedure.

**Prerequisites**

- The `containers-tool` meta-package is installed.
- The web server for a signature reading is set up and you can publish files on it.
  - You can check the system-wide registries configuration in the `/etc/containers/registries.d/default.yaml` file. The `lookaside` option references a web server for signature reading. The `lookaside` option has to be set for verifying signatures.

```
# cat /etc/containers/registries.d/default.yaml
docker: 
  <registry>:
```

---

**CHAPTER 8. SIGNING CONTAINER IMAGES**
Procedure

1. Update a trust scope for the `<registry>`:

   ```bash
   $ podman image trust set -f <path>/key.gpg <registry>/<namespace>
   ```

2. Optional: Verify the trust policy configuration by displaying the `/etc/containers/policy.json` file:

   ```bash
   $ cat /etc/containers/policy.json
   {
   ...
   "transports": {
   "docker": {
   "<registry>/<namespace>": [
   {
   "type": "signedBy",
   "keyType": "GPGKeys",
   "keyPath": "<path>/key.gpg"
   }
   ]
   }
   }
   }
   ```

   **NOTE**

   Typically, the `/etc/containers/policy.json` file is configured at a level of organization where the same keys are used. For example, `<registry>/<namespace>` for a public registry, or just a `<registry>` for a single-company dedicated registry.

3. Pull the image:

   ```bash
   # podman pull <registry>/<namespace>/<image>
   ```

   Storing signatures
   e7d92cd71feacf90708cb59182d0df1b91f8ae022d29e8e95d75ca6a99776a

   The `podman pull` command enforces signature presence as configured, no extra options are required.

   **NOTE**

   You can edit the system-wide registry configuration in the `/etc/containers/registries.d/default.yaml` file. You can also edit the registry or repository configuration section in any YAML file in the `/etc/containers/registries.d` directory. All YAML files are read and the filename can be arbitrary. A single scope (default–docker, registry, or namespace) can only exist in one file within the `/etc/containers/registries.d` directory.
IMPORTANT

The system-wide registries configuration in the 
/etc/containers/registries.d/default.yaml file allows accessing the published signatures. The sigstore and sigstore-staging options are now deprecated. These options refer to signing storage, and they are not connected to the sigstore signature format. Use the new equivalent lookaside and lookaside-staging options instead.

Additional resources

- podman-image-trust man page
- podman-pull man page

8.3. SIGNING CONTAINER IMAGES WITH SIGSTORE SIGNATURES USING A PRIVATE KEY

Starting with Podman version 4.2, you can use the sigstore format of container signatures.

Prerequisites

- The containers-tool meta-package is installed.

Procedure

1. Generate a sigstore public/private key pair:

   $ skopeo generate-sigstore-key --output-prefix myKey

   - The public and private keys myKey.pub and myKey.private are generated.

   NOTE

   The skopeo generate-sigstore-key command is available from RHEL 9.2. Otherwise, you must use the upstream Cosign project to generate public/private key pair:

   - Install the cosign tool:

     $ git clone -b v2.0.0 https://github.com/sigstore/cosign
     $ cd cosign
     $ make ./cosign

   - Generate a public/private key pair:

     $ ./cosign generate-key-pair

     Private key written to cosign.key
     Public key written to cosign.pub

2. Add the following content to the /etc/containers/registries.d/default.yaml file:
By setting the `use-sigstore-attachments` option, Podman and Skopeo can read and write the container sigstore signatures together with the image and save them in the same repository as the signed image.

**NOTE**

You can edit the system-wide registry configuration in the `/etc/containers/registries.d/default.yaml` file. You can also edit the registry or repository configuration section in any YAML file in the `/etc/containers/registries.d` directory. All YAML files are read and the filename can be arbitrary. A single scope (default-docker, registry, or namespace) can only exist in one file within the `/etc/containers/registries.d` directory.

3. Build the container image using `Containerfile` in the current directory:

   ```
   $ podman build -t <registry>/<namespace>/<image>
   ```

4. Sign the image and push it to the registry:

   ```
   $ podman push --sign-by-sigstore-private-key ./myKey.private <registry>/<namespace>/<image>
   ```

   The `podman push` command pushes the `<registry>/<namespace>/<image>` local image to the remote registry as `<registry>/<namespace>/<image>`. The `--sign-by-sigstore-private-key` option adds a sigstore signature using the `myKey.private` private key to the `<registry>/<namespace>/<image>` image. The image and the sigstore signature are uploaded to the remote registry.

   **NOTE**

   If you need to sign existing images while moving them across container registries, you can use the `skopeo copy` command.

**Verification**

- For more details, see [Verifying sigstore image signatures using a public key](#).

**Additional resources**

- `podman-push` man page
- `podman-build` man page
- Sigstore: An open answer to software supply chain trust and security

**8.4. VERIFYING SIGSTORE IMAGE SIGNATURES USING A PUBLIC KEY**

You can verify that a container image is correctly signed using the following procedure.
Prerequisites

- The **containers-tool** meta-package is installed.

Procedure

1. Add the following content to the `/etc/containers/registries.d/default.yaml` file:

   ```yaml
   docker:
     <registry>:
       use-sigstore-attachments: true
   ```

   By setting the **use-sigstore-attachments** option, Podman and Skopeo can read and write the container sigstore signatures together with the image and save them in the same repository as the signed image.

   **NOTE**
   
   You can edit the system-wide registry configuration in the `/etc/containers/registries.d/default.yaml` file. You can also edit the registry or repository configuration section in any YAML file in the `/etc/containers/registries.d` directory. All YAML files are read and the filename can be arbitrary. A single scope (default-docker, registry, or namespace) can only exist in one file within the `/etc/containers/registries.d` directory.

2. Edit the `/etc/containers/policy.json` file to enforce sigstore signature presence:

   ```json
   ...,
   "transports": {
     "docker": {
       "<registry>/<namespace>": [
         {
           "type": "sigstoreSigned",
           "keyPath": "/some/path/to/cosign.pub"
         }
       ]
     }
   },
   ...
   ```

   By modifying the `/etc/containers/policy.json` configuration file, you change the trust policy configuration. Podman, Buildah, and Skopeo enforce the existence of the container image signatures.

3. Pull the image:

   ```bash
   $ podman pull <registry>/<namespace>/<image>
   ```

   The **podman pull** command enforces signature presence as configured, no extra options are required.

Additional resources

- Sigstore: An open answer to software supply chain trust and security
8.5. SIGNING CONTAINER IMAGES WITH SIGSTORE SIGNATURES USING FULCIO AND REKOR

With Fulcio and Rekor servers, you can now create signatures by using short-term certificates based on an OpenID Connect (OIDC) server authentication, instead of manually managing a private key.

Prerequisites

- The **containers-tool** meta-package is installed.
- You have Fulcio (https://<your-fulcio-server>) and Rekor (https://<your-rekor-server>) servers running and configured.
- You have Podman v4.4 or higher installed.

Procedure

1. Add the following content to the `/etc/containers/registries.conf.d/default.yaml` file:

   ```yaml
   docker:
     <registry>:
       use-sigstore-attachments: true
   
   By setting the **use-sigstore-attachments** option, Podman and Skopeo can read and write the container sigstore signatures together with the image and save them in the same repository as the signed image.

   **NOTE**

   You can edit the registry or repository configuration section in any YAML file in the `/etc/containers/registries.d` directory. A single scope (default-docker, registry, or namespace) can only exist in one file within the `/etc/containers/registries.d` directory. You can also edit the system-wide registry configuration in the `/etc/containers/registries.d/default.yaml` file. Please note that all YAML files are read and the filename is arbitrary.

2. Create the **file.yml** file:

   ```yaml
   fulcio:
     fulcioURL: "https://<your-fulcio-server>"
     oidcMode: "interactive"
     oidcIssuerURL: "https://<your-OIDC-provider>"
     oidcClientId: "sigstore"
     rekorURL: "https://<your-rekor-server>"
   
   The **file.yml** is the sigstore signing parameter YAML file used to store options required to create sigstore signatures.

3. Sign the image and push it to the registry:

   ```bash
   $ podman push --sign-by-sigstore=file.yml <registry>/<namespace>/<image>
   
   You can alternatively use the **skopeo copy** command with similar **--sign-by-sigstore** options to sign existing images while moving them across container registries.
Verification

- Verifying container images with sigstore signatures using Fulcio and Rekor

Additional resources

- containers-sigstore-signing-params.yaml man page
- podman-push man page
- containerregistries.d man page

8.6. VERIFYING CONTAINER IMAGES WITH SIGSTORE SIGNATURES USING FULCIO AND REKOR

You can verify image signatures by adding the Fulcio and Rekor-related information to the policy.json file. Verifying container images signatures ensures that the images come from a trusted source and has not been tampered or modified.

Prerequisites

- The containers-tool meta-package is installed.

Procedure

1. Add the following content to the /etc/containers/registries.conf.d/default.yaml file:

```yaml
docker:
  <registry>:
    use-sigstore-attachments: true
```

- By setting the use-sigstore-attachments option, Podman and Skopeo can read and write the container sigstore signatures together with the image and save them in the same repository as the signed image.

NOTE

You can edit the registry or repository configuration section in any YAML file in the /etc/containers/registries.d directory. A single scope (default-docker, registry, or namespace) can only exist in one file within the /etc/containers/registries.d directory. You can also edit the system-wide registry configuration in the /etc/containers/registries.d/default.yaml file. Please note that all YAML files are read and the filename is arbitrary.
2. Add the **fulcio** section and the **rekorPublicKeyPath** or **rekorPublicKeyData** fields in the `/etc/containers/policy.json` file:

```json
{
... 
  "transports": {
    "docker": {
      "<registry>/<namespace>": [
        {
          "type": "sigstoreSigned",
          "fulcio": {
            "caPath": "/path/to/local/CA/file",
            "oidcIssuer": "https://expected.OIDC.issuer/",
            "subjectEmail": "expected-signing-user@example.com",
          },
          "rekorPublicKeyPath": "/path/to/local/public/key/file",
        }
      ]
    }
  }
... 
}
```

- The **fulcio** section provides that the signature is based on a Fulcio-issued certificate.

- You have to specify one of **caPath** and **caData** fields, containing the CA certificate of the Fulcio instance.

- Both **oidcIssuer** and **subjectEmail** are mandatory, exactly specifying the expected identity provider, and the identity of the user obtaining the Fulcio certificate.

- You have to specify one of **rekorPublicKeyPath** and **rekorPublicKeyData** fields.

3. Pull the image:

```
$ podman pull <registry>/<namespace>/<image>
```

The **podman pull** command enforces signature presence as configured, no extra options are required.

**Additional resources**

- **policy.json** man page
- **container-registries.d** man page

### 8.7. SIGNING CONTAINER IMAGES WITH SIGSTORE SIGNATURES WITH A PRIVATE KEY AND REKOR

Starting with Podman version 4.4, you can use the sigstore format of container signatures together with Rekor servers. You can also upload public signatures to the public rekor.sigstore.dev server, which increases the interoperability with Cosign. You can then use the **cosign verify** command to verify your signatures without having to explicitly disable Rekor.
Prerequisites

- The containers-tool meta-package is installed.

Procedure

1. Generate a sigstore public/private key pair:

   ```
   $ skopeo generate-sigstore-key --output-prefix myKey
   ```

   - The public and private keys `myKey.pub` and `myKey.private` are generated.

2. Add the following content to the `/etc/containers/registries.conf.d/default.yaml` file:

   ```yaml
   docker:
     <registry>:
       use-sigstore-attachments: true
   ```

   - By setting the `use-sigstore-attachments` option, Podman and Skopeo can read and write the container sigstore signatures together with the image and save them in the same repository as the signed image.

   **NOTE**

   You can edit the registry or repository configuration section in any YAML file in the `/etc/containers/registries.d` directory. A single scope (default-docker, registry, or namespace) can only exist in one file within the `/etc/containers/registries.d` directory. You can also edit the system-wide registry configuration in the `/etc/containers/registries.d/default.yaml` file. Please note that all YAML files are read and the filename is arbitrary.

3. Build the container image using `Containerfile` in the current directory:

   ```
   $ podman build -t <registry>/<namespace>/<image>
   ```

4. Create the `file.yml` file:

   ```yaml
   privateKeyFile: "/home/user/sigstore/myKey.private"
   privateKeyPassphraseFile: "/mnt/user/sigstore-myKey-passphrase"
   rekorURL: "https://<your-rekor-server>"
   ```

   - The `file.yml` is the sigstore signing parameter YAML file used to store options required to create sigstore signatures.

5. Sign the image and push it to the registry:

   ```
   $ podman push --sign-by-sigstore=file.yml <registry>/<namespace>/<image>
   ```

   - You can alternatively use the `skopeo copy` command with similar `--sign-by-sigstore` options to sign existing images while moving them across container registries.
WARNING
Note that your submission for public servers includes data about the public key and metadata about the signature.

Verification

- Use one of the following methods to verify that a container image is correctly signed:
  - Use the `cosign verify` command:
    
    ```bash
    $ cosign verify <registry>/<namespace>/<image> --key myKey.pub
    ```
  - Use the `podman pull` command:
    
    ```bash
    podman pull <registry>/<namespace>/<image>
    ```
    
    - Add the `rekorPublicKeyPath` or `rekorPublicKeyData` fields in the `/etc/containers/policy.json` file:
      
      ```json
      {
        ...
        "transports": {
          "docker": {
            
            "<registry>/<namespace>": [
              
              {
                "type": "sigstoreSigned",
                "rekorPublicKeyPath": "/path/to/local/public/key/file",
              }
            ],
          } ...
        } ...
      }
      ```
    - Pull the image:
      
      ```bash
      $ podman pull <registry>/<namespace>/<image>
      ```
    
    - The `podman pull` command enforces signature presence as configured, no extra options are required.

Additional resources

- `podman-push` man page
- `podman-build` man page
- `container-registries.d` man page
- Sigstore: An open answer to software supply chain trust and security
CHAPTER 9. MANAGING A CONTAINER NETWORK

The chapter provides information about how to communicate among containers.

9.1. LISTING CONTAINER NETWORKS

In Podman, there are two network behaviors - rootless and rootful:

- Rootless networking - the network is setup automatically, the container does not have an IP address.
- Rootful networking - the container has an IP address.

Prerequisites

- The `containers-tool` meta-package is installed.

Procedure

- List all networks as a root user:

```bash
# podman network ls
NETWORK ID    NAME        VERSION     PLUGINS
2f259bab93aa  podman      0.4.0       bridge,portmap,firewall,tuning
```

- By default, Podman provides a bridged network.
- List of networks for a rootless user is the same as for a rootful user.

Additional resources

- `podman-network-ls` man page

9.2. INSPECTING A NETWORK

Display the IP range, enabled plugins, type of network, and so on, for a specified network listed by the `podman network ls` command.

Prerequisites

- The `containers-tool` meta-package is installed.

Procedure

- Inspect the default `podman` network:

```bash
$ podman network inspect podman
[
  {
    "cniVersion": "0.4.0",
    "name": "podman",
    "plugins": [
    
```
You can see the IP range, enabled plugins, type of network, and other network settings.

Additional resources

- podman-network-inspect man page

### 9.3. CREATING A NETWORK

Use the `podman network create` command to create a new network.

**NOTE**

By default, Podman creates an external network. You can create an internal network using the `podman network create --internal` command. Containers in an internal network can communicate with other containers on the host, but cannot connect to the network outside of the host nor be reached from it.
Prerequisites

- The **containers-tool** meta-package is installed.

Procedure

- Create the external network named **mynet**:

  ```
  # podman network create mynet
  /etc/cni/net.d/mynet.conflist
  ```

Verification

- List all networks:

  ```
  # podman network ls
  NETWORK ID    NAME        VERSION     PLUGINS
  2f259bab93aa  podman      0.4.0       bridge,portmap,firewall,tuning
  11c844f95e28  mynet       0.4.0       bridge,portmap,firewall,tuning,dnsname
  ```

You can see the created **mynet** network and default **podman** network.

**NOTE**

Beginning with Podman 4.0, the DNS plugin is enabled by default if you create a new external network using the **podman network create** command.

Additional resources

- **podman-network-create** man page

### 9.4. CONNECTING A CONTAINER TO A NETWORK

Use the **podman network connect** command to connect the container to the network.

Prerequisites

- The **containers-tool** meta-package is installed.

- A network has been created using the **podman network create** command.

- A container has been created.

Procedure

- Connect a container named **mycontainer** to a network named **mynet**:

  ```
  # podman network connect mynet mycontainer
  ```

Verification

- Verify that the **mycontainer** is connected to the **mynet** network:
# podman inspect --format='{{.NetworkSettings.Networks}}' mycontainer
map[_podman:0xc00042ab40 mynet:0xc00042ac60_]

You can see that **mycontainer** is connected to **mynet** and **podman** networks.

Additional resources
- **podman-network-connect** man page

## 9.5. DISCONNECTING A CONTAINER FROM A NETWORK

Use the **podman network disconnect** command to disconnect the container from the network.

**Prerequisites**
- The **containers-tool** meta-package is installed.
- A network has been created using the **podman network create** command.
- A container is connected to a network.

**Procedure**
- Disconnect the container named **mycontainer** from the network named **mynet**:

  ```bash
  # podman network disconnect mynet mycontainer
  ```

**Verification**
- Verify that the **mycontainer** is disconnected from the **mynet** network:

  ```bash
  # podman inspect --format='{{.NetworkSettings.Networks}}' mycontainer
  map[podman:0xc000537440]
  ```

You can see that **mycontainer** is disconnected from the **mynet** network, **mycontainer** is only connected to the default **podman** network.

Additional resources
- **podman-network-dismiss** man page

## 9.6. REMOVING A NETWORK

Use the **podman network rm** command to remove a specified network.

**Prerequisites**
- The **containers-tool** meta-package is installed.

**Procedure**
1. List all networks:

```bash
- ```
# podman network ls
NETWORK ID    NAME        VERSION     PLUGINS
2f259bab93aa  podman      0.4.0       bridge,portmap,firewall,tuning
11c844f95e28  mynet       0.4.0       bridge,portmap,firewall,tuning,dnsname

2. Remove the **mynet** network:

```bash
# podman network rm mynet
mynet
```

**NOTE**

If the removed network has associated containers with it, you have to use the **podman network rm -f** command to delete containers and pods.

## Additional resources

- **podman-network-rm** man page

### 9.7. REMOVING ALL UNUSED NETWORKS

Use the **podman network prune** to remove all unused networks. An unused network is a network which has no containers connected to it. The **podman network prune** command does not remove the default **podman** network.

## Prerequisites

- The **containers-tool** meta-package is installed.

## Procedure

- Remove all unused networks:

```bash
# podman network prune
WARNING! This will remove all networks not used by at least one container.
Are you sure you want to continue? [y/N] y
```

## Verification

- Verify that all networks were removed:

```bash
# podman network ls
NETWORK ID    NAME        VERSION     PLUGINS
2f259bab93aa  podman      0.4.0       bridge,portmap,firewall,tuning
```
Additional resources

- podman-network-prune man page
CHAPTER 10. WORKING WITH PODS

Containers are the smallest unit that you can manage with Podman, Skopeo and Buildah container tools. A Podman pod is a group of one or more containers. The Pod concept was introduced by Kubernetes. Podman pods are similar to the Kubernetes definition. Pods are the smallest compute units that you can create, deploy, and manage in OpenShift or Kubernetes environments. Every Podman pod includes an infra container. This container holds the namespaces associated with the pod and allows Podman to connect other containers to the pod. It allows you to start and stop containers within the pod and the pod will stay running. The default infra container on the `registry.access.redhat.com/ubi9/pause` image.

10.1. CREATING PODS

This procedure shows how to create a pod with one container.

Prerequisites

- The `containers-tool` meta-package is installed.

Procedure

1. Create an empty pod:

```
$ podman pod create --name mypod
223df6b390b4ea87a090a4b520717b9b003187a6960bd37631ae9bc12c433aff
The pod is in the initial state Created.
```

   The pod is in the initial state Created.

2. Optional: List all pods:

```
$ podman pod ps
POD ID  NAME    STATUS    CREATED                  # OF CONTAINERS   INFRA ID
223df6b390b4  mypod   Created   Less than a second ago   1                 3afdcd93de3e
```

   Notice that the pod has one container in it.

3. Optional: List all pods and containers associated with them:

```
$ podman ps -a --pod
CONTAINER ID  IMAGE                 COMMAND  CREATED                 STATUS   PORTS NAMES               POD
3afcd93de3e  registry.access.redhat.com/ubi9/pause            Less than a second ago
Created        223df6b390b4-infra  223df6b390b4
```

   You can see that the pod ID from `podman ps` command matches the pod ID in the `podman pod ps` command. The default infra container is based on the `registry.access.redhat.com/ubi9/pause` image.

4. Run a container named `myubi` in the existing pod named `mypod`:

```
$ podman run -dt --name myubi --pod mypod registry.access.redhat.com/ubi9/ubi /bin/bash
5df5c48f6ea87860c75822c02ebab8370548b04c78be9fc156570949013863ccf71
```
5. Optional: List all pods:

```
$ podman pod ps
POD ID     NAME    STATUS    CREATED                  # OF CONTAINERS   INFRA ID
223df6b390b4   mypod   Running   Less than a second ago   2                 3afdc93de3e
```

You can see that the pod has two containers in it.

6. Optional: List all pods and containers associated with them:

```
$ podman ps -a --pod
CONTAINER ID  IMAGE                                       COMMAND    CREATED
STATUS                     PORTS  NAMES               POD
5df5c48fea87  registry.access.redhat.com/ubi9/ubi:latest  /bin/bash  Less than a second ago
Up Less than a second ago         myubi               223df6b390b4
3afdc93de3e  registry.access.redhat.com/ubi9/pause                                   Less than a second ago
Up Less than a second ago         223df6b390b4-infra  223df6b390b4
```

Additional resources

- podman-pod-create man page
- Podman: Managing pods and containers in a local container runtime

### 10.2. DISPLAYING POD INFORMATION

This procedure provides information about how to display pod information.

**Prerequisites**

- The containers-tool meta-package is installed.
- The pod has been created. For details, see section Creating pods.

**Procedure**

- Display active processes running in a pod:
  - To display the running processes of containers in a pod, enter:
    
    ```
    $ podman pod top mypod
    USER   PID   PPID   %CPU    ELAPSED         TTY     TIME   COMMAND
    0      1     0      0.000   24.07743518s   ?       0s     /pause
    root   1     0      0.000   24.078146025s   pts/0   0s     /bin/bash
    ```
  - To display a live stream of resource usage stats for containers in one or more pods, enter:
    
    ```
    $ podman pod stats -a --no-stream
    ID             NAME              CPU %   MEM USAGE / LIMIT   MEM %   NET IO    BLOCK IO
    PIDS
    a9f807faaecd  frosty_hodgkin    --      3.092MB / 16.7GB    0.02%   -- / --   -- / --    2
    3b33001239ee  sleepy_stallman   --      -- / --             --      -- / --   -- / --    --
    ```
  - To display information describing the pod, enter:
$ podman pod inspect mypod
{
   "Id": "db99446fa9c6d10b973d1ce55a42a6850357e0cd447d9bac5627bb2516b5b19a",
   "Name": "mypod",
   "Created": "2020-09-08T10:35:07.536541534+02:00",
   "CreateCommand": [
      "podman",
      "pod",
      "create",
      "--name",
      "mypod"
   ],
   "State": "Running",
   "Hostname": "mypod",
   "CreateCgroup": false,
   "CgroupParent": "/libpod_parent",
   "CgroupPath": "/libpod_parent/db99446fa9c6d10b973d1ce55a42a6850357e0cd447d9bac5627bb2516b5b19a",
   "CreateInfra": false,
   "InfraContainerID": "891c54f70783dcad596d888040700d93f3ead01921894bc19c10b0a03c738ff7",
   "SharedNamespaces": [
      "uts",
      "ipc",
      "net"
   ],
   "NumContainers": 2,
   "Containers": [
      {
         "Id": "891c54f70783dcad596d888040700d93f3ead01921894bc19c10b0a03c738ff7",
         "Name": "db99446fa9c6-infra",
         "State": "running"
      },
      {
         "Id": "effc5bbcfe505b522e3bf8bb5705a39f94a455a66fd81e542bcc27d39727d2d",
         "Name": "myubi",
         "State": "running"
      }
   ]
}

You can see information about containers in the pod.

Additional resources

- **podman pod top** man page
- **podman-pod-stats** man page
- **podman-pod-inspect** man page

### 10.3. STOPPING PODS
You can stop one or more pods using the `podman pod stop` command.

**Prerequisites**

- The `containers-tool` meta-package is installed.
- The pod has been created. For details, see section Creating pods.

**Procedure**

1. Stop the pod **mypod**:

   ```bash
   $ podman pod stop mypod
   ```

2. Optional: List all pods and containers associated with them:

   ```bash
   $ podman ps -a --pod
   ```

<table>
<thead>
<tr>
<th>CONTAINER ID</th>
<th>IMAGE</th>
<th>COMMAND</th>
<th>CREATED</th>
<th>STATUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>5df5c48ea87</td>
<td>registry.redhat.io/ubi9/ubi:latest</td>
<td>/bin/bash</td>
<td>About a minute ago</td>
<td>Exited (0) 7 seconds ago</td>
</tr>
<tr>
<td>3afdc93de3e</td>
<td>registry.access.redhat.com/9/pause</td>
<td></td>
<td>About a minute ago</td>
<td>Exited (0) 7 seconds ago</td>
</tr>
</tbody>
</table>

   You can see that the pod **mypod** and container **myubi** are in "Exited" status.

**Additional resources**

- `podman-pod-stop` man page

10.4. REMOVING PODS

You can remove one or more stopped pods and containers using the `podman pod rm` command.

**Prerequisites**

- The `containers-tool` meta-package is installed.
- The pod has been created. For details, see section Creating pods.
- The pod has been stopped. For details, see section Stopping pods.

**Procedure**

1. Remove the pod **mypod**, type:

   ```bash
   $ podman pod rm mypod
   ```

   Note that removing the pod automatically removes all containers inside it.

2. Optional: Check that all containers and pods were removed:
$ podman ps
$ podman pod ps

Additional resources

- podman-pod-rm man page
CHAPTER 11. COMMUNICATING AMONG CONTAINERS

This chapter provides information about how to communicate among containers.

11.1. THE NETWORK MODES AND LAYERS

There are several different network modes in Podman:

- **bridge** - creates another network on the default bridge network
- **container:<id>** - uses the same network as the container with `<id>` id
- **host** - uses the host network stack
- **network-id** - uses a user-defined network created by the `podman` network create command
- **private** - creates a new network for the container
- **slirp4nets** - creates a user network stack with slirp4netns, the default option for rootless containers

**NOTE**

The host mode gives the container full access to local system services such as D-bus, a system for interprocess communication (IPC), and is therefore considered insecure.

11.2. INSPECTING A NETWORK SETTINGS OF A CONTAINER

Use the `podman inspect` command with the `--format` option to display individual items from the `podman inspect` output.

Prerequisites

- The `containers-tool` meta-package is installed.

Procedure

1. Display the IP address of a container:

   ```bash
   # podman inspect --format='{{.NetworkSettings.IPAddress}}' <containerName>
   ```

2. Display all networks to which container is connected:

   ```bash
   # podman inspect --format='{{.NetworkSettings.Networks}}' <containerName>
   ```

3. Display port mappings:

   ```bash
   # podman inspect --format='{{.NetworkSettings.Ports}}' <containerName>
   ```

Additional resources

- `podman-inspect` man page
11.3. COMMUNICATING BETWEEN A CONTAINER AND AN APPLICATION

You can communicate between a container and an application. An application ports are in either listening or open state. These ports are automatically exposed to the container network, therefore, you can reach those containers using these networks. By default, the web server listens on port 80. Using this procedure, the myubi container communicates with the web-container application.

Prerequisites

- The containers-tool meta-package is installed.

Procedure

1. Start the container named web-container:

```
# podman run -dt --name=web-container docker.io/library/httpd
```

2. List all containers:

```
# podman ps -a
```

```
CONTAINER ID  IMAGE                           COMMAND           CREATED        STATUS
PORTS       NAMES
b8c057333513  docker.io/library/httpd:latest  httpd-foreground  4 seconds ago  Up 5 seconds ago  web-container
```

3. Inspect the container and display the IP address:

```
# podman inspect --format="{{.NetworkSettings.IPAddress}}" web-container
10.88.0.2
```

4. Run the myubi container and verify that web server is running:

```
# podman run -it --name=myubi ubi9/ubi curl 10.88.0.2:80
<html><body><h1>It works!</h1></body></html>
```

11.4. COMMUNICATING BETWEEN A CONTAINER AND A HOST

By default, the podman network is a bridge network. It means that a network device is bridging a container network to your host network.

Prerequisites

- The containers-tool meta-package is installed.

- The web-container is running. For more information, see section Communicating between a container and an application.

Procedure
1. Verify that the bridge is configured:

```
# podman network inspect podman | grep bridge
"bridge": "cni-podman0",
"type": "bridge"
```

2. Display the host network configuration:

```
# ip addr show cni-podman0
6: cni-podman0: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc noqueue
state UP group default qlen 1000
    link/ether 62:af:a1:0a:ca:2e brd ff:ff:ff:ff:ff:ff
    inet 10.88.0.1/16 brd 10.88.255.255 scope global cni-podman0
        valid_lft forever preferred_lft forever
    inet6 fe80::60af:a1ff:fe0a:ca2e/64 scope link
        valid_lft forever preferred_lft forever
```

You can see that the `web-container` has an IP of the `cni-podman0` network and the network is bridged to the host.

3. Inspect the `web-container` and display its IP address:

```
# podman inspect --format='{{.NetworkSettings.IPAddress}}' web-container
10.88.0.2
```

4. Access the `web-container` directly from the host:

```
$ curl 10.88.0.2:80
<html><body><h1>It works!</h1></body></html>
```

Additional resources

- `podman-network` man page

11.5. COMMUNICATING BETWEEN CONTAINERS USING PORT MAPPING

The most convenient way to communicate between two containers is to use published ports. Ports can be published in two ways: automatically or manually.

Prerequisites

- The `containers-tool` meta-package is installed.

Procedure

1. Run the unpublished container:

```
# podman run -dt --name=web1 ubi9/httpd-24
```
2. Run the automatically published container:

   ```
   # podman run -dt --name=web2 -P ubi9/httpd-24
   ```

3. Run the manually published container and publish container port 80:

   ```
   # podman run -dt --name=web3 -p 9090:80 ubi9/httpd-24
   ```

4. List all containers:

   ```
   # podman ps
   CONTAINER ID  IMAGE                                            COMMAND               CREATED                  STATUS                  PORTS                                             NAMES
   f12fa79b8b39  registry.access.redhat.com/ubi9/httpd-24:latest  /usr/bin/run-http...  23 seconds ago  Up 24 seconds ago                                                    web1
   9024d9e815e2  registry.access.redhat.com/ubi9/httpd-24:latest  /usr/bin/run-http...  13 seconds ago  Up 13 seconds ago  0.0.0.0:43595->8080/tcp, 0.0.0.0:42423->8443/tcp  web2
   03bc2a019f1b  registry.access.redhat.com/ubi9/httpd-24:latest  /usr/bin/run-http...  2 seconds ago   Up 2 seconds ago   0.0.0.0:9090->80/tcp                              web3
   ```

   You can see that:

   - Container **web1** has no published ports and can be reached only by container network or a bridge.
   - Container **web2** has automatically mapped ports 43595 and 42423 to publish the application ports 8080 and 8443, respectively.

   **NOTE**

   The automatic port mapping is possible because the `registry.access.redhat.com/9/httpd-24` image has the `EXPOSE 8080` and `EXPOSE 8443` commands in the **Containerfile**.

   - Container **web3** has a manually published port. The host port 9090 is mapped to the container port 80.

5. Display the IP addresses of **web1** and **web3** containers:

   ```
   # podman inspect --format='{{.NetworkSettings.IPAddress}}' web1
   # podman inspect --format='{{.NetworkSettings.IPAddress}}' web3
   ```

6. Reach **web1** container using `<IP>:<port>` notation:

   ```
   # curl 10.88.0.14:8080
   ...
   <title>Test Page for the HTTP Server on Red Hat Enterprise Linux</title>
   ...
   ```

7. Reach **web2** container using `localhost:<port>` notation:

   ```
   # curl localhost:43595
   ```
8. Reach `<web3>` container using `<IP>:<port>` notation:

```
# curl 10.88.0.14:9090
```

### 11.6. COMMUNICATING BETWEEN CONTAINERS USING DNS

When a DNS plugin is enabled, use a container name to address containers.

**Prerequisites**

- The `containers-tool` meta-package is installed.
- A network with the enabled DNS plugin has been created using the `podman network create` command.

**Procedure**

1. Run a `receiver` container attached to the `mynet` network:

```
# podman run -d --net mynet --name receiver ubi9 sleep 3000
```

2. Run a `sender` container and reach the `receiver` container by its name:

```
# podman run -it --rm --net mynet --name sender alpine ping receiver
```

PING rcv01 (10.89.0.2): 56 data bytes
64 bytes from 10.89.0.2: seq=0 ttl=42 time=0.041 ms
64 bytes from 10.89.0.2: seq=1 ttl=42 time=0.125 ms
64 bytes from 10.89.0.2: seq=2 ttl=42 time=0.109 ms

Exit using the `CTRL+C`.

You can see that the `sender` container can ping the `receiver` container using its name.

### 11.7. COMMUNICATING BETWEEN TWO CONTAINERS IN A POD

All containers in the same pod share the IP addresses, MAC addresses and port mappings. You can communicate between containers in the same pod using `localhost:port` notation.

**Prerequisites**

- The `containers-tool` meta-package is installed.

**Procedure**

1. Create a pod named `web-pod`:
$ podman pod create --name=web-pod

2. Run the web container named **web-container** in the pod:

```
podman container run -d --pod web-pod --name=web-container
docker.io/library/httpd
```

3. List all pods and containers associated with them:

```
podman ps --pod
```

```
CONTAINER ID  IMAGE                           COMMAND           CREATED        STATUS
PORTS       NAMES               POD ID        PODNAME
58653cf0cf09  k8s.gcr.io/pause:3.5                              4 minutes ago  Up 3 minutes ago
4e61a300c194-infra  4e61a300c194 web-pod
b3f4255afdb3  docker.io/library/httpd:latest httpd-foreground 3 minutes ago  Up 3 minutes ago
ago              web-container  4e61a300c194 web-pod
```

4. Run the container in the **web-pod** based on the docker.io/library/fedora image:

```
podman container run -it --rm --pod web-pod docker.io/library/fedora curl localhost
```

```
<html><body><h1>It works!</h1></body></html>
```

You can see that the container can reach the **web-container**.

### 11.8. COMMUNICATING IN A POD

You must publish the ports for the container in a pod when a pod is created.

**Prerequisites**

- The **containers-tool** meta-package is installed.

**Procedure**

1. Create a pod named **web-pod**:

```
# podman pod create --name=web-pod-publish -p 80:80
```

2. List all pods:

```
# podman pod ls
```

```
POD ID   NAME         STATUS   CREATED        INFRA ID      # OF CONTAINERS
26fe5de43ab3 publish-pod Created 5 seconds ago 7de09076d2b3 1
```

3. Run the web container named **web-container** inside the **web-pod**:

```
# podman container run -d --pod web-pod-publish --name=web-container
docker.io/library/httpd
```
4. List containers

```
# podman ps
CONTAINER ID  IMAGE                    COMMAND           CREATED             STATUS PORTS               NAMES
7de09076d2b3  k8s.gcr.io/pause:3.5                       About a minute ago  Up 23 seconds ago 0.0.0.0:80->80/tcp  26fe5de43ab3-infra
088befb90e59 docker.io/library/httpd httpd-foreground 23 seconds ago Up 23 seconds ago 0.0.0.0:80->80/tcp web-container
```

5. Verify that the web-container can be reached:

```
$ curl localhost:80
<html><body><h1>It works!</h1></body></html>
```

11.9. ATTACHING A POD TO THE CONTAINER NETWORK

Attach containers in pod to the network during the pod creation.

Prerequisites

- The containers-tool meta-package is installed.

Procedure

1. Create a network named pod-net:

```
# podman network create pod-net
/etc/cni/net.d/pod-net.conflist
```

2. Create a pod web-pod:

```
# podman pod create --net pod-net --name web-pod
```

3. Run a container named web-container inside the web-pod:

```
# podman run -d --pod webt-pod --name=web-container docker.io/library/httpd
```

4. Optional: Display the pods the containers are associated with:

```
# podman ps -p
CONTAINER ID  IMAGE                           COMMAND           CREATED        STATUS PORTS               NAMES               POD ID        PODNAME
b7d6871d018c   registry.access.redhat.com/ubi9/pause:latest                             9 minutes ago  Up 6 minutes ago              a8e7360326ba-infra a8e7360326ba web-pod
645835585e24 docker.io/library/httpd:latest httpd-foreground 6 minutes ago Up 6 minutes ago web-container a8e7360326ba web-pod
```

Verification
• Show all networks connected to the container:

```bash
# podman ps --format="{{.Networks}}"

pod-net
```
CHAPTER 12. SETTING CONTAINER NETWORK MODES

The chapter provides information about how to set different network modes.

12.1. RUNNING CONTAINERS WITH A STATIC IP

The `podman run` command with the `--ip` option sets the container network interface to a particular IP address (for example, 10.88.0.44). To verify that you set the IP address correctly, run the `podman inspect` command.

Prerequisites

- The `containers-tool` meta-package is installed.

Procedure

- Set the container network interface to the IP address 10.88.0.44:

```
# podman run -d --name=myubi --ip=10.88.0.44 registry.access.redhat.com/ubi9/ubi
efde5f0a8c723f70dd5cb5dc3d5039df3b962fae65575b08662e0d5b5f9fbe85
```

Verification

- Check that the IP address is set properly:

```
# podman inspect --format='{{.NetworkSettings.IPAddress}}' myubi
10.88.0.44
```

12.2. RUNNING THE DHCP PLUGIN WITHOUT SYSTEMD

Use the `podman run --network` command to connect to a user-defined network. While most of the container images do not have a DHCP client, the `dhcp` plugin acts as a proxy DHCP client for the containers to interact with a DHCP server.

NOTE

This procedure only applies to rootfull containers. Rootless containers do not use the `dhcp` plugin.

Prerequisites

- The `containers-tool` meta-package is installed.

Procedure

1. Manually run the `dhcp` plugin:

```
#/usr/libexec/cni/dhcp daemon &
[1] 4966
```

2. Check that the `dhcp` plugin is running:
3. Run the `alpine` container:

```bash
# podman run -it --rm --network=example alpine ip addr show enp1s0
Resolved "alpine" as an alias (/etc/containers/registries.conf.d/000-shortnames.conf)
Trying to pull docker.io/library/alpine:latest...
... Storing signatures
2: eth0@eth0: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc noqueue state UP
   link/ether f6:dd:1b:a7:9b:92 brd ff:ff:ff:ff:ff:ff
   inet 192.168.1.22/24 brd 192.168.1.255 scope global eth0
   ... 
```

In this example:

- The `--network=example` option specifies the network named example to connect.
- The `ip addr show enp1s0` command inside the `alpine` container checks the IP address of the network interface `enp1s0`.
- The host network is 192.168.1.0/24
- The `eth0` interface leases an IP address of 192.168.1.122 for the `alpine` container.

**NOTE**

This configuration may exhaust the available DHCP addresses if you have a large number of short-lived containers and a DHCP server with long leases.

Additional resources

- Leasing routable IP addresses with Podman containers

### 12.3. RUNNING THE DHCP PLUGIN USING SYSTEMD

You can use the `systemd` unit file to run the `dhcp` plugin.

**Prerequisites**

- The `containers-tool` meta-package is installed.

**Procedure**

1. Create the socket unit file:

```bash
# cat /usr/lib/systemd/system/io.podman.dhcp.socket
[Unit]
Description=DHCP Client for CNI

[Socket]
```
ListenStream=\%t/cni/dhcp.sock  
SocketMode=0600

[Install]  
WantedBy=sockets.target

2. Create the service unit file:

```bash
# cat /usr/lib/systemd/system/io.podman.dhcp.service
[Unit]
Description=DHCP Client CNI Service
Requires=io.podman.dhcp.socket
After=io.podman.dhcp.socket

[Service]
Type=simple
ExecStart=/usr/libexec/cni/dhcp daemon
TimeoutStopSec=30
KillMode=process

[Install]
WantedBy=multi-user.target
Also=io.podman.dhcp.socket
```

3. Start the service immediately:

```bash
# systemctl --now enable io.podman.dhcp.socket
```

**Verification**

- Check the status of the socket:

```bash
# systemctl status io.podman.dhcp.socket
io.podman.dhcp.socket - DHCP Client for CNI
Loaded: loaded (/usr/lib/systemd/system/io.podman.dhcp.socket; enabled; vendor preset: disabled)
Active: active (listening) since Mon 2022-01-03 18:08:10 CET; 39s ago
Listen: /run/cni/dhcp.sock (Stream)
CGroup: /system.slice/io.podman.dhcp.socket
```

**Additional resources**

- [Leasing routable IP addresses with Podman containers](#)

**12.4. THE MACVLAN PLUGIN**

Most of the container images do not have a DHCP client, the `dhcp` plugin acts as a proxy DHCP client for the containers to interact with a DHCP server.

The host system does not have network access to the container. To allow network connections from outside the host to the container, the container has to have an IP on the same network as the host. The `macvlan` plugin enables you to connect a container to the same network as the host.
NOTE

This procedure only applies to rootful containers. Rootless containers are not able to use the `macvlan` and `dhcp` plugins.

NOTE

You can create a macvlan network using the `podman network create --macvlan` command.

Additional resources

- Leasing routable IP addresses with Podman containers
- `podman-network-create` man page

12.5. SWITCHING THE NETWORK STACK FROM CNI TO NETAVARK

Previously, containers were able to use DNS only when connected to the single Container Network Interface (CNI) plugin. Netavark is a network stack for containers. You can use Netavark with Podman and other Open Container Initiative (OCI) container management applications. The advanced network stack for Podman is compatible with advanced Docker functionalities. Now, containers in multiple networks access containers on any of those networks.

Netavark is capable of the following:

- Create, manage, and remove network interfaces, including bridge and MACVLAN interfaces.
- Configure firewall settings, such as network address translation (NAT) and port mapping rules.
- Improve support for containers in multiple networks.

Prerequisites

- The `containers-tool` meta-package is installed.

Procedure

1. If the `/etc/containers/containers.conf` file does not exist, copy the `/usr/share/containers/containers.conf` file to the `/etc/containers/` directory:
   
   ```bash
   # cp /usr/share/containers/containers.conf /etc/containers/
   ```

2. Edit the `/etc/containers/containers.conf` file, and add the following content to the `[network]` section:

   ```plaintext
   network_backend="netavark"
   ```

3. If you have any containers or pods, reset the storage back to the initial state:
   
   ```bash
   # podman system reset
   ```
4. Reboot the system:

   ```
   # reboot
   ```

Verification

- Verify that the network stack is changed to Netavark:

   ```
   # cat /etc/containers/containers.conf
   ...
   [network]
   network_backend="netavark"
   ...
   ```

**NOTE**

If you are using Podman 4.0.0 or later, use the `podman info` command to check the network stack setting.

Additional resources

- Podman 4.0’s new network stack: What you need to know
- `podman-system-reset` man page

12.6. SWITCHING THE NETWORK STACK FROM NETAVARK TO CNI

You can switch the network stack from Netavark to CNI.

**WARNING**

The CNI network stack is going to be deprecated. Red Hat recommends using the Netavark network stack instead.

Prerequisites

- The `containers-tool` meta-package is installed.

Procedure

1. If the `/etc/containers/containers.conf` file does not exist, copy the `/usr/share/containers/containers.conf` file to the `/etc/containers/` directory:

   ```
   # cp /usr/share/containers/containers.conf /etc/containers/
   ```

2. Edit the `/etc/containers/containers.conf` file, and add the following content to the `[network]` section:
network_backend="cni"

3. If you have any containers or pods, reset the storage back to the initial state:

   # podman system reset

4. Reboot the system:

   # reboot

Verification

- Verify that the network stack is changed to CNI:

   # cat /etc/containers/containers.conf

       ... 
       [network]
       network_backend="cni"
       ...

   NOTE

   If you are using Podman 4.0.0 or later, use the `podman info` command to check the network stack setting.

Additional resources

- Podman 4.0’s new network stack: What you need to know
- `podman-system-reset` man page
CHAPTER 13. PORTING CONTAINERS TO OPENSHIFT USING PODMAN

You can generate portable descriptions of containers and pods by using the YAML (“YAML Ain’t Markup Language”) format. The YAML is a text format used to describe the configuration data.

The YAML files are:

- Readable.
- Easy to generate.
- Portable between environments (for example between RHEL and OpenShift).
- Portable between programming languages.
- Convenient to use (no need to add all the parameters to the command line).

Reasons to use YAML files:

1. You can re-run a local orchestrated set of containers and pods with minimal input required which can be useful for iterative development.

2. You can run the same containers and pods on another machine. For example, to run an application in an OpenShift environment and to ensure that the application is working correctly. You can use `podman generate kube` command to generate a Kubernetes YAML file. Then, you can use `podman play` command to test the creation of pods and containers on your local system before you transfer the generated YAML files to the Kubernetes or OpenShift environment. Using the `podman play` command, you can also recreate pods and containers originally created in OpenShift or Kubernetes environments.

NOTE

The `podman kube play` command supports a subset of Kubernetes YAML capabilities. For more information, see the support matrix of supported YAML fields.

13.1. GENERATING A KUBERNETES YAML FILE USING PODMAN

This procedure describes how to create a pod with one container and generate the Kubernetes YAML file using the `podman generate kube` command.

Prerequisites

- The `containers-tool` meta-package is installed.
- The pod has been created. For details, see section Creating pods.

Procedure

1. List all pods and containers associated with them:

   ```
   $ podman ps -a --pod
   CONTAINER ID   IMAGE                                       COMMAND       CREATED       STATUS          PORTS               NAMES               POD
   RED HAT ENTERPRISE LINUX 9 Building, running, and managing containers
   ```
2. Use the pod name or ID to generate the Kubernetes YAML file:

```
$ podman generate kube mypod > mypod.yaml
```

Note that the `podman generate` command does not reflect any Logical Volume Manager (LVM) logical volumes or physical volumes that might be attached to the container.

3. Display the `mypod.yaml` file:

```
$ cat mypod.yaml
# Generation of Kubernetes YAML is still under development!
#
# Save the output of this file and use kubectl create -f to import
# it into Kubernetes.
#
# Created with podman-1.6.4
apiVersion: v1
kind: Pod
metadata:
  creationTimestamp: "2020-06-09T10:31:56Z"
labels:
  app: mypod
  name: mypod
spec:
  containers:
  - command:
    - /bin/bash
    env:
      - name: PATH
        value: /usr/local/sbin:/usr/local/bin:/usr/sbin:/usr/bin:/sbin:/bin
      - name: TERM
        value: xterm
      - name: HOSTNAME
      - name: container
        value: oci
    image: registry.access.redhat.com/ubi9/ubi:latest
    name: myubi
    resources: {}
    securityContext:
      allowPrivilegeEscalation: true
      capabilities: {}
      privileged: false
      readOnlyRootFilesystem: false
      tty: true
      workingDir: /
  status: {}
```

Additional resources

- [podman-generate-kube man page](#)
13.2. GENERATING A KUBERNETES YAML FILE IN OPENSHIFT ENVIRONMENT

In the OpenShift environment, use the `oc create` command to generate the YAML files describing your application.

**Procedure**

- Generate the YAML file for your `myapp` application:

  ```
  $ oc create myapp --image=me/myapp:v1 -o yaml --dry-run > myapp.yaml
  ```

  The `oc create` command creates and run the `myapp` image. The object is printed using the `--dry-run` option and redirected into the `myapp.yaml` output file.

  **NOTE**
  
  In the Kubernetes environment, you can use the `kubectl create` command with the same flags.

13.3. STARTING CONTAINERS AND PODS WITH PODMAN

With the generated YAML files, you can automatically start containers and pods in any environment. The YAML files can be generated using tools other than Podman, such as Kubernetes or OpenShift. The `podman play kube` command allows you to recreate pods and containers based on the YAML input file.

**Prerequisites**

- The `containers-tool` meta-package is installed.

**Procedure**

1. Create the pod and the container from the `mypod.yaml` file:

   ```
   $ podman play kube mypod.yaml
   Pod:
   b8c5b99ba846ccff76c3ef257e5761c2d8a5ca4d7ffa3880531aec79c0dacb22
   Container:
   848179395ebd33dd91d14ffbde7ae273158d9695a081468f487af4e356888ece
   ```

2. List all pods:

   ```
   $ podman pod ps
   POD ID     NAME    STATUS    CREATED          # OF CONTAINERS   INFRA ID
   b8c5b99ba846 mypod Running 19 seconds ago   2                 aa4220eaf4bb
   ```

3. List all pods and containers associated with them:

   ```
   $ podman ps -a --pod
   CONTAINER ID IMAGE COMMAND CREATED STATUS
   ```
PORTS NAMES               POD
848179395ebd  registry.access.redhat.com/ubi9/ubi:latest  /bin/bash  About a minute ago  Up
About a minute ago  myubi  b8c5b99ba846
aa4220eaf4bb  k8s.gcr.io/pause:3.1  About a minute ago  Up
About a minute ago  b8c5b99ba846-infra  b8c5b99ba846

The pod IDs from `podman ps` command matches the pod ID from the `podman pod ps` command.

Additional resources

- `podman-play-kube` man page
- Podman can now ease the transition to Kubernetes and CRI-O

13.4. STARTING CONTAINERS AND PODS IN OPENSIFT ENVIRONMENT

You can use the `oc create` command to create pods and containers in the OpenShift environment.

Procedure

- Create a pod from the YAML file in the OpenShift environment:

  ```bash
  $ oc create -f mypod.yaml
  ```

  **NOTE**

  In the Kubernetes environment, you can use the `kubectl create` command with the same flags.

13.5. MANUALLY RUNNING CONTAINERS AND PODS USING PODMAN

The following procedure shows how to manually create a WordPress content management system paired with a MariaDB database using Podman.

Suppose the following directory layout:

```
├── mariadb-conf
│   └── Containerfile
│       └── my.cnf
```

Prerequisites

- The `containers-tool` meta-package is installed.

Procedure

1. Display the `mariadb-conf/Containerfile` file:
$ cat mariadb-conf/Containerfile
FROM docker.io/library/mariadb
COPY my.cnf /etc/mysql/my.cnf

2. Display the mariadb-conf/my.cnf file:

```
[client-server]
# Port or socket location where to connect
port = 3306
socket = /run/mysqld/mysqld.sock

# Import all .cnf files from the configuration directory
[mariadbd]
skip-host-cache
skip-name-resolve
bind-address = 127.0.0.1

!includedir /etc/mysql/mariadb.conf.d/
!includedir /etc/mysql/conf.d/
```

3. Build the docker.io/library/mariadb image using mariadb-conf/Containerfile:

```
$ cd mariadb-conf
$ podman build -t mariadb-conf .
$ cd ..
STEP 1: FROM docker.io/library/mariadb
Trying to pull docker.io/library/mariadb:latest...
Getting image source signatures
Copying blob 7b1a6ab2e44d done
...
Storing signatures
STEP 2: COPY my.cnf /etc/mysql/my.cnf
STEP 3: COMMIT mariadb-conf
---> ffae584aa6e
Successfully tagged localhost/mariadb-conf:latest
ffae584aa6e733ee1cdf89c053337502e1089d1620ff05680b6818a96eeec3c17
```

4. Optional: List all images:

```
$ podman images
LIST IMAGES
REPOSITORY                      TAG         IMAGE ID      CREATED      SIZE
localhost/mariadb-conf          latest      b66fa0fa0ef2  57 seconds ago 416 MB
```

5. Create the pod named wordpresspod and configure port mappings between the container and the host system:

```
$ podman pod create --name wordpresspod -p 8080:80
```

6. Create the mydb container inside the wordpresspod pod:

```
$ podman run --detach --pod wordpresspod \
```
7. Create the myweb container inside the wordpresspod pod:

```bash
$ podman run --detach --pod wordpresspod \
- e WORDPRESS_DB_HOST=127.0.0.1 \
- e WORDPRESS_DB_NAME=mywpdb \
- e WORDPRESS_DB_USER=mywpuser \
- e WORDPRESS_DB_PASSWORD=1234 \
--name myweb docker.io/wordpress
```

8. Optional. List all pods and containers associated with them:

```bash
$ podman ps --pod -a
CONTAINER ID  IMAGE                               COMMAND               STATUS                     PORTS                 NAMES               POD ID        PODNAME
9ea56f771915  k8s.gcr.io/pause:3.5                                      Less than a second ago  Up Less than a second ago  0.0.0.0:8080->80/tcp  4b7f054a6f01-infra  4b7f054a6f01  wordpresspod
60e8dbbac5  localhost/mariadb-conf:latest       mariadbd              Less than a second ago  Up Less than a second ago  0.0.0.0:8080->80/tcp  mydb                4b7f054a6f01
045d3d506e50  docker.io/library/wordpress:latest  apache2-foreground...  Less than a second ago  Up Less than a second ago  0.0.0.0:8080->80/tcp  myweb               4b7f054a6f01
```

Verification

- Verify that the pod is running: Visit the http://localhost:8080/wp-admin/install.php page or use the `curl` command:

```bash
<!DOCTYPE html>
<html lang="en-US" xml:lang="en-US">
<head>
...
</head>
<body class="wp-core-ui">
<p id="logo">WordPress</p>
<h1>Welcome</h1>
...
</body>
</html>
```

Additional resources

- Build Kubernetes pods with Podman play kube
- podman-play-kube man page

### 13.6. GENERATING A YAML FILE USING PODMAN

You can generate a Kubernetes YAML file using the podman generate kube command.
Prerequisites

- The **containers-tool** meta-package is installed.
- The pod named **wordpresspod** has been created. For details, see section Creating pods.

Procedure

1. List all pods and containers associated with them:

   ```bash
   podman ps --pod -a
   ```

<table>
<thead>
<tr>
<th>CONTAINER ID</th>
<th>IMAGE</th>
<th>COMMAND</th>
<th>STATUS</th>
<th>PORTS</th>
<th>NAMES</th>
<th>POD ID</th>
<th>PODNAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>9ea56f771915</td>
<td>k8s.gcr.io/pause:3.5</td>
<td></td>
<td>Less than a second ago</td>
<td>Up Less than a second ago</td>
<td>0.0.0.0:8080-&gt;80/tcp</td>
<td>4b7f054a6f01-infra</td>
<td>wordpresspod</td>
</tr>
<tr>
<td>60e8dbbabac5</td>
<td>localhost/mariadb-conf:latest</td>
<td>mariadb</td>
<td>Less than a second ago</td>
<td>Up Less than a second ago</td>
<td>0.0.0.0:8080-&gt;80/tcp</td>
<td>mydb</td>
<td>4b7f054a6f01</td>
</tr>
<tr>
<td>045d3d506e50</td>
<td>docker.io/library/wordpress:latest</td>
<td>apache2-foreground</td>
<td></td>
<td>Up Less than a second ago</td>
<td>0.0.0.0:8080-&gt;80/tcp</td>
<td>myweb</td>
<td>4b7f054a6f01</td>
</tr>
</tbody>
</table>
   
2. Use the pod name or ID to generate the Kubernetes YAML file:

   ```bash
   podman generate kube wordpresspod >> wordpresspod.yaml
   ```

Verification

- Display the **wordpresspod.yaml** file:

   ```bash
   cat wordpresspod.yaml
   ```

   ```yaml
   apiVersion: v1
   kind: Pod
   metadata:
     creationTimestamp: "2021-12-09T15:09:30Z"
   labels:
     app: wordpresspod
     name: wordpresspod
   spec:
     containers:
     - args:
         value: podman
     - name: MYSQL_PASSWORD
       value: "1234"
     - name: MYSQL_MAJOR
       value: "8.0"
     - name: MYSQL_VERSION
       value: 8.0.27-1debian10
     - name: MYSQL_ROOT_PASSWORD
       value: "1234"
     - name: MYSQL_DATABASE
       value: mywpdb
     - name: MYSQL_USER
       value: mywpuser
   ```
image: mariadb
name: mydb
ports:
  - containerPort: 80
    hostPort: 8080
    protocol: TCP
- args:
  - name: WORDPRESS_DB_NAME
    value: mywpdb
  - name: WORDPRESS_DB_PASSWORD
    value: "1234"
  - name: WORDPRESS_DB_HOST
    value: 127.0.0.1
  - name: WORDPRESS_DB_USER
    value: mywpuser
image: docker.io/library/wordpress:latest
name: myweb

Additional resources

- Build Kubernetes pods with Podman play kube
- podman-play-kube man page

13.7. AUTOMATICALLY RUNNING CONTAINERS AND PODS USING PODMAN

You can use the podman play kube command to test the creation of pods and containers on your local system before you transfer the generated YAML files to the Kubernetes or OpenShift environment.

The podman play kube command can also automatically build and run multiple pods with multiple containers in the pod using the YAML file similarly to the docker compose command. The images are automatically built if the following conditions are met:

1. a directory with the same name as the image used in YAML file exists
2. that directory contains a Containerfile

Prerequisites

- The containers-tool meta-package is installed.
- The pod named wordpresspod has been created. For details, see section Manually running containers and pods using Podman.
- The YAML file has been generated. For details, see section Generating a YAML file using Podman.
- To repeat the whole scenario from the beginning, delete locally stored images:

```bash
$ podman rmi localhost/mariadb-conf
$ podman rmi docker.io/library/wordpress
$ podman rmi docker.io/library/mysql
```
Procedure

1. Create the wordpress pod using the `wordpress.yaml` file:

   ```
   $ podman play kube wordpress.yaml
   STEP 1/2: FROM docker.io/library/mariadb
   STEP 2/2: COPY my.cnf /etc/mysql/my.cnf
   COMMIT localhost/mariadb-conf:latest
   --> 428832c45d0
   Successfully tagged localhost/mariadb-conf:latest
   428832c45d07d78bb9cb34e0296a7dc205026c2fe4d636c54912c3d6bab7f399
   Trying to pull docker.io/library/wordpress:latest...
   Getting image source signatures
   Copying blob 99c3c1c4d556 done
   ...
   Storing signatures
   Pod:
   3e391d091d190756e655219a34de55583eed3ef59470aadd214c1fc48cae92ac
   Containers:
   6c59eb96968467d7f6d9617c74a175c88c5b5257fed7fb3d375c002899ea855ae1f
   29717878452f56299531f79832723d3a620a403f4a996090ea987233df0bc3d
   ```

   The `podman play kube` command:
   - Automatically build the `localhost/mariadb-conf:latest` image based on `docker.io/library/mariadb` image.
   - Pull the `docker.io/library/wordpress:latest` image.
   - Create a pod named `wordpresspod` with two containers named `wordpresspod-mydb` and `wordpresspod-myweb`.

2. List all containers and pods:

   ```
   $ podman ps --pod -a
   CONTAINER ID IMAGE COMMAND CREATED STATUS
   PORTS NAMES POD ID PODNAME
   a1dbf7b5606c k8s.gcr.io/pause:3.5 3 minutes ago Up 2 minutes ago
   0.0.0.0:8080->80/tcp 3e391d091d19-infra 3e391d091d19 wordresspod
   6c59eb9696846 localhost/mariadb-conf:latest mariadb 2 minutes ago Exited (1)
   2 minutes ago 0.0.0.0:8080->80/tcp wordresspod-mydb 3e391d091d19 wordresspod
   29717878452f docker.io/library/wordpress:latest apache2-foreground 2 minutes ago Up 2 minutes ago
   0.0.0.0:8080->80/tcp wordresspod-myweb 3e391d091d19 wordresspod
   ```

Verification

- Verify that the pod is running: Visit the http://localhost:8080/wp-admin/install.php page or use the `curl` command:

  ```
  <!DOCTYPE html>
  <html lang="en-US" xml:lang="en-US">
  <head>
  ...
  ```
13.8. AUTOMATICALLY STOPPING AND REMOVING PODS USING PODMAN

The podman play kube --down command stops and removes all pods and their containers.

**NOTE**
If a volume is in use, it is not removed.

Prerequisites

- The containers-tool meta-package is installed.
- The pod named wordpresspod has been created. For details, see section Manually running containers and pods using Podman.
- The YAML file has been generated. For details, see section Generating a YAML file using Podman.
- The pod is running. For details, see section Automatically running containers and pods using Podman.

Procedure

- Remove all pods and containers created by the wordpresspod.yaml file:

  ```
  $ podman play kube --down wordpresspod.yaml
  Pods stopped:
  3e391d091d190756e655219a34de55583eed3ef59470aadd214c1fc48cae92ac
  Pods removed:
  3e391d091d190756e655219a34de55583eed3ef59470aadd214c1fc48cae92ac
  ```

Verification

- Verify that all pods and containers created by the wordpresspod.yaml file were removed:

  ```
  $ podman ps --pod -a
  CONTAINER ID  IMAGE                               COMMAND               CREATED
  STATUS                     PORTS                 NAMES               POD ID        PODNAME
  ```

Additional resources

- Build Kubernetes pods with Podman play kube
- `podman-play-kube` man page

CHAPTER 13. PORTING CONTAINERS TO OPENSIFT USING PODMAN
• **Build Kubernetes pods with Podman play kube**

• **podman-play-kube** man page
CHAPTER 14. PORTING CONTAINERS TO SYSTEMD USING PODMAN

Podman (Pod Manager) is a simple daemonless tool fully featured container engine. Podman provides a Docker-CLI comparable command line that makes the transition from other container engines easier and enables the management of pods, containers, and images.

Originally, Podman was not designed to provide an entire Linux system or manage services, such as start-up order, dependency checking, and failed service recovery. systemd was responsible for a complete system initialization. Due to Red Hat integrating containers with systemd, you can manage OCI and Docker-formatted containers built by Podman in the same way as other services and features are managed in a Linux system. You can use the systemd initialization service to work with pods and containers.

With systemd unit files, you can:

- Set up a container or pod to start as a systemd service.
- Define the order in which the containerized service runs and check for dependencies (for example making sure another service is running, a file is available or a resource is mounted).
- Control the state of the systemd system using the systemctl command.

You can generate portable descriptions of containers and pods by using systemd unit files.

14.1. AUTO-GENERATING A SYSTEMD UNIT FILE USING QUADLETS

With Quadlet, you describe how to run a container in a format that is very similar to regular systemd unit files. The container descriptions focus on the relevant container details and hide technical details of running containers under systemd. Create the `<CTRNAME>.container` unit file in one of the following directories:

- For root users: `/usr/share/containers/systemd/` or `/etc/containers/systemd/
- For rootless users: `$HOME/.config/containers/systemd/`, `$XDG_CONFIG_HOME/containers/systemd/`, `/etc/containers/systemd/users/$(UID)`, or `/etc/containers/systemd/users/`

NOTE

Quadlet is available beginning with Podman v4.6.

Prerequisites

- The containers-tool meta-package is installed.

Procedure

1. Create the `mysleep.container` unit file:

   ```
   $ cat $HOME/.config/containers/systemd/mysleep.container
   [Unit]
   Description=The sleep container
   After=local-fs.target
   ```
In the **[Container]** section you must specify:

- **Image** - container mage you want to run
- **Exec** - the command you want to run inside the container

This enables you to use all other fields specified in a **systemd** unit file.

2. Create the **mysleep.service** based on the **mysleep.container** file:

```bash
$ systemctl --user daemon-reload
```

3. Optional: Check the status of the **mysleep.service**:

```bash
$ systemctl --user status mysleep.service
● mysleep.service - The sleep container
  Loaded: loaded (/home/username/.config/containers/systemd/mysleep.container; generated)
  Active: inactive (dead)
```

4. Start the **mysleep.service**:

```bash
$ systemctl --user start mysleep.service
```

**Verification**

1. Check the status of the **mysleep.service**:

```bash
$ systemctl --user status mysleep.service
mysleep.service - The sleep container
Loaded: loaded (/home/username/.config/containers/systemd/mysleep.container; generated)
Active: active (running) since Thu 2023-02-09 18:07:23 EST; 2s ago
  Main PID: 265651 (conmon)
  Tasks: 3 (limit: 76815)
  Memory: 1.6M
  CPU: 94ms
  CGroup: ...
```

2. List all containers:

```bash
$ podman ps -a
CONTAINER ID  IMAGE                            COMMAND               CREATED            STATUS
PORTS   NAMES
421c8293fc1b  registry.access.redhat.com/ubi9-minimal:latest sleep 1000 30 seconds ago Up 10 seconds ago systemd-mysleep
```
Note that the name of the created container consists of the following elements:

- a **systemd**-prefix
- a name of the **systemd** unit, that is **systemd-mysleep**
  
  This naming helps to distinguish common containers from containers running in **systemd** units. It also helps to determine which unit a container runs in. If you want to change the name of the container, use the **ContainerName** field in the **[Container]** section.

### Additional resources

- Make systemd better for Podman with Quadlet
- Quadlet upstream documentation

#### 14.2. ENABLING SYSTEMD SERVICES

When enabling the service, you have different options.

**Procedure**

- Enable the service:
  
  - To enable a service at system start, no matter if user is logged in or not, enter:
    
    ```
    # systemctl enable <service>
    ```
  
  You have to copy the **systemd** unit files to the **/etc/systemd/system** directory.
  
  - To start a service at user login and stop it at user logout, enter:
    
    ```
    $ systemctl --user enable <service>
    ```
  
  You have to copy the **systemd** unit files to the **$HOME/.config/systemd/user** directory.
  
  - To enable users to start a service at system start and persist over logouts, enter:
    
    ```
    # loginctl enable-linger <username>
    ```

### Additional resources

- **systemctl** man page
- **loginctl** man page
- Enabling a system service to start at boot

#### 14.3. AUTO-STARTING CONTAINERS USING SYSTEMD

You can control the state of the **systemd** system and service manager using the **systemctl** command. You can enable, start, stop the service as a non-root user. To install the service as a root user, omit the **--user** option.
Prerequisites

- The **containers-tool** meta-package is installed.

Procedure

1. Reload **systemd** manager configuration:

   ```
   # systemctl --user daemon-reload
   ```

2. Enable the service **container.service** and start it at boot time:

   ```
   # systemctl --user enable container.service
   ```

3. Start the service immediately:

   ```
   # systemctl --user start container.service
   ```

4. Check the status of the service:

   ```
   $ systemctl --user status container.service
   ```

You can check if the service is enabled using the **systemctl is-enabled container.service** command.

Verification steps

- List containers that are running or have exited:

  ```
  # podman ps
  ```

<table>
<thead>
<tr>
<th>CONTAINER ID</th>
<th>IMAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMMAND</td>
<td>CREATED</td>
</tr>
<tr>
<td>--------------</td>
<td>---------</td>
</tr>
</tbody>
</table>
NOTE

To stop \texttt{container.service}, enter:

\begin{verbatim}
# systemctl --user stop container.service
\end{verbatim}

Additional resources

- \texttt{systemctl} man page
- Running containers with Podman and shareable systemd services
- Enabling a system service to start at boot

\section*{14.4. ADVANTAGES OF USING QUADLETS OVER THE PODMAN GENERATE SYSTEMD COMMAND}

You can use the Quadlets tool, which describes how to run a container in a format similar to regular \texttt{systemd} unit files.

\begin{quote}
\textbf{NOTE}

Quadlet is available beginning with Podman v4.6.
\end{quote}

Quadlets have many advantages over generating unit files using the \texttt{podman generate systemd} command, such as:

- \textbf{Easy to maintain}: The container descriptions focus on the relevant container details and hide technical details of running containers under \texttt{systemd}.

- \textbf{Automatically updated}: Quadlets do not require manually regenerating unit files after an update. If a newer version of Podman is released, your service is automatically updated when the \texttt{systemctl daemon-reload} command is executed, for example, at boot time.

- \textbf{Simplified workflow}: Thanks to the simplified syntax, you can create Quadlet files from scratch and deploy them anywhere.

- \textbf{Support standard systemd options}: Quadlet extends the existing systemd-unit syntax with new tables, for example, a table to configure a container.
NOTE

Quadlet supports a subset of Kubernetes YAML capabilities. For more information, see the support matrix of supported YAML fields. You can generate the YAML files by using one of the following tools:

- Podman: `podman generate kube` command
- OpenShift: `oc generate` command with the `--dry-run` option
- Kubernetes: `kubectl create` command with the `--dry-run` option

Quadlet supports these unit file types:

- **Container units**: Used to manage containers by running the `podman run` command.
  - File extension: `.container`
  - Section name: `[Container]`
  - Required fields: `Image` describing the container image the service runs

- **Kube units**: Used to manage containers defined in Kubernetes YAML files by running the `podman kube play` command.
  - File extension: `.kube`
  - Section name: `[Kube]`
  - Required fields: `Yaml` defining the path to the Kubernetes YAML file

- **Network units**: Used to create Podman networks that may be referenced in `.container` or `.kube` files.
  - File extension: `.network`
  - Section name: `[Network]`
  - Required fields: None

- **Volume units**: Used to create Podman volumes that may be referenced in `.container` files.
  - File extension: `.volume`
  - Section name: `[Volume]`
  - Required fields: None

Additional resources

- Quadlet upstream documentation

14.5. GENERATING A SYSTEMD UNIT FILE USING PODMAN

Podman allows `systemd` to control and manage container processes. You can generate a `systemd` unit file for the existing containers and pods using `podman generate systemd` command. It is recommended to use `podman generate systemd` because the generated units files change frequently.
(via updates to Podman) and the **podman generate systemd** ensures that you get the latest version of unit files.

**NOTE**

Starting with Podman v4.6, you can use the Quadlets that describe how to run a container in a format similar to regular `systemd` unit files and hides the complexity of running containers under `systemd`.

**Prerequisites**

- The **containers-tool** meta-package is installed.

**Procedure**

1. Create a container (for example **myubi**):

   ```
   $ podman create --name myubi registry.access.redhat.com/ubi9:latest sleep infinity
   0280afe98bb75a5c5e713b28de4b7c5cbb49f156f1ccee4a208f13fee2f75cb453
   ```

2. Use the container name or ID to generate the `systemd` unit file and direct it into the `~/.config/systemd/user/container-myubi.service` file:

   ```
   $ podman generate systemd --name myubi > ~/.config/systemd/user/container-myubi.service
   ```

**Verification steps**

- Display the content of generated `systemd` unit file:

   ```
   $ cat ~/.config/systemd/user/container-myubi.service
   # container-myubi.service
   # autogenerated by Podman 3.3.1
   # Wed Sep  8 20:34:46 CEST 2021
   
   [Unit]
   Description=Podman container-myubi.service
   Documentation=man:podman-generate-systemd(1)
   Wants=network-online.target
   After=network-online.target
   RequiresMountsFor=/run/user/1000/containers
   
   [Service]
   Environment=PODMAN_SYSTEMD_UNIT=%n
   Restart=on-failure
   TimeoutStopSec=70
   ExecStart=/usr/bin/podman start myubi
   ExecStop=/usr/bin/podman stop -t 10 myubi
   ExecStopPost=/usr/bin/podman stop -t 10 myubi
   PIDFile=/run/user/1000/containers/overlay-containers/9683103f58a32192c84801f0be93446cb33c1ee7d9cdda225b78049d7c5deea4/user
data/common.pid
   Type=forking
   ```
WantedBy=multi-user.target default.target

- The **Restart=on-failure** line sets the restart policy and instructs **systemd** to restart when the service cannot be started or stopped cleanly, or when the process exits non-zero.

- The **ExecStart** line describes how we start the container.

- The **ExecStop** line describes how we stop and remove the container.

Additional resources

- Running containers with Podman and shareable systemd services

### 14.6. AUTOMATICALLY GENERATING A SYSTEMD UNIT FILE USING PODMAN

By default, Podman generates a unit file for existing containers or pods. You can generate more portable systemd unit files using the `podman generate systemd --new`. The **--new** flag instructs Podman to generate unit files that create, start and remove containers.

**NOTE**

Starting with Podman v4.6, you can use the Quadlets that describe how to run a container in a format similar to regular systemd unit files and hides the complexity of running containers under systemd.

**Prerequisites**

- The **containers-tool** meta-package is installed.

**Procedure**

1. Pull the image you want to use on your system. For example, to pull the **httpd-24** image:

   ```
   # podman pull registry.access.redhat.com/ubi9/httpd-24
   ```

2. Optional: List all images available on your system:

   ```
   # podman images
   REPOSITORY                              TAG                      IMAGE ID       CREATED       SIZE
   registry.access.redhat.com/ubi9/httpd-24 latest 8594be0a0b57 2 weeks ago 462 MB
   ```

3. Create the **httpd** container:

   ```
   # podman create --name httpd -p 8080:80 registry.access.redhat.com/ubi9/httpd-24
cdb9f981cf143021b1679599d86026b13a77187f75e46cc0eac85293710a4b1
   ```

4. Optional: Verify the container has been created:

   ```
   # podman ps -a
   ```
5. Generate a **systemd** unit file for the **httpd** container:

   ```
   # podman generate systemd --new --files --name httpd
   /root/container-httpd.service
   ```

6. Display the content of the generated **container-httpd.service systemd** unit file:

   ```
   # cat /root/container-httpd.service
   # container-httpd.service
   # autogenerated by Podman 3.3.1
   # Wed Sep  8 20:41:44 CEST 2021
   
   [Unit]
   Description=Podman container-httpd.service
   Documentation=man:podman-generate-systemd(1)
   Wants=network-online.target
   After=network-online.target
   RequiresMountsFor=%t/containers
   
   [Service]
   Environment=PODMAN_SYSTEMD_UNIT=%n
   Restart=on-failure
   TimeoutStopSec=70
   ExecStartPre=/bin/rm -f %t/%n.ctr-id
   ExecStart=/usr/bin/podman run --cidfile=%t/%n.ctr-id --sdnotify=conmon --cgroups=no-conmon --rm -d --replace --name httpd -p 8080:8080 registry.access.redhat.com/ubi9/httpd-24
   ExecStop=/usr/bin/podman stop --ignore --cidfile=%t/%n.ctr-id
   ExecStopPost=/usr/bin/podman rm -f --ignore --cidfile=%t/%n.ctr-id
   Type=notify
   NotifyAccess=all
   
   [Install]
   WantedBy=multi-user.target default.target
   ```

**NOTE**

Unit files generated using the **--new** option do not expect containers and pods to exist. Therefore, they perform the **podman run** command when starting the service (see the **ExecStart** line) instead of the **podman start** command. For example, see section **Generating a systemd unit file using Podman**.

- The **podman run** command uses the following command-line options:
  - The **--conmon-pidfile** option points to a path to store the process ID for the **conmon** process running on the host. The **conmon** process terminates with the same exit status as the container, which allows **systemd** to report the correct service status and restart the container if needed.
- The `--cidfile` option points to the path that stores the container ID.
- The `%t` is the path to the run time directory root, for example `/run/user/$UserID`.
- The `%n` is the full name of the service.

1. Copy unit files to `/etc/systemd/system` for installing them as a root user:

   ```bash
   # cp -Z container-httpd.service /etc/systemd/system
   ```

2. Enable and start the `container-httpd.service`:

   ```bash
   # systemctl daemon-reload
   # systemctl enable --now container-httpd.service
   ```

   Created symlink `/etc/systemd/system/multi-user.target.wants/container-httpd.service` → `/etc/systemd/system/container-httpd.service.`
   Created symlink `/etc/systemd/system/default.target.wants/container-httpd.service` → `/etc/systemd/system/container-httpd.service`.

**Verification steps**

- Check the status of the `container-httpd.service`:

  ```bash
  # systemctl status container-httpd.service
  ```

  ```text
  ● container-httpd.service - Podman container-httpd.service
  Loaded: loaded (/etc/systemd/system/container-httpd.service; enabled; vendor preset: disabled)
  Active: active (running) since Tue 2021-08-24 09:53:40 EDT; 1min 5s ago
  Docs: man:podman-generate-systemd(1)
  Process: 493317 ExecStart=/usr/bin/podman run --conmon-pidfile /run/container-httpd.pid --cidfile /run/container-httpd.ctr-id --cgroups=no-conmon -d --replace>
  Process: 493315 ExecStartPre=/bin/rm -f /run/container-httpd.pid /run/container-httpd.ctr-id (code=exited, status=0/SUCCESS)
  Main PID: 493435 (conmon)
  ...
  ```

**Additional resources**

- [Improved Systemd Integration with Podman 2.0](#)
- [Enabling a system service to start at boot](#)

### 14.7. AUTOMATICALLY STARTING PODS USING SYSTEMD

You can start multiple containers as systemd services. Note that the `systemctl` command should only be used on the pod and you should not start or stop containers individually via `systemctl`, as they are managed by the pod service along with the internal infra-container.

**NOTE**

Starting with Podman v4.6, you can use the Quadlets that describe how to run a container in a format similar to regular systemd unit files and hides the complexity of running containers under systemd.
Prerequisites

- The containers-tool meta-package is installed.

Procedure

1. Create an empty pod, for example named systemd-pod:

   ```
   $ podman pod create --name systemd-pod
   11d4646ba41b1fffa51c108cbdf97cfab3213f7bd9b3e1ca52fe81b90fed5577
   ```

2. Optional: List all pods:

   ```
   $ podman pod ps
   POD ID        NAME         STATUS   CREATED         # OF CONTAINERS  INFRA ID
   11d4646ba41b  systemd-pod  Created  40 seconds ago  1                8a428b257111
   11d4646ba41b1fffa51c108cbdf97cfab3213f7bd9b3e1ca52fe81b90fed5577
   ```

3. Create two containers in the empty pod. For example, to create container0 and container1 in systemd-pod:

   ```
   $ podman create --pod systemd-pod --name container0
   registry.access.redhat.com/ubi9 top
   $ podman create --pod systemd-pod --name container1
   registry.access.redhat.com/ubi9 top
   ```

4. Optional: List all pods and containers associated with them:

   ```
   $ podman ps -a --pod
   CONTAINER ID  IMAGE                        COMMAND   CREATED       STATUS
   PORTS   NAMES               POD ID        PODNAME
   24666f47d9b2  registry.access.redhat.com/ubi9:latest top       3 minutes ago Created
   56eb1bf0cdfe k8s.gcr.io/pause:3.2 k8s.gcr.io/pause:3.2 top      4 minutes ago Created
   3130f724e229-infra 3130f724e229-systemd-pod
   62118d170e43 registry.access.redhat.com/ubi9:latest top       3 seconds ago Created
   ```

5. Generate the systemd unit file for the new pod:

   ```
   $ podman generate systemd --files --name systemd-pod
   /home/user1/pod-systemd-pod.service
   /home/user1/container-container0.service
   /home/user1/container-container1.service
   ```

   Note that three systemd unit files are generated, one for the systemd-pod pod and two for the containers container0 and container1.

6. Display pod-systemd-pod.service unit file:

   ```
   $ cat pod-systemd-pod.service
   # pod-systemd-pod.service
   # autogenerated by Podman 3.3.1
   # Wed Sep 8 20:49:17 CEST 2021
   ```
The `Requires` line in the `[Unit]` section defines dependencies on `container-container0.service` and `container-container1.service` unit files. Both unit files will be activated.

- The `ExecStart` and `ExecStop` lines in the `[Service]` section start and stop the infra-container, respectively.

7. Display `container-container0.service` unit file:

```
$ cat container-container0.service
# container-container0.service
# autogenerated by Podman 3.3.1
# Wed Sep 8 20:49:17 CEST 2021

[Unit]
Description=Podman container-container0.service
Documentation=man:podman-generate-systemd(1)
Wants=network-online.target
After=network-online.target
RequiresMountsFor=
Requires=container-container0.service container-container1.service
Before=container-container0.service container-container1.service

[Service]
Environment=PODMAN_SYSTEMD_UNIT=%n
Restart=on-failure
TimeoutStopSec=70
ExecStart=/usr/bin/podman start container0
ExecStop=/usr/bin/podman stop -t 10 container0
ExecStopPost=/usr/bin/podman stop -t 10 container0
PIDFile=/run/user/1000/containers/overlay-containers/1dfdcf20e35043939ea3f80f002c65c00d560e47223685dbc3230e26fe001b29/userdata/conmon.pid
Type=forking

[Install]
WantedBy=multi-user.target default.target
```
The BindsTo line in the [Unit] section defines the dependency on the pod-systemd-pod.service unit file.

The ExecStart and ExecStop lines in the [Service] section start and stop the container0 respectively.

8. Display container-container1.service unit file:

```
$ cat container-container1.service
```

9. Copy all the generated files to $HOME/.config/systemd/user for installing as a non-root user:

```
$ cp pod-systemd-pod.service container-container0.service container-container1.service $HOME/.config/systemd/user
```

10. Enable the service and start at user login:

```
$ systemctl enable --user pod-systemd-pod.service
```

Note that the service stops at user logout.

**Verification steps**

- Check if the service is enabled:

```
$ systemctl is-enabled pod-systemd-pod.service
enabled
```

**Additional resources**

- podman-create man page
- podman-generate-systemd man page
- systemctl man page
- Running containers with Podman and shareable systemd services
- Enabling a system service to start at boot

**14.8. AUTOMATICALLY UPDATING CONTAINERS USING PODMAN**

The podman auto-update command allows you to automatically update containers according to their
auto-update policy. The `podman auto-update` command updates services when the container image is updated on the registry. To use auto-updates, containers must be created with the `--label "io.containers.autoupdate=image"` label and run in a `systemd` unit generated by `podman generate systemd --new` command.

Podman searches for running containers with the "io.containers.autoupdate" label set to "image" and communicates to the container registry. If the image has changed, Podman restarts the corresponding `systemd` unit to stop the old container and create a new one with the new image. As a result, the container, its environment, and all dependencies, are restarted.

**NOTE**

Starting with Podman v4.6, you can use the Quadlets that describe how to run a container in a format similar to regular `systemd` unit files and hides the complexity of running containers under `systemd`.

**Prerequisites**

- The `containers-tool` meta-package is installed.

**Procedure**

1. Start a `myubi` container based on the `registry.access.redhat.com/ubi9/ubi-init` image:

   ```
   # podman run --label "io.containers.autoupdate=image" \
   --name myubi -dt registry.access.redhat.com/ubi9/ubi-init top
   bc219740a210455fa27deacc96d50a9e20516492f1417507c13ce1533dbcd9d
   ```

2. Optional: List containers that are running or have exited:

   ```
   # podman ps -a
   CONTAINER ID   IMAGE                                            COMMAND          CREATED              STATUS       PORTS   NAMES
   76465a5e2933   registry.access.redhat.com/9/ubi-init:latest   top              24 seconds ago       Up 23 seconds ago myubi
   ```

3. Generate a `systemd` unit file for the `myubi` container:

   ```
   # podman generate systemd --new --files --name myubi /root/container-myubi.service
   ```

4. Copy unit files to `/usr/lib/systemd/system` for installing it as a root user:

   ```
   # cp -Z ~/container-myubi.service /usr/lib/systemd/system
   ```

5. Reload `systemd` manager configuration:

   ```
   # systemctl daemon-reload
   ```

6. Start and check the status of a container:

   ```
   # systemctl start container-myubi.service
   # systemctl status container-myubi.service
   ```
7. Auto-update the container:

```bash
# podman auto-update
```

Additional resources

- Improved Systemd Integration with Podman 2.0
- Running containers with Podman and shareable systemd services
- Enabling a system service to start at boot

### 14.9. AUTOMATICALLY UPDATING CONTAINERS USING SYSTEMD

As mentioned in section Auto-updating containers using Podman,
you can update the container using the `podman auto-update` command. It integrates into custom scripts and can be invoked when needed. Another way to auto update the containers is to use the pre-installed `podman-auto-update.timer` and `podman-auto-update.service systemd` service. The `podman-auto-update.timer` can be configured to trigger auto updates at a specific date or time. The `podman-auto-update.service` can further be started by the `systemctl` command or be used as a dependency by other `systemd` services. As a result, auto updates based on time and events can be triggered in various ways to meet individual needs and use cases.

**NOTE**

Starting with Podman v4.6, you can use the Quadlets that describe how to run a container in a format similar to regular `systemd` unit files and hides the complexity of running containers under `systemd`.

**Prerequisites**

- The `containers-tool` meta-package is installed.

**Procedure**

1. Display the `podman-auto-update.service` unit file:

```bash
# cat /usr/lib/systemd/system/podman-auto-update.service

[Unit]
Description=Podman auto-update service
Documentation=man:podman-auto-update(1)
Wants=network.target
After=network-online.target

[Service]
Type=oneshot
ExecStart=/usr/bin/podman auto-update

[Install]
WantedBy=multi-user.target default.target
```

2. Display the `podman-auto-update.timer` unit file:
# cat /usr/lib/systemd/system/podman-auto-update.timer

[Unit]
Description=Podman auto-update timer

[Timer]
OnCalendar=daily
Persistent=true

[Install]
WantedBy=timers.target

In this example, the **podman auto-update** command is launched daily at midnight.

3. Enable the **podman-auto-update.timer** service at system start:

    ```
    # systemctl enable podman-auto-update.timer
    ```

4. Start the **systemd** service:

    ```
    # systemctl start podman-auto-update.timer
    ```

5. Optional: List all timers:

    ```
    # systemctl list-timers --all
    ```

    | NEXT                        | LEFT | LAST | PASSED   | UNIT                      |
    |-----------------------------|------|------|----------|---------------------------|
    | Wed 2020-12-09 00:00:00 CET | 9h   | n/a  | n/a      | podman-auto-update.timer |

    You can see that **podman-auto-update.timer** activates the **podman-auto-update.service**.

**Additional resources**

- [Improved Systemd Integration with Podman 2.0](#)
- [Running containers with Podman and shareable systemd services](#)
- [Enabling a system service to start at boot](#)
CHAPTER 15. MANAGING CONTAINERS USING THE ANSIBLE PLAYBOOK

With Podman 4.2, you can use the Podman RHEL System Role to manage Podman configuration, containers, and systemd services which run Podman containers.

RHEL System Roles provide a configuration interface to remotely manage multiple RHEL systems. You can use the interface to manage system configurations across multiple versions of RHEL, as well as adopting new major releases. For more information, see the Automating system administration by using RHEL System Roles.

15.1. CREATING A ROOTLESS CONTAINER WITH BIND MOUNT

You can use the Podman System Role to create rootless containers with bind mount by running an Ansible playbook and with that, manage your application configuration.

Prerequisites

- Access and permissions to a control node, which is a system from which Red Hat Ansible Engine configures other systems.

- On the control node:
  - The rhel-system-roles package is installed.
  - An Ansible inventory file listing the hosts to be managed and any other parameters you want to apply.

NOTE

The ansible-playbook command is provided by the ansible-core package which should be automatically installed as a dependency of the rhel-system-roles package.

Procedure

1. Create a new playbook.yml file with the following content:

```yaml
- hosts: all
  vars:
    podman_create_host_directories: true
    podman_firewall:
      - port: 8080-8081/tcp
        state: enabled
      - port: 12340/tcp
        state: enabled
    podman_selinux_ports:
      - ports: 8080-8081
        setype: http_port_t
    podman_kube_specs:
      - state: started
        run_as_user: dbuser
        run_as_group: dbgroup
        kube_file_content:
          apiVersion: v1
```
This procedure creates a pod with two containers. The podman_kube_specs role variable describes a pod.

- The run_as_user and run_as_group fields specify that containers are rootless.
- The kube_file_content field containing a Kubernetes YAML file defines the first container named db. You can generate the Kubernetes YAML file using the podman generate systemd command.
  - The db container is based on the quay.io/db/db:stable container image.
  - The db bind mount maps the /var/lib/db directory on the host to the /var/lib/db directory in the container. The Z flag labels the content with a private unshared label, therefore, only the db container can access the content.
- The kube_file_src field defines the second container. The content of the /path/to/webapp.yml file on the controller node will be copied to the kube_file field on the managed node.
- Set the podman_create_host_directories: true to create the directory on the host. This instructs the role to check the kube specification for hostPath volumes and create those directories on the host. If you need more control over the ownership and permissions, use podman_host_directories.

2. Optional: Verify playbook syntax.

    # ansible-playbook --syntax-check playbook.yml -i inventory_file

3. Run the playbook on your inventory file:

    # ansible-playbook -i inventory_file playbook.yml
Additional resources

- The `/usr/share/ansible/roles/rhel-system-roles.podman/README.md` file
- The Podman System Role documentation

15.2. CREATING A ROOTFUL CONTAINER WITH PODMAN VOLUME

You can use the Podman System Role to create a rootful container with a Podman volume by running an Ansible playbook and with that, manage your application configuration.

Prerequisites

- Access and permissions to a control node, which is a system from which Red Hat Ansible Engine configures other systems.
- On the control node:
  - The `rhel-system-roles` package is installed.
  - An Ansible inventory file listing the hosts to be managed and any other parameters you want to apply.
- The `ubi8-html-volume` volume has been created.

**NOTE**

The `ansible-playbook` command is provided by the `ansible-core` package which should be automatically installed as a dependency of the `rhel-system-roles` package.

Procedure

1. Create a new `playbook.yml` file with the following content:

```yaml
- hosts: all
  vars:
    podman_firewall:
      - port: 8080/tcp
        state: enabled
    podman_kube_specs:
      - state: started
        kube_file_content:
          apiVersion: v1
          kind: Pod
          metadata:
            name: ubi8-httpd
          spec:
            containers:
              - name: ubi8-httpd
                image: registry.access.redhat.com/ubi8/httpd-24
                ports:
                  - containerPort: 8080
                    hostPort: 8080
                volumeMounts:
                  - mountPath: /var/www/html
```
The procedure creates a pod with one container. The `podman_kube_specs` role variable describes a pod.

- By default, the Podman role creates rootful containers.
- The `kube_file_content` field containing a Kubernetes YAML file defines the container named `ubi8-httpd`.
  - The `ubi8-httpd` container is based on the `registry.access.redhat.com/ubi8/httpd-24` container image.
  - The `ubi8-html-volume` maps the `/var/www/html` directory on the host to the container. The `Z` flag labels the content with a private unshared label, therefore, only the `ubi8-httpd` container can access the content.
  - The pod mounts the existing persistent volume named `ubi8-html-volume` with the mount path `/var/www/html`.

2. Optional: Verify playbook syntax.

```
# ansible-playbook --syntax-check playbook.yml -i inventory_file
```

3. Run the playbook on your inventory file:

```
# ansible-playbook -i inventory_file playbook.yml
```

Additional resources

- The `/usr/share/ansible/roles/rhel-system-roles.podman/README.md` file
- The Podman System Role documentation

## 15.3. CREATING A QUADLET APPLICATION WITH SECRETS

You can use the Podman System Role to create a Quadlet application with secrets by running an Ansible playbook.

**NOTE**

The `podman_quadlet_specs` variable is available beginning with Podman v4.6.

Prerequisites

- Access and permissions to a control node, which is a system from which Red Hat Ansible Engine configures other systems.
- On the control node:
- The `rhel-system-roles` package is installed.
- An Ansible inventory file listing the hosts to be managed and any other parameters you want to apply.
- Secrets - you must define the following, preferably using Ansible Vault encrypted variables:
  - root password for MySQL ("root_password_from_vault")
  - TLS certificate and key ("cert_from_vault" and "key_from_vault")

**NOTE**

- The `ansible-playbook` command is provided by the `ansible-core` package which should be automatically installed as a dependency of the `rhel-system-roles` package.
- The files used by this example are provided by the `rhel-system-roles` package in `/usr/share/ansible/roles/rhel-system-roles.podman/tests/files` and `/usr/share/ansible/roles/rhel-system-roles.podman/tests/templates` directories.

**Procedure**

1. Create a new `playbook.yml` file with the following content:

```yaml
podman_create_host_directories: true
podman_activate_systemd_unit: false
podman_quadlet_specs:
  - name: quadlet-demo
    type: network
    file_content: |
      [Network]
      Subnet=192.168.30.0/24
      Gateway=192.168.30.1
      Label=app=wordpress
    - file_src: quadlet-demo-mysql.volume
    - template_src: quadlet-demo-mysql.container.j2
    - file_src: envoy-proxy-configmap.yml
    - file_src: quadlet-demo.yml
    - file_src: quadlet-demo.kube
    activate_systemd_unit: true
podman_firewall:
  - port: 8000/tcp
    state: enabled
  - port: 9000/tcp
    state: enabled
podman_secrets:
  - name: mysql-root-password-container
    state: present
    skip_existing: true
    data: "{{ root_password_from_vault }}"
  - name: mysql-root-password-kube
    state: present
    skip_existing: true
    data: |
```
apiVersion: v1
data:
  password: "{{ root_password_from_vault | b64encode }}"
kind: Secret
metadata:
  name: mysql-root-password-kube
- name: envoy-certificates
  state: present
  skip_existing: true
data:
  apiVersion: v1
data:
  certificate.key: "{{ key_from_vault | b64encode }}"
  certificate.pem: "{{ cert_from_vault | b64encode }}"
kind: Secret
metadata:
  name: envoy-certificates

The procedure creates a WordPress content management system paired with a MySQL database. The `podman_quadlet_specs` role variable defines a set of configurations for the Quadlet, which refers to a group of containers or services that work together in a certain way. It includes the following specifications:

- The Wordpress network is defined by the `quadlet-demo` network unit.
- The volume configuration for MySQL container is defined by the `file_src: quadlet-demo-mysql.volume` field.
- The `template_src: quadlet-demo-mysql.container.j2` field is used to generate a configuration for the MySQL container.
- Two YAML files follow: `file_src: envoy-proxy-configmap.yml` and `file_src: quadlet-demo.yml`. Note that `.yml` is not a valid Quadlet unit type, therefore these files will just be copied and not processed as a Quadlet specification.
- The Wordpress and envoy proxy containers and configuration are defined by the `file_src: quadlet-demo.kube` field. The kube unit refers to the previous YAML files in the [Kube] section as `Yaml=quadlet-demo.yml` and `ConfigMap=envoy-proxy-configmap.yml`.

2. Optional: Verify playbook syntax.

```
# ansible-playbook --syntax-check playbook.yml -i inventory_file
```

3. Run the playbook on your inventory file:

```
# ansible-playbook -i inventory_file playbook.yml
```

Additional resources

- The `/usr/share/ansible/roles/rhel-system-roles/podman/README.md` file
- The Podman System Role documentation
CHAPTER 16. MANAGING CONTAINER IMAGES BY USING THE RHEL WEB CONSOLE

Additional resources

You can use the RHEL web console web-based interface to pull, prune, or delete your container images.

16.1. PREREQUISITES

- Installed and accessible web console. See Installing the web console and Logging in to the web console.

- Installed the cockpit-podman add-on:

  # dnf install cockpit-podman

16.2. PULLING CONTAINER IMAGES IN THE WEB CONSOLE

You can download container images to your local system and use them to create your containers.

Procedure

1. Click Podman containers in the main menu.

2. In the Images table, click the overflow menu in the upper-right corner and select Download new image.

3. The Search for an image dialog box appears.

4. In the Search for field, enter the name of the image or specify its description.

5. In the in drop-down list, select the registry from which you want to pull the image.

6. Optional: In the Tag field, enter the tag of the image.

7. Click Download

Verification

- Click Podman containers in the main menu. You can see the newly downloaded image in the Images table.

NOTE

You can create a container from the downloaded image by clicking the Create container in the Images table. To create the container, follow steps 3.–8. in Creating containers in the web console.

16.3. PRUNING CONTAINER IMAGES IN THE WEB CONSOLE

You can remove all unused images that do not have any containers based on it.

Prerequisites
16.4. DELETING CONTAINER IMAGES IN THE WEB CONSOLE

You can delete the image.

Prerequisites

- At least one container image is pulled.

Procedure

1. Click **Podman containers** in the main menu.

2. In the **Images** table, select the image you want to delete and click the overflow menu and select **Delete**.

3. The pop-up window appears. Click **Delete tagged images** to confirm your choice.

Verification

- Click the **Podman containers** in the main menu. The deleted container should not be listed in the **Images** table.
CHAPTER 17. MANAGING CONTAINERS BY USING THE RHEL WEB CONSOLE

You can use the RHEL web console web-based interface to manage your containers and pods. You can create containers in the RHEL web console as a non-root user or as a root user.

- As a root user, you can create system containers with extra privileges and options.
- As a non-root user you have two options:
  - Log in to the web console with limited privileges, then you can create user containers.
  - Log in to the web console with administrative privileges, then you can create both types of containers – user containers and system containers.

For details about Limited access and Administrative access, see Logging in to the web console. For details about differences between root and rootless containers, see Special considerations for rootless containers.

17.1. PREREQUISITES

- Installed and accessible web console. See Installing the web console and Logging in to the web console.

- Installed the cockpit-podman add-on:

  # dnf install cockpit-podman

17.2. CREATING CONTAINERS IN THE WEB CONSOLE

You can create a container and add port mappings, volumes, environment variables, health checks, and so on.

Procedure

1. Click Podman containers in the main menu.

2. Click Create container.

3. In the Name field, enter the name of your container.

4. Provide desired info in the Details tab.

   - Available only with the administrative access: Select the Owner of the container: System or User.

   - In the Image drop down list select or search the container image in selected registries.
     - Optional: Check the Pull latest image checkbox to pull the latest container image.

   - The Command field specifies the command. You can change the default command if you need.
     - Optional: Check the With terminal checkbox to run your container with a terminal.
• The Memory limit field specifies the memory limit for the container. To change the default memory limit, check the checkbox and specify the limit.

• Available only for system containers: In the CPU shares field, specify the relative amount of CPU time. Default value is 1024. Check the checkbox to modify the default value.

• Available only for system containers: In the Restart policy drop down menu, select one of the following options:
  o No (default value): No action.
  o On Failure: Restarts a container on failure.
  o Always: Restarts container when exits or after system boot.

5. Provide desired info in the Integration tab.

• Click Add port mapping to add port mapping between container and host system.
  o Enter the IP address, Host port, Container port and Protocol.

• Click Add volume to add volume.
  o Enter the host path, Container path. You can check theWritable checkbox to create a writable volume. In the SELinux drop down list, select one of the following options: No Label, Shared or Private.

• Click Add variable to add environment variable.
  o Enter the Key and Value.

6. Provide desired info in the Health check tab.

• In the Command fields, enter the healthcheck command.

• Specify the healthcheck options:
  o Interval (default is 30 seconds)
  o Timeout (default is 30 seconds)
  o Start period
  o Retries (default is 3) for the healthcheck command
  o When unhealthy: Select one of the following options:
    ■ No action (default): Take no action.
    ■ Restart: Restart the container.
    ■ Stop: Stop the container.
    ■ Force stop: Force stops the container, it does not wait for the container to exit.

7. Click Create and run to create and run the container.
17.3. INSPECTING CONTAINERS IN THE WEB CONSOLE

You can display detailed information about the container.

Prerequisites

- A container was created.

Procedure

1. Click Podman containers in the main menu.
2. Click the > arrow icon to see details of the container.
   - In the Details tab, you can see container ID, Image, Command, Created (timestamp when the container was created), and its State.
     - Available only for system containers: You can also see IP address, MAC address, and Gateway address.
   - In the Integration tab, you can see environment variables, port mappings, and volumes.
   - In the Log tab, you can see container logs.
   - In the Console tab, you can interact with the container using the command line.

17.4. CHANGING THE STATE OF CONTAINERS IN THE WEB CONSOLE

You can change the status of the container.

Prerequisites

- A container was created.

Procedure

1. Click Podman containers in the main menu.
2. In the Containers table, select the container you want to modify and click the overflow menu and select the action you want to perform:
   - Start
   - Stop
   - Force stop
17.5. COMMITTING CONTAINERS IN THE WEB CONSOLE

You can create a new image based on the current state of the container.

Prerequisites

- A container was created.

Procedure

1. Click Podman containers in the main menu.

2. In the Containers table, select the container you want to modify and click the overflow menu and select Commit.

3. In the Commit container form, add the following details:
   - In the New image name field, enter the image name.
   - Optional: In the Tag field, enter the tag.
   - Optional: In the Author field, enter your name.
   - Optional: In the Command field, change command if you need.
   - Optional: Check the Options you need:
     - Pause container when creating image: The container and its processes are paused while the image is committed.
     - Use legacy Docker format: if you do not use the Docker image format, the OCI format is used.

4. Click Commit.

Verification

- Click the Podman containers in the main menu. You can see the newly created image in the Images table.

17.6. CREATING A CONTAINER CHECKPOINT IN THE WEB CONSOLE

Using the web console, you can set a checkpoint on a running container or an individual application and store its state to disk.
Prerequisites

- A container is running.

Procedure

1. Click **Podman containers** in the main menu.

2. In the **Containers** table, select the container you want to modify and click the overflow icon and select **Checkpoint**.

3. Optional: In the **Checkpoint container** form, check the options you need:
   - Keep all temporary checkpoint files: keep all temporary log and statistics files created by CRIU during checkpointing. These files are not deleted if checkpointing fails for further debugging.
   - Leave running after writing checkpoint to disk: leave the container running after checkpointing instead of stopping it.
   - Support preserving established TCP connections

4. Click **Checkpoint**.

Verification

- Click the **Podman containers** in the main menu. Select the container you checkpointed, click the overflow menu icon and verify that there is a **Restore** option.

17.7. RESTORING A CONTAINER CHECKPOINT IN THE WEB CONSOLE

You can use data saved to restore the container after a reboot at the same point in time it was checkpointed.

NOTE

Creating a checkpoint is available only for system containers.

Prerequisites

- A container was checkpointed.

Procedure

1. Click **Podman containers** in the main menu.

2. In the **Containers** table, select the container you want to modify and click the overflow menu and select **Restore**.

3. Optional: In the **Restore container** form, check the options you need:
- Keep all temporary checkpoint files: Keep all temporary log and statistics files created by CRIU during checkpointing. These files are not deleted if checkpointing fails for further debugging.

- Restore with established TCP connections

- Ignore IP address if set statically: If the container was started with IP address the restored container also tries to use that IP address and restore fails if that IP address is already in use. This option is applicable if you added port mapping in the Integration tab when you create the container.

- Ignore MAC address if set statically: If the container was started with MAC address the restored container also tries to use that MAC address and restore fails if that MAC address is already in use.

4. Click **Restore**.

**Verification**
- Click the **Podman containers** in the main menu. You can see that the restored container in the **Containers** table is running.

### 17.8. DELETING CONTAINERS IN THE WEB CONSOLE

You can delete the container.

**Prerequisites**
- A container exists.

**Procedure**

1. Click **Podman containers** in the main menu.

2. In the **Containers** table, select the container you want to delete and click the overflow menu and select **Delete**.

3. The pop-up window appears. Click **Delete** to confirm your choice.

**Verification**
- Click the **Podman containers** in the main menu. The deleted container should not be listed in the **Containers** table.

### 17.9. CREATING PODS IN THE WEB CONSOLE

You can create pods in the RHEL web console interface.

**Procedure**

1. Click **Podman containers** in the main menu.

2. Click **Create pod**.

3. Provide desired information in the **Create pod** form:
• Available only with the administrative access: Select the Owner of the container: System or User.

• In the Name field, enter the name of your container.

• Click Add port mapping to add port mapping between container and host system.
  • Enter the IP address, Host port, Container port and Protocol.

• Click Add volume to add volume.
  • Enter the host path, Container path. You can check the Writable checkbox to create a writable volume. In the SELinux drop down list, select one of the following options: No Label, Shared or Private.

4. Click Create.

Verification

• Click Podman containers in the main menu. You can see the newly created pod in the Containers table.

17.10. CREATING CONTAINERS IN THE POD IN THE WEB CONSOLE

You can create a container in a pod.

Procedure

1. Click Podman containers in the main menu.

2. Click Create container in pod.

3. Follow the steps 3.–8. in Creating containers in the web console.

NOTE

The Owner of a container will be the same as the Owner of a pod.

NOTE

In the pod, you can inspect containers, change the status of containers, commit containers, or delete containers.

Verification

• Click Podman containers in the main menu. You can see the newly created container in the pod under the Containers table.

17.11. CHANGING THE STATE OF PODS IN THE WEB CONSOLE

You can change the status of the pod.

Prerequisites
• A pod was created.

Procedure

1. Click Podman containers in the main menu.

2. In the Containers table, select the pod you want to modify and click the overflow menu and select the action you want to perform:
   • Start
   • Stop
   • Force stop
   • Restart
   • Force restart
   • Pause

17.12. DELETING PODS IN THE WEB CONSOLE

You can delete the pod.

Prerequisites

• A pod exists.

Procedure

1. Click Podman containers in the main menu.

2. In the Containers table, select the pod you want to delete and click the overflow menu and select Delete.

3. The pop-up window appears. Click Delete to confirm your choice.

WARNING

All containers in a pod will be removed.

Verification

• Click the Podman containers in the main menu. The deleted pod should not be listed in the Containers table.
CHAPTER 18. RUNNING SKOPEO, BUILDAH, AND PODMAN IN A CONTAINER

You can run Skopeo, Buildah, and Podman in a container.

With Skopeo, you can inspect images on a remote registry without having to download the entire image with all its layers. You can also use Skopeo for copying images, signing images, syncing images, and converting images across different formats and layer compressions.

Buildah facilitates building OCI container images. With Buildah, you can create a working container, either from scratch or using an image as a starting point. You can create an image either from a working container or using the instructions in a Containerfile. You can mount and unmount a working container’s root filesystem.

With Podman, you can manage containers and images, volumes mounted into those containers, and pods made from groups of containers. Podman is based on a libpod library for container lifecycle management. The libpod library provides APIs for managing containers, pods, container images, and volumes.

Reasons to run Buildah, Skopeo, and Podman in a container:

- **CI/CD system:**
  - **Podman and Skopeo:** You can run a CI/CD system inside of Kubernetes or use OpenShift to build your container images, and possibly distribute those images across different container registries. To integrate Skopeo into a Kubernetes workflow, you need to run it in a container.
  - **Buildah:** You want to build OCI/container images within a Kubernetes or OpenShift CI/CD systems that are constantly building images. Previously, people used a Docker socket to connect to the container engine and perform a `docker build` command. This was the equivalent of giving root access to the system without requiring a password which is not secure. For this reason, Red Hat recommends using Buildah in a container.

- **Different versions:**
  - **All:** You are running an older operating system on the host but you want to run the latest version of Skopeo, Buildah, or Podman. The solution is to run the container tools in a container. For example, this is useful for running the latest version of the container tools provided in Red Hat Enterprise Linux 8 on a Red Hat Enterprise Linux 7 container host which does not have access to the newest versions natively.

- **HPC environment:**
  - **All:** A common restriction in HPC environments is that non-root users are not allowed to install packages on the host. When you run Skopeo, Buildah, or Podman in a container, you can perform these specific tasks as a non-root user.

18.1. RUNNING SKOPEO IN A CONTAINER

This procedure demonstrates how to inspect a remote container image using Skopeo. Running Skopeo in a container means that the container root filesystem is isolated from the host root filesystem. To share or copy files between the host and container, you have to mount files and directories.

**Prerequisites**
The containers-tool meta-package is installed.

Procedure

1. Log in to the registry.redhat.io registry:

```bash
$ podman login registry.redhat.io
Username: myuser@mycompany.com
Password: <password>
Login Succeeded!
```

2. Get the registry.redhat.io/rhel9/skopeo container image:

```bash
$ podman pull registry.redhat.io/rhel9/skopeo
```

3. Inspect a remote container image registry.access.redhat.com/ubi9/ubi using Skopeo:

```bash
$ podman run --rm registry.redhat.io/rhel9/skopeo \
   skopeo inspect docker://registry.access.redhat.com/ubi9/ubi
{
   "Name": "registry.access.redhat.com/ubi9/ubi",
   ...
   "Labels": {
      "architecture": "x86_64",
      ...
      "name": "ubi9",
      ...
      "summary": "Provides the latest release of Red Hat Universal Base Image 9.",
      "url": 
      ...
   },
   "Architecture": "amd64",
   "Os": "linux",
   "Layers": [
      ...
   ],
   "Env": [
      "PATH=/usr/local/sbin:/usr/local/bin:/usr/sbin:/usr/bin:/sbin:/bin",
      "container=oci"
   ]
}
```

The --rm option removes the registry.redhat.io/rhel9/skopeo image after the container exits.

Additional resources

- How to run skopeo in a container

18.2. RUNNING SKOPEO IN A CONTAINER USING CREDENTIALS

Working with container registries requires an authentication to access and alter data. Skopeo supports various ways to specify credentials.
With this approach you can specify credentials on the command line using the `--cred
USERNAME[:PASSWORD]` option.

Prerequisites

- The `containers-tool` meta-package is installed.

Procedure

- Inspect a remote container image using Skopeo against a locked registry:

```bash
$ podman run --rm registry.redhat.io/rhel9/skopeo inspect --creds
$USER:$PASSWORD docker://$IMAGE
```

Additional resources

- How to run skopeo in a container

## 18.3. RUNNING SKOPEO IN A CONTAINER USING AUTHFILES

You can use an authentication file (authfile) to specify credentials. The `skopeo login` command logs into the specific registry and stores the authentication token in the authfile. The advantage of using authfiles is preventing the need to repeatedly enter credentials.

When running on the same host, all container tools such as Skopeo, Buildah, and Podman share the same authfile. When running Skopeo in a container, you have to either share the authfile on the host by volume-mounting the authfile in the container, or you have to reauthenticate within the container.

Prerequisites

- The `containers-tool` meta-package is installed.

Procedure

- Inspect a remote container image using Skopeo against a locked registry:

```bash
$ podman run --rm -v $AUTHFILE:/auth.json registry.redhat.io/rhel9/skopeo inspect
docker://$IMAGE
```

The `-v $AUTHFILE:/auth.json` option volume-mounts an authfile at `/auth.json` within the container. Skopeo can now access the authentication tokens in the authfile on the host and get secure access to the registry.

Other Skopeo commands work similarly, for example:

- Use the `skopeo-copy` command to specify credentials on the command line for the source and destination image using the `--source-creds` and `--dest-creds` options. It also reads the `/auth.json` authfile.

- If you want to specify separate authfiles for the source and destination image, use the `--source-authfile` and `--dest-authfile` options and volume-mount those authfiles from the host into the container.

Additional resources
How to run skopeo in a container

18.4. COPYING CONTAINER IMAGES TO OR FROM THE HOST

Skopeo, Buildah, and Podman share the same local container-image storage. If you want to copy containers to or from the host container storage, you need to mount it into the Skopeo container.

**NOTE**

The path to the host container storage differs between root (/var/lib/containers/storage) and non-root users ($HOME/.local/share/containers/storage).

**Prerequisites**

- The **containers-tool** meta-package is installed.

**Procedure**

1. Copy the `registry.access.redhat.com/ubi9/ubi` image into your local container storage:

   ```
   $ podman run --privileged --rm -v $HOME/.local/share/containers/storage:/var/lib/containers/storage
   registry.redhat.io/rhel9/skopeo skopeo copy
docker://registry.access.redhat.com/ubi9/ubi containers-storage:registry.access.redhat.com/ubi9/ubi
   ```

   - The **--privileged** option disables all security mechanisms. Red Hat recommends only using this option in trusted environments.

   - To avoid disabling security mechanisms, export the images to a tarball or any other path-based image transport and mount them in the Skopeo container:

     ```
     $ podman save --format oci-archive -o oci.tar $IMAGE
     $ podman run --rm -v oci.tar:/oci.tar registry.redhat.io/rhel9/skopeo copy
     oci-archive:/oci.tar $DESTINATION
     ```

2. Optional: List images in local storage:

   ```
   $ podman images
   REPOSITORY                              TAG IMAGE ID CREATED       SIZE
   registry.access.redhat.com/ubi9/ubi     latest  ecbc6f53bba0  8 weeks ago  211 MB
   ```

**Additional resources**

- How to run skopeo in a container

18.5. RUNNING BUILDAH IN A CONTAINER

The procedure demonstrates how to run Buildah in a container and create a working container based on an image.
Prerequisites

- The **containers-tool** meta-package is installed.

Procedure

1. Log in to the registry.redhat.io registry:

   ```
   $ podman login registry.redhat.io
   Username: myuser@mycompany.com
   Password: <password>
   Login Succeeded!
   ```

2. Pull and run the **registry.redhat.io/rhel9/buildah** image:

   ```
   # podman run --rm --device /dev/fuse -it \
   registry.redhat.io/rhel9/buildah /bin/bash
   ```

   - The **--rm** option removes the **registry.redhat.io/rhel9/buildah** image after the container exits.
   - The **--device** option adds a host device to the container.
   - The **sys_chroot** capability to change to a different root directory. It is not included in the default capabilities of a container.

3. Create a new container using a **registry.access.redhat.com/ubi9** image:

   ```
   # buildah from registry.access.redhat.com/ubi9
   ```

4. Run the **ls /** command inside the **ubi9-working-container** container:

   ```
   # buildah run --isolation=chroot ubi9-working-container ls /
   bin  boot  dev  etc  home  lib  lib64  lost+found  media  mnt  opt  proc  root  run  sbin  srv
   ```

5. Optional: List all images in a local storage:

   ```
   # buildah images
   REPOSITORY                        TAG      IMAGE ID       CREATED       SIZE
   registry.access.redhat.com/ubi9   latest   ecbc6f53bba0   5 weeks ago   211 MB
   ```

6. Optional: List the working containers and their base images:

   ```
   # buildah containers
   CONTAINER ID  BUILDER  IMAGE ID     IMAGE NAME                       CONTAINER NAME
   0aaba7192762     *     ecbc6f53bba0 registry.access.redhat.com/ub... ubi9-working-container
   ```

7. Optional: Push the **registry.access.redhat.com/ubi9** image to the a local registry located on **registry.example.com**:

   ```
   # buildah push ecbc6f53bba0 registry.example.com:5000/ubi9/ubi
   ```
18.6. PRIVILEGED AND UNPRIVILEGED PODMAN CONTAINERS

By default, Podman containers are unprivileged and cannot, for example, modify parts of the operating system on the host. This is because by default a container is only allowed limited access to devices.

The following list emphasizes important properties of privileged containers. You can run the privileged container using the `podman run --privileged <image_name>` command.

- A privileged container is given the same access to devices as the user launching the container.
- A privileged container disables the security features that isolate the container from the host. Dropped Capabilities, limited devices, read-only mount points, Apparmor/SELinux separation, and Seccomp filters are all disabled.
- A privileged container cannot have more privileges than the account that launched them.

Additional resources

- How to use the `--privileged` flag with container engines
- `podman-run` man page

18.7. RUNNING PODMAN WITH EXTENDED PRIVILEGES

If you cannot run your workloads in a rootless environment, you need to run these workloads as a root user. Running a container with extended privileges should be done judiciously, because it disables all security features.

Prerequisites

- The `containers-tool` meta-package is installed.

Procedure

- Run the Podman container in the Podman container:

```sh
$ podman run --privileged --name=privileged_podman
registry.access.redhat.com/podman podman run ubi9 echo hello
Resolved "ubi9" as an alias (/etc/containers/registries.conf.d/001-rhel-shortnames.conf)
Trying to pull registry.access.redhat.com/ubi9:latest...
...  Storing signatures
hello
```

- Run the outer container named `privileged_podman` based on the `registry.access.redhat.com/ubi9/podman` image.

- The `--privileged` option disables the security features that isolate the container from the host.

- Run `podman run ubi9 echo hello` command to create the inner container based on the `ubi9` image.
• Notice that the **ubi9** short image name was resolved as an alias. As a result, the `registry.access.redhat.com/ubi9:latest` image is pulled.

**Verification**

• List all containers:

```
$ podman ps -a
CONTAINER ID  IMAGE                            COMMAND               CREATED            STATUS
PORTS   NAMES
52537876caf4  registry.access.redhat.com/ubi9/podman               podman run ubi9 e... 30 seconds ago     Exited (0) 13 seconds ago     privileged_podman
```

**Additional resources**

• How to use Podman inside of a container

• `podman-run` man page

### 18.8. RUNNING PODMAN WITH LESS PRIVILEGES

You can run two nested Podman containers without the `--privileged` option. Running the container without the `--privileged` option is a more secure option.

This can be useful when you want to try out different versions of Podman in the most secure way possible.

**Prerequisites**

• The `containers-tool` meta-package is installed.

**Procedure**

• Run two nested containers:

```
$ podman run --name=unprivileged_podman --security-opt label=disable \ 
  --user podman --device /dev/fuse \ 
  registry.access.redhat.com/ubi9/podman \ 
  podman run ubi9 echo hello
```

• Run the outer container named `unprivileged_podman` based on the `registry.access.redhat.com/ubi9/podman` image.

• The `--security-opt label=disable` option disables SELinux separation on the host Podman. SELinux does not allow containerized processes to mount all of the file systems required to run inside a container.

• The `--user podman` option automatically causes the Podman inside the outer container to run within the user namespace.

• The `--device /dev/fuse` option uses the `fuse-overlayfs` package inside the container. This option adds `/dev/fuse` to the outer container, so that Podman inside the container can use it.
• Run `podman run ubi9 echo hello` command to create the inner container based on the `ubi9` image.

• Notice that the `ubi9` short image name was resolved as an alias. As a result, the `registry.access.redhat.com/ubi9:latest` image is pulled.

**Verification**

• List all containers:

```
$ podman ps -a
CONTAINER ID   IMAGE                  COMMAND                  CREATED              STATUS        PORTS             NAMES
a47b26290f43   podman run ubi9 e... 30 seconds ago   Exited (0) 13 seconds ago
unprivileged_podman
```

**18.9. BUILDING A CONTAINER INSIDE A PODMAN CONTAINER**

This procedure shows how to run a container in a container using Podman. This example shows how to use Podman to build and run another container from within this container. The container will run "Moon-buggy", a simple text-based game.

**Prerequisites**

• The `containers-tool` meta-package is installed.

• You are logged in to the registry.redhat.io registry:

  ```
  # podman login registry.redhat.io
  ```

**Procedure**

1. Run the container based on `registry.redhat.io/rhel9/podman` image:

  ```
  # podman run --privileged --name podman_container -it \
  registry.redhat.io/rhel9/podman /bin/bash
  ```

• Run the outer container named `podman_container` based on the `registry.redhat.io/rhel9/podman` image.

• The `--it` option specifies that you want to run an interactive bash shell within a container.

• The `--privileged` option disables the security features that isolate the container from the host.

2. Create a `Containerfile` inside the `podman_container` container:

  ```
  # vi Containerfile
  FROM registry.access.redhat.com/ubi9/ubi
  RUN dnf -y install moon-buggy & & dnf clean all
  CMD ["/usr/bin/moon-buggy"]
  ```

The commands in the `Containerfile` cause the following build command to:
• Build a container from the registry.access.redhat.com/ubi9/ubi image.
• Install the epel-release-latest-8.noarch.rpm package.
• Install the moon-buggy package.
• Set the container command.

3. Build a new container image named moon-buggy using the Containerfile:

   # podman build -t moon-buggy .

4. Optional: List all images:

   # podman images
   REPOSITORY                  TAG      IMAGE ID      CREATED        SIZE
   localhost/moon-buggy  latest  c97c58abb564  13 seconds ago  1.67 GB
   registry.access.redhat.com/ubi9/ubi latest 4199acc83c6a  132seconds ago 213 MB

5. Run a new container based on a moon-buggy container:

   # podman run -it --name moon moon-buggy

6. Optional: Tag the moon-buggy image:

   # podman tag moon-buggy registry.example.com/moon-buggy

7. Optional: Push the moon-buggy image to the registry:

   # podman push registry.example.com/moon-buggy

Additional resources

• Technology preview: Running a container inside a container
CHAPTER 19. BUILDING CONTAINER IMAGES WITH BUILDAH

Buildah facilitates building OCI container images that meet the OCI Runtime Specification. With Buildah, you can create a working container, either from scratch or using an image as a starting point. You can create an image either from a working container, using the instructions in a Containerfile, or by using a series of Buildah commands that emulate the commands found in a Containerfile.

19.1. THE BUILDAH TOOL

Using Buildah is different from building images with the docker command in the following ways:

No Daemon
Buildah requires no container runtime.

Base image or scratch
You can build an image based on another container or start with an empty image (scratch).

Build tools are external
Buildah does not include build tools within the image itself. As a result, Buildah:

- Reduces the size of built images.
- Increases security of images by excluding software (for example gcc, make, and dnf) from the resulting image.
- Allows to transport the images using fewer resources because of the reduced image size.

Compatibility
Buildah supports building container images with Dockerfiles allowing for an easy migration from Docker to Buildah.

NOTE
The default location Buildah uses for container storage is the same as the location the CRI-O container engine uses for storing local copies of images. As a result, the images pulled from a registry by either CRI-O or Buildah, or committed by the buildah command, are stored in the same directory structure. However, even though CRI-O and Buildah are currently able to share images, they cannot share containers.

Additional resources
- Buildah - a tool that facilitates building Open Container Initiative (OCI) container images
- Buildah Tutorial 1: Building OCI container images
- Buildah Tutorial 2: Using Buildah with container registries
- Building with Buildah: Dockerfiles, command line, or scripts
- How rootless Buildah works: Building containers in unprivileged environments

19.2. INSTALLING BUILDAH

Install the Buildah tool using the dnf command.
Prerequisites

- The `containers-tool` meta-package is installed.

Procedure

- Install the Buildah tool:
  
  ```
  # dnf -y install buildah
  ```

Verification

- Display the help message:
  
  ```
  # buildah -h
  ```

19.3. GETTING IMAGES WITH BUILDHAH

Use the `buildah from` command to create a new working container from scratch or based on a specified image as a starting point.

Prerequisites

- The `containers-tool` meta-package is installed.

Procedure

- Create a new working container based on the `registry.redhat.io/ubi9/ubi` image:
  
  ```
  # buildah from registry.access.redhat.com/ubi9/ubi
  ```

Verification

1. List all images in local storage:

  ```
  # buildah images
  ```

2. List the working containers and their base images:

  ```
  # buildah containers
  ```

Additional resources
19.4. BUILDING AN IMAGE FROM A CONTAINERFILE WITH BUILDAH

Use the `buildah bud` command to build an image using instructions from a Containerfile.

**NOTE**

The `buildah bud` command uses a Containerfile if found in the context directory, if it is not found the `buildah bud` command uses a Dockerfile; otherwise any file can be specified with the --file option. The available commands that are usable inside a Containerfile and a Dockerfile are equivalent.

**Prerequisites**

- The containers-tool meta-package is installed.

**Procedure**

1. Create a Containerfile:

   ```
   # cat Containerfile
   FROM registry.access.redhat.com/ubi9/ubi
   ADD myecho /usr/local/bin
   ENTRYPOINT "/usr/local/bin/myecho"
   ```

2. Create a myecho script:

   ```
   # cat myecho
   echo "This container works!"
   ```

3. Change the access permissions of myecho script:

   ```
   # chmod 755 myecho
   ```

4. Build the myecho image using Containerfile in the current directory:

   ```
   # buildah bud -t myecho .
   STEP 1: FROM registry.access.redhat.com/ubi9/ubi
   STEP 2: ADD myecho /usr/local/bin
   STEP 3: ENTRYPOINT "/usr/local/bin/myecho"
   STEP 4: COMMIT myecho
   ... Storing signatures
   ```

**Verification**

1. List all images:
2. Run the `myecho` container based on the `localhost/myecho` image:

```bash
# podman run --name=myecho localhost/myecho
```

This container works!

3. List all containers:

```bash
# podman ps -a
```

<table>
<thead>
<tr>
<th>ID</th>
<th>Image</th>
</tr>
</thead>
<tbody>
<tr>
<td>0d97517428d</td>
<td>localhost/myecho</td>
</tr>
<tr>
<td>0d975174cd8</td>
<td>myecho</td>
</tr>
</tbody>
</table>

NOTE

You can use the `podman history` command to display the information about each layer used in the image.

Additional resources

- `buildah-bud` man page

19.5. CREATING IMAGES FROM SCRATCH WITH BUILDAH

Instead of starting with a base image, you can create a new container that holds only a minimal amount of container metadata.

When creating an image from scratch container, consider:

- You can copy the executable with no dependencies into the scratch image and make a few configuration settings to get a minimal container to work.
- You must initialize an RPM database and add a release package in the container to use tools like `dnf` or `rpm`.
- If you add a lot of packages, consider using the standard UBI or minimal UBI images instead of scratch images.

Prerequisites

- The `containers-tool` meta-package is installed.

Procedure

This procedure adds a web service `httpd` to a container and configures it to run.

1. Create an empty container:

```bash
# buildah from scratch
working-container
```
2. Mount the `working-container` container and save the mount point path to the `scratchmnt` variable:

```bash
# scratchmnt=$(buildah mount working-container)
# echo $scratchmnt
/var/lib/containers/storage/overlay/be2eaecf9f74b6acfe4d0017dd5534fde06b2fa8de9ed875691f6ccc791c1836/merged
```

3. Initialize an RPM database within the scratch image and add the `redhat-release` package:

```bash
# dnf install -y --releasever=8 --installroot=$scratchmnt redhat-release
```

4. Install the `httpd` service to the `scratch` directory:

```bash
# dnf install -y --setopt=reposdir=/etc/yum.repos.d --installroot=$scratchmnt --setopt=cachedir=/var/cache/dnf httpd
```

5. Create the `$scratchmnt/var/www/html/index.html` file:

```bash
# mkdir -p $scratchmnt/var/www/html
# echo "Your httpd container from scratch works!" > $scratchmnt/var/www/html/index.html
```

6. Configure `working-container` to run the `httpd` daemon directly from the container:

```bash
# buildah config --cmd "/usr/sbin/httpd -DFOREGROUND" working-container
# buildah config --port 80/tcp working-container
# buildah commit working-container localhost/myhttpd:latest
```

**Verification**

1. List all images in local storage:

```bash
# podman images
REPOSITORY TAG IMAGE ID CREATED SIZE
localhost/myhttpd latest 08da72792f60 2 minutes ago 121 MB
```

2. Run the `localhost/myhttpd` image and configure port mappings between the container and the host system:

```bash
# podman run -p 8080:80 -d --name myhttpd 08da72792f60
```

3. Test the web server:

```bash
# curl localhost:8080
Your httpd container from scratch works!
```

**Additional resources**

158
19.6. REMOVING IMAGES WITH BUILDAH

Use the buildah rmi command to remove locally stored container images. You can remove an image by its ID or name.

Prerequisites

- The containers-tool meta-package is installed.

Procedure

1. List all images on your local system:

   ```
   # buildah images
   
<table>
<thead>
<tr>
<th>REPOSITORY</th>
<th>TAG</th>
<th>IMAGE ID</th>
<th>CREATED</th>
<th>SIZE</th>
</tr>
</thead>
<tbody>
<tr>
<td>localhost/johndoe/webserver</td>
<td>latest</td>
<td>dc5fcc610313</td>
<td>46 minutes ago</td>
<td>263 MB</td>
</tr>
<tr>
<td>docker.io/library/mynewecho</td>
<td>latest</td>
<td>fa2091a7d8b6</td>
<td>17 hours ago</td>
<td>234 MB</td>
</tr>
<tr>
<td>docker.io/library/myecho2</td>
<td>latest</td>
<td>4547d2c3e436</td>
<td>6 days ago</td>
<td>234 MB</td>
</tr>
<tr>
<td>localhost/myecho</td>
<td>latest</td>
<td>b28cd00741b3</td>
<td>6 days ago</td>
<td>234 MB</td>
</tr>
<tr>
<td>localhost/ubi-micro-httpd</td>
<td>latest</td>
<td>c6a7678c4139</td>
<td>12 days ago</td>
<td>152 MB</td>
</tr>
<tr>
<td>registry.access.redhat.com/ubi9/ubi</td>
<td>latest</td>
<td>272209ff0ae5</td>
<td>3 weeks ago</td>
<td>234 MB</td>
</tr>
</tbody>
</table>
   ```

2. Remove the localhost/myecho image:

   ```
   # buildah rmi localhost/myecho
   ```

   - To remove multiple images:

     ```
     # buildah rmi docker.io/library/mynewecho docker.io/library/myecho2
     ```

   - To remove all images from your system:

     ```
     # buildah rmi -a
     ```

   - To remove images that have multiple names (tags) associated with them, add the -f option to remove them:

     ```
     # buildah rmi -f localhost/ubi-micro-httpd
     ```

Verification

- Ensure that images were removed:

  ```
  # buildah images
  ```

Additional resources

- buildah-rmi man page
CHAPTER 20. WORKING WITH CONTAINERS USING BUILDAH

With Buildah, you can do several operations on a container image or container from the command line. Examples of operations are: create a working container from scratch or from a container image as a starting point, create an image from a working container or using a Containerfile, configure a container’s entrypoint, labels, port, shell, and working directory. You can mount working containers directories for filesystem manipulation, delete a working container or container image, and more.

You can then create an image from a working container and push the image to the registry.

20.1. RUNNING COMMANDS INSIDE OF THE CONTAINER

Use the buildah run command to execute a command from the container.

Prerequisites

- The containers-tool meta-package is installed.
- A pulled image is available on the local system.

Procedure

- Display the operating system version:

  ```
  # buildah run ubi-working-container cat /etc/redhat-release
  Red Hat Enterprise Linux release 8.4 (Ootpa)
  ```

Additional resources

- buildah-run man page

20.2. INSPECTING CONTAINERS AND IMAGES WITH BUILDAH

Use the buildah inspect command to display information about a container or image.

Prerequisites

- The containers-tool meta-package is installed.
- An image was built using instructions from Containerfile. For details, see section Building an image from a Containerfile with Buildah.

Procedure

- Inspect the image:
  - To inspect the myecho image, enter:

  ```
  # buildah inspect localhost/myecho
  {
  "Type": "buildah 0.0.1",
  "FromImage": "localhost/myecho:latest",
  "FromImageID":
  ```
To inspect the working container from the myecho image:

i. Create a working container based on the localhost/myecho image:

```
# buildah from localhost/myecho
```

ii. Inspect the myecho-working-container container:

```
# buildah inspect ubi-working-container
{
  "Type": "buildah 0.0.1",
  "FromImage": "registry.access.redhat.com/ubi8/ubi:latest",
  "FromImageID": "272209ff0ae5fe54c119b9c32a25887e13625c9035a1599feba654aa7638262d",
  "FromImageDigest": "sha256:77623387101abefbf83161c7d5a0378379d0424b2244009282acb39d42f1fe13",
  "Config": ...
  "Container": "ubi-working-container",
  "ContainerID": "01eab9588ae1523746bb706479063ba103f6281ebaeeccb5dc42b70e450d5ad0",
  "ProcessLabel": "system_u:system_r:container_t:s0:c162,c1000",
  "MountLabel": "system_u:object_r:container_file_t:s0:c162,c1000",
  ...
}
```

Additional resources

- buildah-inspect man page

## 20.3. MODIFYING A CONTAINER USING BUILDAH MOUNT

Use the buildah mount command to display information about a container or image.

**Prerequisites**

- The containers-tool meta-package is installed.
- An image built using instructions from Containerfile. For details, see section Building an image from a Containerfile with Buildah.
Procedure

1. Create a working container based on the registry.access.redhat.com/ubi8/ubi image and save the name of the container to the mycontainer variable:

```
# mycontainer=$(buildah from localhost/myecho)
# echo $mycontainer
myecho-working-container
```

2. Mount the myecho-working-container container and save the mount point path to the mymount variable:

```
# mymount=$(buildah mount $mycontainer)
# echo $mymount
/var/lib/containers/storage/overlay/c1709df40031dda7c49e93575d9c8ebca5d8129033a58e5b6a95019684cc25/merged
```

3. Modify the myecho script and make it executable:

```
# echo 'echo "We modified this container."' >> $mymount/usr/local/bin/myecho
# chmod +x $mymount/usr/local/bin/myecho
```

4. Create the myecho2 image from the myecho-working-container container:

```
# buildah commit $mycontainer containers-storage:myecho2
```

Verification

1. List all images in local storage:

```
# buildah images
REPOSITORY                                  TAG      IMAGE ID       CREATED          SIZE
   docker.io/library/myecho2                   latest   4547d2c3e436   4 minutes ago    234 MB
   localhost/myecho                            latest   b28cd00741b3   56 minutes ago   234 MB
```

2. Run the myecho2 container based on the docker.io/library/myecho2 image:

```
# podman run --name=myecho2 docker.io/library/myecho2
This container works!
We even modified it.
```

Additional resources

- buildah-mount man page
- buildah-commit man page

20.4. MODIFYING A CONTAINER USING BUILDAH COPY AND BUILDAH CONFIG
Use `buildah copy` command to copy files to a container without mounting it. You can then configure the container using the `buildah config` command to run the script you created by default.

**Prerequisites**

- The `containers-tool` meta-package is installed.
- An image built using instructions from Containerfile. For details, see section Building an image from a Containerfile with Buildah.

**Procedure**

1. Create a script named `newecho` and make it executable:
   ```
   # cat newecho
   echo "I changed this container"
   # chmod 755 newecho
   ```

2. Create a new working container:
   ```
   # buildah from myecho:latest
   myecho-working-container-2
   ```

3. Copy the `newecho` script to `/usr/local/bin` directory inside the container:
   ```
   # buildah copy myecho-working-container-2 newecho /usr/local/bin
   ```

4. Change the configuration to use the `newecho` script as the new entrypoint:
   ```
   # buildah config --entrypoint "/bin/sh -c /usr/local/bin/newecho" myecho-working-container-2
   ```

5. Optional: Run the `myecho-working-container-2` container which triggers the `newecho` script to be executed:
   ```
   # buildah run myecho-working-container-2 -- sh -c '/usr/local/bin/newecho'
   I changed this container
   ```

6. Commit the `myecho-working-container-2` container to a new image called `mynewecho`:
   ```
   # buildah commit myecho-working-container-2 containers-storage:mynewecho
   ```

**Verification**

- List all images in local storage:
  ```
  # buildah images
  REPOSITORY                              TAG IMAGE ID       CREATED       SIZE
  docker.io/library/mynewecho             latest fa2091a7d8b6 8 seconds ago 234 MB
  ```
20.5. PUSHING CONTAINERS TO A PRIVATE REGISTRY

Use `buildah push` command to push an image from local storage to a public or private repository.

Prerequisites

- The `containers-tool` meta-package is installed.
- An image was built using instructions from Containerfile. For details, see section Building an image from a Containerfile with Buildah.

Procedure

1. Create the local registry on your machine:

   ```bash
   # podman run -d -p 5000:5000 registry:2
   ```

2. Push the `myecho:latest` image to the `localhost` registry:

   ```bash
   # buildah push --tls-verify=false myecho:latest localhost:5000/myecho:latest
   Getting image source signatures
   Copying blob sha256:e4efd0...
   ... Writing manifest to image destination
   Storing signatures
   ```

Verification

1. List all images in the `localhost` repository:

   ```bash
   # curl http://localhost:5000/v2/_catalog
   {"repositories":["myecho2"]}
   # curl http://localhost:5000/v2/myecho2/tags/list
   {"name":"myecho","tags":["latest"]}
   ```

2. Inspect the `docker://localhost:5000/myecho:latest` image:

   ```bash
   # skopeo inspect --tls-verify=false docker://localhost:5000/myecho:latest | less
   {"Name": "localhost:5000/myecho","Digest": "sha256:8999ff6050...", "RepoTags": ["latest"]}
   ```
3. Pull the **localhost:5000/myecho** image:

```bash
# podman pull --tls-verify=false localhost:5000/myecho2
# podman run localhost:5000/myecho2
This container works!
```

Additional resources

- **buildah-push** man page

### 20.6. PUSHING CONTAINERS TO THE DOCKER HUB

Use your Docker Hub credentials to push and pull images from the Docker Hub with the **buildah** command.

**Prerequisites**

- The **containers-tool** meta-package is installed.

- An image built using instructions from Containerfile. For details, see section Building an image from a Containerfile with Buildah.

**Procedure**

1. Push the **docker.io/library/myecho:latest** to your Docker Hub. Replace **username** and **password** with your Docker Hub credentials:

```bash
# buildah push --creds username:password \
  docker.io/library/myecho:latest docker://testaccountXX/myecho:latest
```

**Verification**

- Get and run the **docker.io/testaccountXX/myecho:latest** image:

  - Using Podman tool:

    ```bash
    # podman run docker.io/testaccountXX/myecho:latest
    This container works!
    ```

  - Using Buildah and Podman tools:

    ```bash
    # buildah from docker.io/testaccountXX/myecho:latest
    myecho2-working-container-2
    # podman run myecho-working-container-2
    ```
**Additional resources**

- [buildah-push](#) man page

### 20.7. REMOVING CONTAINERS WITH BUILDAH

Use the `buildah rm` command to remove containers. You can specify containers for removal with the container ID or name.

**Prerequisites**

- The [containers-tool](#) meta-package is installed.
- At least one container has been stopped.

**Procedure**

1. List all containers:

   ```bash
   # buildah containers
   CONTAINER ID  BUILDER  IMAGE ID     IMAGE NAME                       CONTAINER NAME
   05387e29ab93     *     c37e14066ac7 docker.io/library/myecho:latest  myecho-working-container
   ```

2. Remove the myecho-working-container container:

   ```bash
   # buildah rm myecho-working-container
   05387e29ab93151cf52e9c85c573f3e8ab64af1592b1ff9315db8a10a77d7c22
   ```

**Verification**

- Ensure that containers were removed:

  ```bash
  # buildah containers
  ```

**Additional resources**

- [buildah-rm](#) man page
CHAPTER 21. MONITORING CONTAINERS

Use Podman commands to manage a Podman environment. With that, you can determine the health of the container, by displaying system and pod information, and monitoring Podman events.

21.1. USING A HEALTH CHECK ON A CONTAINER

You can use the health check to determine the health or readiness of the process running inside the container.

If the health check succeeds, the container is marked as "healthy"; otherwise, it is "unhealthy". You can compare a health check with running the `podman exec` command and examining the exit code. The zero exit value means that the container is "healthy".

Health checks can be set when building an image using the `HEALTHCHECK` instruction in the `Containerfile` or when creating the container on the command line. You can display the health-check status of a container using the `podman inspect` or `podman ps` commands.

A health check consists of six basic components:

- Command
- Retries
- Interval
- Start-period
- Timeout
- Container recovery

The description of health check components follows:

Command (--health-cmd option)

Podman executes the command inside the target container and waits for the exit code.

The other five components are related to the scheduling of the health check and they are optional.

Retries (--health-retries option)

Defines the number of consecutive failed health checks that need to occur before the container is marked as "unhealthy". A successful health check resets the retry counter.

Interval (--health-interval option)

Describes the time between running the health check command. Note that small intervals cause your system to spend a lot of time running health checks. The large intervals cause struggles with catching time outs.

Start-period (--health-start-period option)

Describes the time between when the container starts and when you want to ignore health check failures.

Timeout (--health-timeout option)

Describes the period of time the health check must complete before being considered unsuccessful.
NOTE

The values of the Retries, Interval, and Start-period components are time durations, for example “30s” or “1h15m”. Valid time units are "ns," "us," or "µs", "ms," "s," "m," and "h".

Container recovery (--health-on-failure option)

Determines which actions to perform when the status of a container is unhealthy. When the application fails, Podman restarts it automatically to provide robustness. The --health-on-failure option supports four actions:

- **none**: Take no action, this is the default action.
- **kill**: Kill the container.
- **restart**: Restart the container.
- **stop**: Stop the container.

NOTE

The --health-on-failure option is available in Podman version 4.2 and later.

WARNING

Do not combine the **restart** action with the **--restart** option. When running inside of a **systemd** unit, consider using the **kill** or **stop** action instead, to make use of **systemd** restart policy.

Health checks run inside the container. Health checks only make sense if you know what the health state of the service is and can differentiate between a successful and unsuccessful health check.

Additional resources

- podman-healthcheck man page
- podman-run man page
- Podman at the edge: Keeping services alive with custom healthcheck actions
- Monitoring container vitality and availability with Podman

21.2. PERFORMING A HEALTH CHECK USING THE COMMAND LINE

You can set a health check when creating the container on the command line.

Prerequisites

- The **containers-tool** meta-package is installed.
Procedure

1. Define a health check:


- The `--health-cmd` option sets a health check command for the container.
- The `--health-interval=0` option with 0 value indicates that you want to run the health check manually.

2. Check the health status of the `hc-container` container:

- Using the `podman inspect` command:

  $ podman inspect --format='{{json .State.Health.Status}}' hc-container
  healthy

- Using the `podman ps` command:

  $ podman ps
  CONTAINER ID  IMAGE                 COMMAND               CREATED      STATUS PORTS       NAMES
  a680c6919fe  localhost/hc-container:latest  /usr/bin/run-http...  2 minutes ago  Up 2 minutes (healthy) hc-container

- Using the `podman healthcheck run` command:

  $ podman healthcheck run hc-container
  healthy

Additional resources

- `podman-healthcheck` man page
- `podman-run` man page
- Podman at the edge: Keeping services alive with custom healthcheck actions
- Monitoring container vitality and availability with Podman

21.3. PERFORMING A HEALTH CHECK USING A CONTAINERFILE

You can set a health check by using the `HEALTHCHECK` instruction in the `Containerfile`.

Prerequisites

- The `containers-tool` meta-package is installed.

Procedure

1. Create a `Containerfile`: 
$ cat Containerfile
FROM registry.access.redhat.com/ubi8/httpd-24
EXPOSE 8080
HEALTHCHECK CMD curl http://localhost:8080 || exit 1

NOTE
The HEALTHCHECK instruction is supported only for the docker image format. For the oci image format, the instruction is ignored.

2. Build the container and add an image name:

```
$ podman build --format=docker -t hc-container .
STEP 1/3: FROM registry.access.redhat.com/ubi8/httpd-24
STEP 2/3: EXPOSE 8080
--> 5aea97430fd
STEP 3/3: HEALTHCHECK CMD curl http://localhost:8080 || exit 1
COMMIT health-check
Successfully tagged localhost/health-check:latest
a680c6919fe6bf1a79219a1b3d6216550d5a8f83570c36d0dadfee1bb74b924e
```

3. Run the container:

```
$ podman run -dt --name=hc-container localhost/hc-container
```

4. Check the health status of the hc-container container:

- Using the podman inspect command:

```
$ podman inspect --format='{{json .State.Health.Status}}' hc-container
healthy
```

- Using the podman ps command:

```
$ podman ps
CONTAINER ID  IMAGE                 COMMAND               CREATED      STATUS
PORTS       NAMES
a680c6919fe localhost/hc-container:latest /usr/bin/run-ht... 2 minutes ago Up 2
minutes (healthy) hc-container
```

- Using the podman healthcheck run command:

```
$ podman healthcheck run hc-container
healthy
```

Additional resources
- podman-healthcheck man page
- podman-run man page
- Podman at the edge: Keeping services alive with custom healthcheck actions
21.4. DISPLAYING PODMAN SYSTEM INFORMATION

The `podman system` command enables you to manage the Podman systems by displaying system information.

**Prerequisites**

- The `containers-tool` meta-package is installed.

**Procedure**

- Display Podman system information:
  - To show Podman disk usage, enter:

```bash
$ podman system df
```

<table>
<thead>
<tr>
<th>TYPE</th>
<th>TOTAL</th>
<th>ACTIVE</th>
<th>SIZE</th>
<th>RECLAIMABLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Images</td>
<td>3</td>
<td>2</td>
<td>1.085GB</td>
<td>233.4MB (0%)</td>
</tr>
<tr>
<td>Containers</td>
<td>2</td>
<td>0</td>
<td>28.17kB</td>
<td>28.17kB (100%)</td>
</tr>
<tr>
<td>Local Volumes</td>
<td>3</td>
<td>0</td>
<td>0B</td>
<td>0B (0%)</td>
</tr>
</tbody>
</table>

  - To show detailed information about space usage, enter:

```bash
$ podman system df -v
```

Images space usage:

<table>
<thead>
<tr>
<th>REPOSITORY</th>
<th>TAG</th>
<th>IMAGE ID</th>
<th>CREATED</th>
<th>SIZE</th>
<th>SHARED SIZE</th>
<th>UNIQUE SIZE</th>
<th>CONTAINERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>registry.access.redhat.com/ubi9</td>
<td>latest</td>
<td>b1e63aaaae5cf</td>
<td>13 days</td>
<td>233.4MB</td>
<td>233.4MB</td>
<td>0B</td>
<td>0</td>
</tr>
<tr>
<td>registry.access.redhat.com/ubi9/httpd-24</td>
<td>latest</td>
<td>0d04740850e8</td>
<td>13 days</td>
<td>461.5MB</td>
<td>461.5MB</td>
<td>0B</td>
<td>1</td>
</tr>
<tr>
<td>registry.redhat.io/rhel8/podman</td>
<td>latest</td>
<td>dce10f591a2d</td>
<td>13 days</td>
<td>390.6MB</td>
<td>233.4MB</td>
<td>157.2MB</td>
<td>1</td>
</tr>
</tbody>
</table>

Containers space usage:

<table>
<thead>
<tr>
<th>CONTAINER ID</th>
<th>IMAGE</th>
<th>COMMAND</th>
<th>LOCAL VOLUMES</th>
<th>SIZE</th>
<th>CREATED</th>
<th>STATUS</th>
<th>NAMES</th>
</tr>
</thead>
<tbody>
<tr>
<td>311180ab99fb</td>
<td>0d04740850e8</td>
<td>/usr/bin/run-httpd</td>
<td>0</td>
<td>28.17kB</td>
<td>16 hours</td>
<td>exited</td>
<td>hc1</td>
</tr>
<tr>
<td>bedb6c287ed6</td>
<td>dce10f591a2d</td>
<td>podman run ubi9 echo hello</td>
<td>0</td>
<td>0B</td>
<td>11 hours</td>
<td>configured</td>
<td>dazzling_tu</td>
</tr>
</tbody>
</table>

Local Volumes space usage:

<table>
<thead>
<tr>
<th>VOLUME NAME</th>
<th>LINKS</th>
<th>SIZE</th>
</tr>
</thead>
<tbody>
<tr>
<td>76de0efa83a3dae1a388b9e9e67161d28187e093955df185ea228ad0b3e435d0</td>
<td>0B</td>
<td>0B</td>
</tr>
<tr>
<td>8a1b4658aacc9ff38711a2c7f2da6de192c5b1e753bb7e3b25e9bf3bb7da8b13</td>
<td>0B</td>
<td>0B</td>
</tr>
<tr>
<td>d9cab4f6ccbcf2ac3cd750d2eff9d2b0f29411d430a119210dd242e8be20e26</td>
<td>0B</td>
<td>0B</td>
</tr>
</tbody>
</table>
To display information about the host, current storage stats, and build of Podman, enter:

```
$ podman system info
```

```
host:
  arch: amd64
  buildahVersion: 1.22.3
  cgroupControllers: []
  cgroupManager: cgroupfs
  cgroupVersion: v1
  conmon:
    package: conmon-2.0.29-1.module+el8.5.0+12381+e822eb26.x86_64
    path: /usr/bin/conmon
    version: 'conmon version 2.0.29, commit: 7d0fa63455025991c2fc641da85922fde889c91b'
  cpus: 2
  distribution:
    distribution: "rhel"
    version: "8.5"
  eventLogger: file
  hostname: localhost.localdomain
  idMappings:
    gidmap:
      - container_id: 0
        host_id: 1000
        size: 1
      - container_id: 1
        host_id: 100000
        size: 65536
    uidmap:
      - container_id: 0
        host_id: 1000
        size: 1
      - container_id: 1
        host_id: 100000
        size: 65536
  kernel: 4.18.0-323.el8.x86_64
  linkmode: dynamic
  memFree: 352288768
  memTotal: 2819129344
  ociRuntime:
    name: runc
    package: runc-1.0.2-1.module+el8.5.0+12381+e822eb26.x86_64
    path: /usr/bin/runc
    version: |-
      runc version 1.0.2
      spec: 1.0.2-dev
      go: go1.16.7
      libseccomp: 2.5.1
  os: linux
  remoteSocket:
    path: /run/user/1000/podman/podman.sock
  security:
    apparmorEnabled: false
    capabilities:
      CAP_NET_RAW,CAP_CHOWN,CAP_DAC_OVERRIDE,CAP_FOWNER,CAP_FSETID,CAP_KILL,CAP_NET_BIND_SERVICE,CAP_SETFCAP,CAP_SETGID,CAP_SETPCAP,CA
```
## CHAPTER 21. MONITORING CONTAINERS

- **P_SETUID, CAP_SYS_CHROOT**
  - rootless: true
  - seccompEnabled: true
  - seccompProfilePath: /usr/share/containers/seccomp.json
  - selinuxEnabled: true
  - serviceIsRemote: false

- **slirp4netns**
  - executable: /usr/bin/slirp4netns
  - package: slirp4netns-1.1.8-1.module+el8.5.0+12381+e822eb26.x86_64
  - version: slirp4netns version 1.1.8
    - commit: d3610f1f495417b880f20329121e3aa431a8f90f
    - libslirp: 4.4.0
    - SLIRP_CONFIG_VERSION_MAX: 3
    - libseccomp: 2.5.1

- **swapFree**: 3113668608
- **swapTotal**: 3124752384
- **uptime**: 11h 24m 12.52s (Approximately 0.46 days)

- **registries**
  - search:
    - registry.fedoraproject.org
    - registry.access.redhat.com
    - registry.centos.org
    - docker.io
  - store:
    - configFile: /home/user/.config/containers/storage.conf
    - containerStore:
      - number: 2
      - paused: 0
      - running: 0
      - stopped: 2
  - graphDriverName: overlay
  - graphOptions:
    - overlay.mount_program:
      - Executable: /usr/bin/fuse-overlayfs
      - Package: fuse-overlayfs-1.7.1-1.module+el8.5.0+12381+e822eb26.x86_64
      - Version: fuseoverlayfs version 1.7.1
      - fusermount3 version: 3.2.1
      - fuseOverlayfs: version 1.7.1
      - FUSE library version 3.2.1
      - using FUSE kernel interface version 7.26
  - graphRoot: /home/user/.local/share/containers/storage
  - graphStatus:
    - Backing Filesystem: xfs
    - Native Overlay Diff: "false"
    - Supports d_type: "true"
    - Using metacopy: "false"

- **imageStore**
  - number: 3
  - runRoot: /run/user/1000/containers
  - volumePath: /home/user/.local/share/containers/storage/volumes

- **version**
  - APIVersion: 3.3.1
  - Built: 1630360721
  - BuiltTime: Mon Aug 30 23:58:41 2021
  - GitCommit: ""
To remove all unused containers, images and volume data, enter:

$ podman system prune

WARNING! This will remove:
  - all stopped containers
  - all stopped pods
  - all dangling images
  - all build cache

Are you sure you want to continue? [y/N] y

- The **podman system prune** command removes all unused containers (both dangling and unreferenced), pods and optionally, volumes from local storage.
- Use the **--all** option to delete all unused images. Unused images are dangling images and any image that does not have any containers based on it.
- Use the **--volume** option to prune volumes. By default, volumes are not removed to prevent important data from being deleted if there is currently no container using the volume.

Additional resources

- **podman-system-df** man page
- **podman-system-info** man page
- **podman-system-prune** man page

### 21.5. PODMAN EVENT TYPES

You can monitor events that occur in Podman. Several event types exist and each event type reports different statuses.

The **container** event type reports the following statuses:

- attach
- checkpoint
- cleanup
- commit
- create
- exec
- export
- import
- init
• kill
• mount
• pause
• prune
• remove
• restart
• restore
• start
• stop
• sync
• unmount
• unpause

The *pod* event type reports the following statuses:

• create
• kill
• pause
• remove
• start
• stop
• unpause

The *image* event type reports the following statuses:

• prune
• push
• pull
• save
• remove
• tag
• untag

The system type reports the following statuses:
The `volume` type reports the following statuses:

- create
- prune
- remove

Additional resources

- `podman-events` man page

### 21.6. MONITORING PODMAN EVENTS

You can monitor and print events that occur in Podman using the `podman events` command. Each event will include a timestamp, a type, a status, name, if applicable, and image, if applicable.

**Prerequisites**

- The `containers-tool` meta-package is installed.

**Procedure**

1. Run the `myubi` container:

   ```
   $ podman run -q --rm --name=myubi registry.access.redhat.com/ubi8/ubi:latest
   ```

2. Display the Podman events:

   ```
   $ now=$(date --iso-8601=seconds) 
   $ podman events --since=now --stream=false 
   ```

   2023-03-08 14:27:20.696167362 +0100 CET container create 
   d474826a2bcd271b1bc4b9f88b54e8271c13ffea9b30529968291c62d72fe09
   (image=registry.access.redhat.com/ubi8/ubi:latest, name=myubi,...)
   
   2023-03-08 14:27:20.652325082 +0100 CET image pull
   registry.access.redhat.com/ubi8/ubi:latest
   
   2023-03-08 14:27:20.795695396 +0100 CET container init
   d474826a2bcd271b1bc4b9f88b54e8271c13ffea9b30529968291c62d72fe09
   (image=registry.access.redhat.com/ubi8/ubi:latest, name=myubi,...)
   
   2023-03-08 14:27:20.809205161 +0100 CET container start
   d474826a2bcd271b1bc4b9f88b54e8271c13ffea9b30529968291c62d72fe09
   (image=registry.access.redhat.com/ubi8/ubi:latest, name=myubi,...)
   
   2023-03-08 14:27:20.831710446 +0100 CET container died
   d474826a2bcd271b1bc4b9f88b54e8271c13ffea9b30529968291c62d72fe09
   (image=registry.access.redhat.com/ubi8/ubi:latest, name=myubi,...)
The `--stream=false` option ensures that the `podman events` command exits when reading the last known event.

You can see several events that happened when you enter the `podman run` command:

- **container create** when creating a new container.
- **image pull** when pulling an image if the container image is not present in the local storage.
- **container init** when initializing the container in the runtime and setting a network.
- **container start** when starting the container.
- **container attach** when attaching to the terminal of a container. That is because the container runs in the foreground.
- **container died** is emitted when the container exits.
- **container remove** because the `--rm` flag was used to remove the container after it exits.

You can also use the `journalctl` command to display Podman events:

```
$ journalctl --user -r SYSLOG_IDENTIFIER=podman
Mar 08 14:27:20 fedora podman[129324]: 2023-03-08 14:27:20.913786892 +0100 CET m=+0.066920979 container remove...
Mar 08 14:27:20 fedora podman[129289]: 2023-03-08 14:27:20.696167362 +0100 CET m=+0.079089208 container create
d4748226a2bcd271b1bc4b9f88b54e8271c13fefa9b30529968291c62d72fe09
```

To show only Podman create events, enter:

```
$ podman events --filter event=create
2023-03-08 14:27:20.696167362 +0100 CET container create
d4748226a2bcd271b1bc4b9f88b54e8271c13fefa9b30529968291c62d72fe09
```

You can also use the `journalctl` command to display Podman create events:

```
$ journalctl --user -r PODMAN_EVENT=create
Mar 08 14:27:20 fedora podman[129289]: 2023-03-08 14:27:20.696167362 +0100 CET m=+0.079089208 container create
d4748226a2bcd271b1bc4b9f88b54e8271c13fefa9b30529968291c62d72fe09
```

**Additional resources**

- `podman-events` man page
- Container Events and Auditing
21.7. USING PODMAN EVENTS FOR AUDITING

Previously, the events had to be connected to an event to interpret them correctly. For example, the `container-create` event had to be linked with an `image-pull` event to know which image had been used. The `container-create` event also did not include all data, for example, the security settings, volumes, mounts, and so on.

Beginning with Podman v4.4, you can gather all relevant information about a container directly from a single event and `journald` entry. The data is in JSON format, the same as from the `podman container inspect` command and includes all configuration and security settings of a container. You can configure Podman to attach the container-inspect data for auditing purposes.

Prerequisites

- The `containers-tool` meta-package is installed.

Procedure

1. Modify the `~/.config/containers/containers.conf` file and add the `events_container_create_inspect_data=true` option to the `[engine]` section:

   ```
   $ cat ~/.config/containers/containers.conf
   [engine]
   events_container_create_inspect_data=true
   ```

   For the system-wide configuration, modify the `/etc/containers/containers.conf` or `/usr/share/container/containers.conf` file.

2. Create the container:

   ```
   $ podman create registry.access.redhat.com/ubi8/ubi:latest
   19524fe3c145df32d4f0c9af83e7964e4fb79fc4c397c514192d9d7620a36cd3
   ```

3. Display the Podman events:

   - Using the `podman events` command:

     ```
     $ now=$(date --iso-8601=seconds)
     $ podman events --since $now --stream=false --format "{{.ContainerInspectData}}"
     | jq "..Config.CreateCommand"
     ["/usr/bin/podman",
      "create",
      "registry.access.redhat.com/ubi8"
     ]
     ``

     - The `--format "{{.ContainerInspectData}}"` option displays the inspect data.

     - The `jq "..Config.CreateCommand"` transforms the JSON data into a more readable format and displays the parameters for the `podman create` command.

   - Using the `journalctl` command:

     ```
     $ journalctl --user -r PODMAN_EVENT=create --all -o json | jq ".PODMAN_CONTAINER_INSPECT_DATA | fromjson" | jq
     ```
The output data for the `podman events` and `journalctl` commands are the same.

Additional resources

- [podman-events](#) man page
- [containers.conf](#) man page
- [Container Events and Auditing](#)
CHAPTER 22. CREATING AND RESTORING CONTAINER CHECKPOINTS

Checkpoint/Restore In Userspace (CRIU) is a software that enables you to set a checkpoint on a running container or an individual application and store its state to disk. You can use data saved to restore the container after a reboot at the same point in time it was checkpointed.

WARNING

The kernel does not support pre-copy checkpointing on AArch64.

22.1. CREATING AND RESTORING A CONTAINER CHECKPOINT LOCALLY

This example is based on a Python based web server which returns a single integer which is incremented after each request.

Prerequisites

- The containers-tool meta-package is installed.

Procedure

1. Create a Python based server:

   ```python
   #!/usr/bin/python3
   import http.server
   counter = 0
   class handler(http.server.BaseHTTPRequestHandler):
       def do_GET(s):
           global counter
           s.send_response(200)
           s.send_header('Content-type', 'text/html')
           s.end_headers()
           s.wfile.write(b'%d
' % counter)
           counter += 1
   server = http.server.HTTPServer(("", 8088), handler)
   server.serve_forever()
   ```

2. Create a container with the following definition:

   ```bash
   # cat Containerfile
   ```
FROM registry.access.redhat.com/ubi9/ubi
COPY counter.py /home/counter.py
RUN useradd -ms /bin/bash counter
RUN dnf -y install python3 && chmod 755 /home/counter.py
USER counter
ENTRYPOINT /home/counter.py

The container is based on the Universal Base Image (UBI 8) and uses a Python based server.

3. Build the container:

   ```
   # podman build . --tag counter
   ```

Files `counter.py` and `Containerfile` are the input for the container build process (podman build). The built image is stored locally and tagged with the tag `counter`.

4. Start the container as root:

   ```
   # podman run --name criu-test --detach counter
   ```

5. To list all running containers, enter:

   ```
   # podman ps
   CONTAINER ID  IMAGE  COMMAND  CREATED   STATUS  PORTS NAMES
   e4f82fd84d48  localhost/counter:latest  5 seconds ago  Up 4 seconds ago  criu-test
   ```

6. Display IP address of the container:

   ```
   # podman inspect criu-test --format "{.NetworkSettings.IPAddress}" 10.88.0.247
   ```

7. Send requests to the container:

   ```
   # curl 10.88.0.247:8088 0
   # curl 10.88.0.247:8088 1
   ```

8. Create a checkpoint for the container:

   ```
   # podman container checkpoint criu-test
   ```

9. Reboot the system.

10. Restore the container:

    ```
    # podman container restore --keep criu-test
    ```

11. Send requests to the container:
# curl 10.88.0.247:8080
2
# curl 10.88.0.247:8080
3
# curl 10.88.0.247:8080
4

The result now does not start at 0 again, but continues at the previous value.

This way you can easily save the complete container state through a reboot.

Additional resources

- Podman checkpoint

## 22.2. REDUCING STARTUP TIME USING CONTAINER RESTORE

You can use container migration to reduce startup time of containers which require a certain time to initialize. Using a checkpoint, you can restore the container multiple times on the same host or on different hosts. This example is based on the container from the Creating and restoring a container checkpoint locally.

### Prerequisites

- The containers-tool meta-package is installed.

### Procedure

1. Create a checkpoint of the container, and export the checkpoint image to a **tar.gz** file:

   ```bash
   # podman container checkpoint criu-test --export /tmp/chkpt.tar.gz
   ```

2. Restore the container from the **tar.gz** file:

   ```bash
   # podman container restore --import /tmp/chkpt.tar.gz --name counter1
   # podman container restore --import /tmp/chkpt.tar.gz --name counter2
   # podman container restore --import /tmp/chkpt.tar.gz --name counter3
   ```

   The `-n` option specifies a new name for containers restored from the exported checkpoint.

3. Display ID and name of each container:

   ```bash
   # podman ps -a --format "{{.ID}} {{.Names}}"
   a8b2e50d463c counter3
   faabc5c27362 counter2
   2ce648af11e5 counter1
   ```

4. Display IP address of each container:

   ```bash
   # podman inspect counter1 --format "{{.NetworkSettings.IPAddress}}"
   10.88.0.248
   ```
5. Send requests to each container:

```
# curl 10.88.0.248:8080
4
# curl 10.88.0.249:8080
4
# curl 10.88.0.250:8080
4
```

Note, that the result is 4 in all cases, because you are working with different containers restored from the same checkpoint.

Using this approach, you can quickly start up stateful replicas of the initially checkpointed container.

Additional resources

- Container migration with Podman on RHEL

### 22.3. MIGRATING CONTAINERS AMONG SYSTEMS

This procedure shows the migration of running containers from one system to another, without losing the state of the applications running in the container. This example is based on the container from the Creating and restoring a container checkpoint locally section tagged with `counter`.

#### IMPORTANT

Migrating containers among systems with the **podman container checkpoint** and **podman container restore** commands is supported only when the configurations of the systems match completely, as shown below:

- Podman version
- OCI runtime (runc/crun)
- Network stack (CNI/Netavark)
- Cgroups version
- kernel version
- CPU features

You can migrate to a CPU with more features, but not to a CPU which does not have a certain feature that you are using. The low-level tool doing the checkpointing (CRIU) has the possibility to check for CPU feature compatibility: [https://criu.org/Cpuinfo](https://criu.org/Cpuinfo).

#### Prerequisites

- The **containers-tool** meta-package is installed.
The following steps are not necessary if the container is pushed to a registry as Podman will automatically download the container from a registry if it is not available locally. This example does not use a registry, you have to export previously built and tagged container (see Creating and restoring a container checkpoint locally).

- Export previously built container:

  ```
  # podman save --output counter.tar counter
  ```

- Copy exported container image to the destination system (other_host):

  ```
  # scp counter.tar other_host:
  ```

- Import exported container on the destination system:

  ```
  # ssh other_host podman load --input counter.tar
  ```

Now the destination system of this container migration has the same container image stored in its local container storage.

**Procedure**

1. Start the container as root:

   ```
   # podman run --name criu-test --detach counter
   ```

2. Display IP address of the container:

   ```
   # podman inspect criu-test --format "{{.NetworkSettings.IPAddress}}"
   10.88.0.247
   ```

3. Send requests to the container:

   ```
   # curl 10.88.0.247:8080
   0
   # curl 10.88.0.247:8080
   1
   ```

4. Create a checkpoint of the container, and export the checkpoint image to a tar.gz file:

   ```
   # podman container checkpoint criu-test --export /tmp/chkpt.tar.gz
   ```

5. Copy the checkpoint archive to the destination host:

   ```
   # scp /tmp/chkpt.tar.gz other_host:/tmp/
   ```

6. Restore the checkpoint on the destination host (other_host):

   ```
   # podman container restore --import /tmp/chkpt.tar.gz
   ```

7. Send a request to the container on the destination host (other_host):
As a result, the stateful container has been migrated from one system to another without losing its state.

**Additional resources**

- Container migration with Podman on RHEL
CHAPTER 23. USING PODMAN IN HPC ENVIRONMENT

You can use Podman with Open MPI (Message Passing Interface) to run containers in a High Performance Computing (HPC) environment.

23.1. USING PODMAN WITH MPI

The example is based on the ring.c program taken from Open MPI. In this example, a value is passed around by all processes in a ring-like fashion. Each time the message passes rank 0, the value is decremented. When each process receives the 0 message, it passes it on to the next process and then quits. By passing the 0 first, every process gets the 0 message and can quit normally.

Prerequisites

- The containers-tool meta-package is installed.

Procedure

1. Install Open MPI:

   ```
   # dnf install openmpi
   ```

2. To activate the environment modules, type:

   ```
   $ . /etc/profile.d/modules.sh
   ```

3. Load the mpi/openmpi-x86_64 module:

   ```
   $ module load mpi/openmpi-x86_64
   ```

   Optionally, to automatically load mpi/openmpi-x86_64 module, add this line to the .bashrc file:

   ```
   $ echo "module load mpi/openmpi-x86_64" >> .bashrc
   ```

4. To combine mpirun and podman, create a container with the following definition:

   ```
   $ cat Containerfile
   FROM registry.access.redhat.com/ubi9/ubi
   RUN dnf -y install openmpi-devel wget && 
       dnf clean all
   RUN wget https://raw.githubusercontent.com/open-mpi/ompi/master/test/simple/ring.c && 
       /usr/lib64/openmpi/bin/mpicc ring.c -o /home/ring && 
       rm -f ring.c
   ```

5. Build the container:

   ```
   $ podman build --tag=mpi-ring .
   ```

6. Start the container. On a system with 4 CPUs this command starts 4 containers:
As a result, `mpirun` starts up 4 Podman containers and each container is running one instance of the `ring` binary. All 4 processes are communicating over MPI with each other.

Additional resources

- Podman in HPC environments

23.2. THE MPIRUN OPTIONS

The following `mpirun` options are used to start the container:

- `--mca orte_tmpdir_base /tmp/podman-mpirun` line tells Open MPI to create all its temporary files in `/tmp/podman-mpirun` and not in `/tmp`. If using more than one node this directory will be named differently on other nodes. This requires mounting the complete `/tmp` directory into the container which is more complicated.

The `mpirun` command specifies the command to start, the `podman` command. The following `podman` options are used to start the container:

- `run` command runs a container.
- `--env-host` option copies all environment variables from the host into the container.
- `-v /tmp/podman-mpirun:/tmp/podman-mpirun` line tells Podman to mount the directory where Open MPI creates its temporary directories and files to be available in the container.
- `--userns=keep-id` line ensures the user ID mapping inside and outside the container.
- `--net=host --pid=host --ipc=host` line sets the same network, PID and IPC namespaces.
- `mpi-ring` is the name of the container.
- `/home/ring` is the MPI program in the container.

Additional resources
- Podman in HPC environments
CHAPTER 24. RUNNING SPECIAL CONTAINER IMAGES

You can run some special types of container images. Some container images have built-in labels called runlabels that enable you to run those containers with preset options and arguments. The \texttt{podman container runlabel \textless label\textgreater} command, you can execute the command defined in the \textless label\textgreater for the container image. Supported labels are \texttt{install}, \texttt{run} and \texttt{uninstall}.

24.1. OPENING PRIVILEGES TO THE HOST

There are several differences between privileged and non-privileged containers. For example, the toolbox container is a privileged container. Here are examples of privileges that may or may not be open to the host from a container:

- **Privileges**: A privileged container disables the security features that isolate the container from the host. You can run a privileged container using the \texttt{podman run --privileged \textless image_name\textgreater} command. You can, for example, delete files and directories mounted from the host that are owned by the root user.

- **Process tables**: You can use the \texttt{podman run --privileged --pid=host \textless image_name\textgreater} command to use the host PID namespace for the container. Then you can use the \texttt{ps -e} command within a privileged container to list all processes running on the host. You can pass a process ID from the host to commands that run in the privileged container (for example, \texttt{kill \textless PID\textgreater}).

- **Network interfaces**: By default, a container has only one external network interface and one loopback network interface. You can use the \texttt{podman run --net=host \textless image_name\textgreater} command to access host network interfaces directly from within the container.

- **Inter-process communications**: The IPC facility on the host is accessible from within the privileged container. You can run commands such as \texttt{ipcs} to see information about active message queues, shared memory segments, and semaphore sets on the host.

24.2. CONTAINER IMAGES WITH RUNLABELS

Some Red Hat images include labels that provide pre-set command lines for working with those images. Using the \texttt{podman container runlabel \textless label\textgreater} command, you can use the \texttt{podman} command to execute the command defined in the \textless label\textgreater for the image.

Existing runlabels include:

- **install**: Sets up the host system before executing the image. Typically, this results in creating files and directories on the host that the container can access when it is run later.

- **run**: Identifies podman command line options to use when running the container. Typically, the options will open privileges on the host and mount the host content the container needs to remain permanently on the host.

- **uninstall**: Cleans up the host system after you finish running the container.

24.3. RUNNING RSYSLOG WITH RUNLABELS

The \texttt{rhel9/rsyslog} container image is made to run a containerized version of the \texttt{rsyslogd} daemon. The \texttt{rsyslog} image contains the following runlabels: \texttt{install}, \texttt{run} and \texttt{uninstall}. The following procedure steps you through installing, running, and uninstalling the \texttt{rsyslog} image:
Prerequisites

- The `containers-tool` meta-package is installed.

Procedure

1. Pull the `rsyslog` image:

```
# podman pull registry.redhat.io/rhel9/rsyslog
```

2. Display the `install` runlabel for `rsyslog`:

```
# podman container runlabel install --display rhel9/rsyslog
```

This shows that the command will open privileges to the host, mount the host root filesystem on /host in the container, and run an `install.sh` script.

3. Run the `install` runlabel for `rsyslog`:

```
# podman container runlabel install rhel9/rsyslog
```

This creates files on the host system that the `rsyslog` image will use later.

4. Display the `run` runlabel for `rsyslog`:

```
# podman container runlabel run --display rhel9/rsyslog
```

This shows that the command opens privileges to the host and mount specific files and directories from the host inside the container, when it launches the `rsyslog` container to run the `rsyslogd` daemon.

5. Execute the `run` runlabel for `rsyslog`:

```
# podman container runlabel run rhel9/rsyslog
```

Red Hat Enterprise Linux 9 Building, running, and managing containers
The `rsyslog` container opens privileges, mounts what it needs from the host, and runs the `rsyslogd` daemon in the background (`-d`). The `rsyslogd` daemon begins gathering log messages and directing messages to files in the `/var/log` directory.

6. Display the `uninstall` runlabel for `rsyslog`:

```
# podman container runlabel uninstall --display rhel9/rsyslog
command: podman run --rm --privileged -v /:/host -e HOST=/host -e IMAGE=registry.redhat.io/rhel9/rsyslog:latest -e NAME=rsyslog
registry.redhat.io/rhel9/rsyslog:latest /bin/uninstall.sh
```

7. Run the `uninstall` runlabel for `rsyslog`:

```
# podman container runlabel uninstall rhel9/rsyslog
command: podman run --rm --privileged -v /:/host -e HOST=/host -e IMAGE=registry.redhat.io/rhel9/rsyslog:latest -e NAME=rsyslog
registry.redhat.io/rhel9/rsyslog:latest /bin/uninstall.sh
```

**NOTE**

In this case, the `uninstall.sh` script just removes the `/etc/logrotate.d/syslog` file. It does not clean up the configuration files.
CHAPTER 25. USING THE CONTAINER-TOOLS API

The new REST based Podman 2.0 API replaces the old remote API for Podman that used the varlink library. The new API works in both a rootful and a rootless environment.

The Podman v2.0 RESTful API consists of the Libpod API providing support for Podman, and Docker-compatible API. With this new REST API, you can call Podman from platforms such as cURL, Postman, Google’s Advanced REST client, and many others.

NOTE

As the podman service supports socket activation, unless connections on the socket are active, podman service will not run. Hence, to enable socket activation functionality, you need to manually start the podman.socket service. When a connection becomes active on the socket, it starts the podman service and runs the requested API action. Once the action is completed, the podman process ends, and the podman service returns to an inactive state.

25.1. ENABLING THE PODMAN API USING SYSTEMD IN ROOT MODE

This procedure shows how to do the following:

1. Use systemd to activate the Podman API socket.
2. Use a Podman client to perform basic commands.

Prerequisites

- The podman-remote package is installed.

```bash
# dnf install podman-remote
```

Procedure

1. Start the service immediately:

```bash
# systemctl enable --now podman.socket
```

2. To enable the link to var/lib/docker.sock using the docker-podman package:

```bash
# dnf install podman-docker
```

Verification steps

1. Display system information of Podman:

```bash
# podman-remote info
```

2. Verify the link:

```bash
# ls -al /var/run/docker.sock
lrwxrwxrwx. 1 root root 23 Nov  4 10:19 /var/run/docker.sock -> /run/podman/podman.sock
```

Red Hat Enterprise Linux 9 Building, running, and managing containers
Additional resources

- Podman v2.0 RESTful API
- A First Look At Podman 2.0 API
- Sneak peek: Podman’s new REST API

25.2. ENABLING THE PODMAN API USING SYSTEMD IN ROOTLESS MODE

This procedure shows how to use `systemd` to activate the Podman API socket and podman API service.

Prerequisites

- The `podman-remote` package is installed.

```
# dnf install podman-remote
```

Procedure

1. Enable and start the service immediately:

```
$ systemctl --user enable --now podman.socket
```

2. Optional: To enable programs using Docker to interact with the rootless Podman socket:

```
$ export DOCKER_HOST=unix:///run/user/<uid>/podman/podman.sock
```

Verification steps

1. Check the status of the socket:

```
$ systemctl --user status podman.socket
```

```
• podman.socket - Podman API Socket
Loaded: loaded (/usr/lib/systemd/user/podman.socket; enabled; vendor preset: enabled)
Active: active (listening) since Mon 2021-08-23 10:37:25 CEST; 9min ago
 Docs: man:podman-system-service(1)
Listen: /run/user/1000/podman/podman.sock (Stream)
 CGroup: /user.slice/user-1000.slice/user@1000.service/podman.socket
```

The `podman.socket` is active and is listening at `/run/user/<uid>/podman.podman.sock`, where `<uid>` is the user’s ID.

2. Display system information of Podman:

```
$ podman-remote info
```

Additional resources

- Podman v2.0 RESTful API
- A First Look At Podman 2.0 API
25.3. RUNNING THE PODMAN API MANUALLY

This procedure describes how to run the Podman API. This is useful for debugging API calls, especially when using the Docker compatibility layer.

Prerequisites

- The `podman-remote` package is installed.

```
# dnf install podman-remote
```

Procedure

1. Run the service for the REST API:

```
# podman system service -t 0 --log-level=debug
```

   - The value of 0 means no timeout. The default endpoint for a rootful service is `unix:/run/podman/podman.sock`.

   - The `--log-level <level>` option sets the logging level. The standard logging levels are `debug`, `info`, `warn`, `error`, `fatal`, and `panic`.

2. In another terminal, display system information of Podman. The `podman-remote` command, unlike the regular `podman` command, communicates through the Podman socket:

```
# podman-remote info
```

3. To troubleshoot the Podman API and display request and responses, use the `curl` command. To get the information about the Podman installation on the Linux server in JSON format:

```
# curl -s --unix-socket /run/podman/podman.sock http://d/v1.0.0/libpod/info | jq
{
  "host": {
    "arch": "amd64",
    "buildahVersion": "1.15.0",
    "cgroupVersion": "v1",
    "conmon": {
      "package": "conmon-2.0.18-1.module+el8.3.0+7084+c16098dd.x86_64",
      "path": "/usr/bin/conmon",
      "version": "conmon version 2.0.18, commit: 7fd3f71a218f8d3a7202e464252aeb1e942d17eb"
    },
    ...
  }
}
```
A jq utility is a command-line JSON processor.

4. Pull the `registry.access.redhat.com/ubi8/ubi` container image:

```
# curl -X POST --unix-socket /run/podman/podman.sock -v 'http://d/v1.0.0/images/create?fromImage=registry.access.redhat.com%2Fubi8%2Fubi'
* Trying /run/podman/podman.sock...
> POST /v1.0.0/images/create?fromImage=registry.access.redhat.com%2Fubi8%2Fubi
HTTP/1.1
> Host: d
> User-Agent: curl/7.61.1
> Accept: /
> < HTTP/1.1 200 OK
< Content-Type: application/json
< Date: Tue, 20 Oct 2020 13:58:37 GMT
< Content-Length: 231
<
{ "status":"pulling image () from registry.access.redhat.com/ubi8:latest, registry.redhat.io/ubi8:latest","error":null,"progress":null,"progressDetail":null,"id":"ecbc6f53bba0d1923ca9e92b3f747da8353a070fccbae93625bd6b47dbee772e"}
* Connection #0 to host d left intact
```

5. Display the pulled image:

```
# curl --unix-socket /run/podman/podman.sock -v 'http://d/v1.0.0/libpod/images/json' | jq
* Trying /run/podman/podman.sock...
% Total    % Received % Xferd Average Speed   Time    Time     Time  Current
 Dload  Upload   Total   Spent    Left  Speed
0     0    0     0    0     0      0      0 --:--:-- --:--:-- --:--:--  2438k
* Connected to d (/run/podman/podman.sock) port 80 (0) > GET /v1.0.0/libpod/images/json HTTP/1.1 > Host: d > User-Agent: curl/7.61.1 > Accept: /
< HTTP/1.1 200 OK
< Content-Type: application/json
< Date: Tue, 20 Oct 2020 13:59:55 GMT
< Transfer-Encoding: chunked
< { [12498 bytes data] 100 12485 0 12485 0 0 2032k 0 --:--:-- --:--:-- --:--:-- 2438k * Connection #0 to host d left intact [{ "id": "ecbc6f53bba0d1923ca9e92b3f747da8353a070fccbae93625bd6b47dbee772e",
"RepoTags": [ "registry.access.redhat.com/ubi8:latest", "registry.redhat.io/ubi8:latest" ],
"Created": "2020-09-01T19:44:12.470032Z",
"Size": 210838671,
"Labels": { "architecture": "x86_64", "build-date": "2020-09-01T19:43:46.041620", "com.redhat.build-host": "cpt-1008.osbs.prod.upshift.rdu2.redhat.com", "maintainer": "Red Hat, Inc.", "name": "ubi8", "summary": "Provides the latest release of Red Hat Universal Base Image 8.", "url": "https://access.redhat.com/containers//registry.access.redhat.com/ubi8/images/8.2-347",
... },
"Names": [
"registry.access.redhat.com/ubi8:latest",
"registry.redhat.io/ubi8:latest"
],...
}`
Additional resources

- Podman v2.0 RESTful API
- Sneak peek: Podman’s new REST API
- Exploring Podman RESTful API using Python and Bash
- **podman-system-service** man page