SUSE Linux Enterprise Server 15 SP1

Docker Open Source Engine Guide

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This guide introduces Docker Open Source Engine, a lightweight virtualization solution to run virtual units simultaneously on a single control host.

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1 Docker Open Source Engine Overview

Docker Open Source Engine is a lightweight virtualization solution to run multiple virtual units (containers) simultaneously on a single control host. Containers are isolated with Kernel Control Groups (*Control groups*) and *Namespaces*.

Full virtualization solutions such as Xen, KVM, or `libvirt` are based on the processor simulating a complete hardware environment and controlling the virtual machines. However, Docker Open Source Engine only provides operating system-level virtualization where the Linux kernel controls isolated containers.

Before going into detail about Docker Open Source Engine, let us define some of the terms used:

Docker Open Source Engine

Docker Open Source Engine is a server-client type application that performs all tasks related to virtual machines. Docker Open Source Engine comprises the following:

- **Daemon:** The server side of Docker Open Source Engine manages all Docker objects (images, containers, network connections used by containers, etc.).
- **REST API:** Applications can use this API to communicate directly with the daemon.
- **CLI Client:** Enables you to communicate with the daemon. If the daemon is running on a different machine than the CLI client, the CLI client can communicate by using network sockets or the REST API provided by Docker Open Source Engine.

Image

An *image* is a read-only template used to create a *virtual machine* on the host server. A Docker image is made by a series of layers built one over the other. Each layer corresponds to a permanent change, for example an update of an application. The changes are stored in a file called a *Dockerfile*. For more details see the official Docker documentation (http://docs.docker.com/engine/reference/glossary#image) .

Dockerfile

A *Dockerfile* stores changes made on top of the base image. *Docker Open Source Engine* reads instructions in the *Dockerfile* and builds a new image according to the instructions.

Container

A *container* is a running instance based on a particular Docker *Image*. Each *container* can be distinguished by a unique container ID.

Registry

A *registry* is storage for already created images. It typically contains several *repositories* There are two types of registry:

- public registry - where everyone (usually registered) can download and use images. A typical public registry is Docker Hub (https://hub.docker.com/).
- private registry - these are accessible for particular users or from a particular private network.

Repository

A *repository* is storage in a *registry* that stores a different version of a particular image. You can pull or push images from or to a repository.

Control groups

Control groups, also called `cgroups`, is a Linux kernel feature that allows aggregating or partitioning tasks (processes) and all their children into hierarchically organized groups to isolate resources.

Namespaces

Docker Open Source Engine uses *namespaces* for its containers, which isolates resources reserved for particular containers.

Orchestration

In a production environment you typically need a cluster with many containers on each cluster node. The containers must cooperate and you need a framework that enables you to manage the containers automatically. The act of automatic container management is called container orchestration and is typically handled by Kubernetes.

Docker Open Source Engine is a platform that allows developers and system administrators to manage the complete lifecycle of images. Docker Open Source Engine makes it easy to build, ship and run images containing applications.

Docker Open Source Engine provides you with the following advantages:

- Isolation of applications and operating systems through containers.
- Near native performance, as Docker Open Source Engine manages allocation of resources in real time.
- Controls network interfaces and resources available inside containers through cgroups.
- Versioning of images.

- Allows building new images based on existing ones.
- Provides you with container orchestration.

On the other hand, Docker Open Source Engine has the following limitations:

LIMITATIONS OF DOCKER OPEN SOURCE ENGINE

- Containers run inside the host system's kernel and cannot use a different kernel.
- Only allows Linux *guest* operating systems.
- Docker Open Source Engine is not a full virtualization stack like Xen, KVM, or `libvirt`.
- Security depends on the host system. Refer to the official security documentation (http://docs.docker.com/articles/security/) for more details.

1.1 Docker Open Source Engine Architecture

Docker Open Source Engine uses a client/server architecture. You can use the *CLI client* to communicate with the *daemon*. The *daemon* then performs operations with containers and manages images locally or in registry. The *CLI client* can run on the same server as the host daemon or on a different machine. The *CLI client* communicates with the *daemon* by using network sockets. The architecture is depicted in *Figure 1.1, "The Docker Open Source Engine Architecture"*.

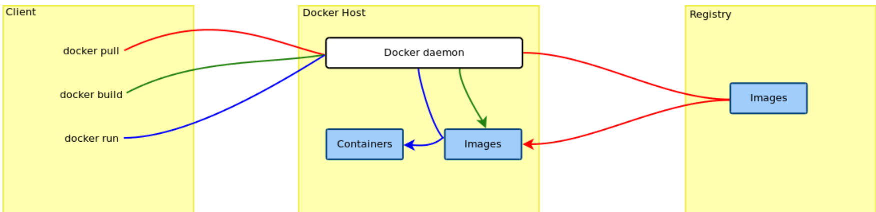

FIGURE 1.1: THE DOCKER OPEN SOURCE ENGINE ARCHITECTURE

1.2 Docker Drivers

1.2.1 Container Drivers

Docker Open Source Engine uses libcontainer (https://github.com/docker/libcontainer) as the back-end driver to handle containers.

1.2.2 Storage Drivers

Docker Open Source Engine supports different storage drivers:

- `vfs`: this driver is automatically used when the Docker host file system does not support copy-on-write. This is a simple driver which does not offer some advantages of Docker Open Source Engine (like sharing layers, more on that in the next sections). It is highly reliable but also slow.
- `devicemapper`: this driver relies on the device-mapper thin provisioning module. It supports copy-on-write, hence it offers all the advantages of Docker Open Source Engine.
- `btrfs`: this driver relies on Btrfs to provide all the features required by Docker Open Source Engine. To use this driver the `/var/lib/docker` directory must be on a Btrfs file system.
- `AUFS`: this driver relies on the AUFS union file system. Neither the upstream kernel nor the SUSE kernel supports this file system. Hence the AUFS driver is not built into the SUSE `docker` package.

SLE 12 uses the Btrfs file system by default, which leads Docker Open Source Engine to use the `btrfs` driver.

It is possible to specify which driver to use by changing the value of the `DOCKER_OPTS` variable defined inside of the `/etc/sysconfig/docker` file. This can be done either manually or using YaST by browsing to *System* › */etc/sysconfig Editor* › *System* › *Management* › *DOCKER_OPTS* menu and entering the `-s storage_driver` string.

For example, to force the usage of the `devicemapper` driver enter the following text:

```
DOCKER_OPTS="-s devicemapper"
```

Important: Mounting `/var/lib/docker`

It is recommended to have `/var/lib/docker` mounted on a separate partition or volume to not affect the operating system that Docker Open Source Engine runs on in case of a file system corruption.

In case you choose the Btrfs file system for `/var/lib/docker`, it is strongly recommended to create a subvolume for it. This ensures that the directory is excluded from file system snapshots. If not excluding `/var/lib/docker` from snapshots, the file system will likely run out of disk space soon after you start deploying containers. In addition, a rollback to a previous snapshot will also reset the Docker database and images. For more information, see *Book “Administration Guide”, Chapter 7 “System Recovery and Snapshot Management with Snapper”, Section 7.1.3.3 “Creating and Mounting New Subvolumes”*.

2 Docker Open Source Engine Installation

2.1 General Preparation

Prepare the host as described below. Before installing any Docker-related packages, you need to enable the container module:

Note: Built-in Docker Orchestration Support

Starting with Docker Open Source Engine 1.12, the container orchestration is now an integral part of Docker Open Source Engine. Even though this feature is available in SUSE Linux Enterprise Server, it is not supported by SUSE and is only provided as a technical preview. Use Kubernetes for Docker container orchestration, for details refer to the Kubernetes documentation (http://kubernetes.io/docs/getting-started-guides/kubeadm/).

PROCEDURE 2.1: ENABLING THE CONTAINER MODULE USING YAST

1. Start YaST, and select *Software* › *Software Repositories*.
2. Click *Add* to open the add-on dialog.
3. Select *Extensions and Modules from Registration Server* and click *Next*.
4. From the list of available extensions and modules, select *Container Module 15 x86_64* and click *Next*.
   The containers module and its repositories will be added to your system.
5. If you use Repository Mirroring Tool, update the list of repositories on the RMT server.

PROCEDURE 2.2: ENABLING THE CONTAINER MODULE USING SUSECONNECT

- The Container Module can be added also with the following command:

  ```
  > sudo SUSEConnect -p sle-module-containers/15.1/x86_64 -r ''
  ```

  ### Note: SUSEConnect Syntax

  The `-r ''` flag is required to avoid a known limitation of SUSEConnect.

PROCEDURE 2.3: INSTALLING AND SETTING UP DOCKER OPEN SOURCE ENGINE

1. Install the `docker` package:

   ```
   > sudo zypper install docker
   ```

2. To automatically start the Docker service at boot time:

   ```
   > sudo systemctl enable docker.service
   ```

   This will automatically enable docker.socket in consequence.

3. In case you will use Portus and an SSL secured registry, open the `/etc/sysconfig/docker` file. Search for the parameter `DOCKER_OPTS` and add `--insecure-registry ADDRESS_OF_YOUR_REGISTRY`.

4. In the production environment when using the SSL secured registry with Portus, add CA certificates to the directory `/etc/docker/certs.d/REGISTRY_ADDRESS` and copy the CA certificates to your system:

   ```
   > sudo cp CA /etc/pki/trust/anchors/ && update-ca-certificates
   ```

5. Start the Docker service:

   ```
   > sudo systemctl start docker.service
   ```

   This will automatically start `docker.socket`.

The Docker daemon listens on a local socket which is accessible only by the `root` user and by the members of the `docker` group. The `docker` group is automatically created at package installation time. To allow a certain user to connect to the local Docker daemon, use the following command:

```
> sudo /usr/sbin/usermod -aG docker USERNAME
```

The user can communicate with the local Docker daemon upon their next login.

2.2 Networking

If you want your containers to be able to access the external network, you must enable the `ipv4 ip_forward` rule. This can be done using YaST by browsing to *System* › *Network Settings* › *Routing* menu and ensuring `Enable IPv4 Forwarding` is checked.

This option cannot be changed when networking is handled by the Network Manager. In such cases you must configure `firewalld` to enable IPv4 masquerading, either from the command line or using the graphical **`firewalld-config`** tool. By default, the `external` zone has masquerading enabled.

You may add masquerading to any zone with **`firewall-cmd`**:

```
> sudo firewall-cmd --zone=containers --add-masquerade
```

When you are satisfied that this is operating correctly, make it permanent:

```
> sudo firewall-cmd --runtime-to-permanent
```

In the **`firewalld-config`** interface, look for the *Masquerade* tab to enable and disable masquerading.

See Chapter 16 of the Security and Hardening Guide for more information on `firewalld`.

2.2.1 Networking Limitations on Power Architecture

Currently Docker networking has two limitations on the POWER architecture.

The first limitation is concerns iptables. SLE machines cannot run Docker Open Source Engine with the iptables support enabled. An update of the kernel is going to solve this issue. In the meantime the `docker` package for POWER has iptables support disabled via a dedicated directive inside of `/etc/sysconfig/docker`.

As a result of this limitation Docker containers will not have access to the outer network. A possible workaround is to share the same network namespace between the host and the containers. This however reduces the isolation of the containers.

The network namespace of the host can be shared on a per-container basis by adding `--net=host` to the `docker run` command.

Note: iptables Support on SUSE Linux Enterprise Server

SUSE Linux Enterprise Server hosts are not affected by this limitation but they may have iptables support disabled. This can be changed by removing the `--iptables=false` setting inside of `/etc/sysconfig/docker`.

The second limitation is about network isolation between the containers and the host. Currently it is not possible to prevent containers from probing or accessing arbitrary ports of each other.

2.3 Updates

All updates to the `docker` package are marked as interactive (that is, no automatic updates) to avoid accidental updates break running container workloads. In general, we recommend stopping all running containers before applying an update to Docker Open Source Engine.

To avoid the potential for data loss, we do not recommend having workloads rely on containers being startable after an update to Docker Open Source Engine. Although it is technically possible to keep containers running during an update via the `--live-restore` option, experience has shown that such updates can introduce regressions. SUSE does not support this feature.

3 Storing Images

Prior to creating your own images, you should decide where you will store the images. The easiest solution is to push these images to the Docker Hub (https://hub.docker.com). By default, all images pushed to the Docker Hub are public. This is probably fine as long as this does not violate your company's policy and your images do not contain sensitive data or proprietary software.

If you need to restrict access to your Docker images, there are two options:

- Get a subscription on Docker Hub that unlocks the feature to create private repositories.
- Run an on-site Docker Registry where to store all the Docker images used by your organization or company and combine them with Portus to secure the registry.

This chapter describes the second option, how to set up an on-site Docker Registry and how to combine it with Portus.

3.1 What is Docker Registry?

The Docker Registry is an open-source project created by Docker Inc. It allows the storage and retrieval of Docker images. By running a local instance of the Docker Registry it is possible to completely avoid usage of Docker Hub.

Docker Registry is also used by Docker Hub. However, Docker Hub, as seen from the user perspective, is made of the following parts at least:

- The user interface (UI): The part that is accessed by users with their browser. The UI provides a nice and intuitive way to browse the contents of Docker Hub either manually or by using a search feature. It also allows to create organizations made by different users.
  This component is closed-source.
- The authentication component: This is used to protect the images stored inside of Docker Hub. It validates all push, pull and search requests.
  This component is closed-source.
- The storage back-end: This is where Docker images are sent and downloaded from. It is provided by Docker Registry.
  This component is open-source.

3.2 Installing and Setting Up Docker Registry

1. Install the `docker-distribution-registry` package. This package is in SUSE Package-Hub. If you have not enabled PackageHub, run the following commands to enable it:

   ```
   > sudo SUSEConnect --product PackageHub/15.1/x86_64
   > sudo zypper refresh
   ```

   Then install `docker-distribution-registry`:

   ```
   > sudo zypper install docker-distribution-registry
   ```

2. To automatically start the Docker Registry at boot time:

   ```
   > sudo systemctl enable registry
   ```

3. Start the Docker Registry:

   ```
   > sudo systemctl start registry
   ```

The Docker Registry configuration is defined inside of `/etc/registry/config.yml`.

With the default configuration the registry listens on ports `5000` and stores the Docker images under `/var/lib/docker-registry`.

Note: Incompatible Versions of Docker Open Source Engine and Docker Registry

Docker Registry 2.3 is not compatible with Docker Open Source Engine versions older than 1.10, because v2 manifests were only introduced with Docker Open Source Engine 1.10. As Docker Open Source Engine and Docker Registry can be installed on different boxes, the versions might be incompatible. If you experience communication errors between Docker Open Source Engine and Docker Registry, update both to the latest versions.

For more details about Docker Registry and its configuration, see the official documentation at: https://docs.docker.com/registry/ .

3.3 Limitations

The Docker Registry has two major limitations:

- It lacks any form of authentication. That means everybody with access to the Docker Registry can push and pull images to it. That also includes the possibility to overwrite already existing images.
- There is no way to see which images have been pushed to the Docker Registry. You need to manually take notes of what is being stored inside of it. There is also no search functionality, which makes collaboration harder. These limitations are resolved by installing Portus.

3.4 Portus

Portus is an authentication service and user interface for the Docker Registry. It is an open source project created by SUSE to address all the limitations faced by the local instances of Docker Registry. By combining Portus and Docker Registry, it is possible to have a secure and enterprise ready on-premise version of the Docker Hub.

Portus is available for SLES customers as a Docker image from SUSE Container Registry. For example, to pull the `2.4.0` tag, run the following command:

```
> docker pull registry.suse.com/sles12/portus:2.4.0
```

Note that this pulls a SLES12-based image, and it is valid for SUSE Linux Enterprise 15 systems (and any Docker environment).

In addition to the official version of the Portus image from SUSE Container Registry, there is a community version that can be found on Docker Hub. However, as a SLES customer, we strongly suggest you use the official Portus image instead. The Portus image for SLES customers has the same code as the one from the community. Therefore, the setup instructions from http://port.us.org/docs/deploy.html apply for both images.

4 Creating Custom Images

For creating your custom image you need a base Docker image of SLES. You can use any of the pre-built SLES images that you can obtain as described in *Section 4.2, “Customizing SLES Docker Images”*.

After you obtain your base Docker image, you can modify the image by using a `Dockerfile` (usually placed in the build directory). Then use the standard **`docker`** building tool to create your custom image:

```
> docker build PATH_TO_BUILD_DIRECTORY
```

For more information about `docker build` options, see the official Docker documentation (https://docs.docker.com/engine/reference/commandline/build/).

Note: Creating a Docker Image for an Application

For information about creating a `Dockerfile` for the application you want to run inside a Docker container, see *Chapter 5, Creating Docker Images of Applications*.

4.1 Obtaining Base SLES Images

Base images of SLES are provided on the SUSE registry in the `suse/` namespace. To obtain the base SLES images from SUSE registry and make them available to the local Docker instance, use the following command:

```
> docker pull registry.suse.com/suse/IMAGENAME
```

Pre-built images do not have repositories configured. But when the Docker host has a SLE subscription that provides access to the product used in the image, Zypper will automatically have access to the right repositories.

You can customize the Docker image as described in *Section 4.2, “Customizing SLES Docker Images”*.

4.1.1 Obtaining Base Images of SLE 12 SP3 and Later Service Packs

Base images of SLE 12 SP3 and later Service Packs can be found on registry.suse.com at `registry.suse.com/suse/sles12spX`, with *X* being the number of the Service Pack.

The `latest` tag refers to the most recently built and published image, while tags in the form *`12.34`* refer to a specific build which will not change in the future. The full reference including the tag to a specific image is part of the meta information, see *Section 4.2.3, "Meta Information in SLE Container Images"*.

4.1.2 Obtaining Base Images of SLE 15 and Later

Base images of SLE 15 and later can be found on registry.suse.com at `registry.suse.com/suse/sleX`, with *`X`* being the number of the major version.

The `latest` tag refers to the most recently built and published image for the newest Service Pack release, while builds for a specific Service Pack can be referenced by *`MAJOR.SP`*. To refer to a specific image build, the build identification numbers need to be appended, e.g. `15.0.3.2.1` or `15.1.2.3`. The full reference including the tag to a specific image is part of the meta information, see *Section 4.2.3, "Meta Information in SLE Container Images"*.

For example, to get the latest image for SUSE Linux Enterprise Server 15 SP1, use:

```
> docker pull registry.suse.com/suse/sle15:15.1
```

4.2 Customizing SLES Docker Images

The pre-built images do not have any repository configured and do not include any modules or extensions. They contain a zypper service (https://github.com/SUSE/container-suseconnect) that contacts either the SUSE® Customer Center (SUSE Customer Center) or your Repository Mirroring Tool (RMT) server, according to the configuration of the SLE host that runs the Docker container. The service obtains the list of repositories available for the product used by the Docker image. You can also directly declare extensions in your `Dockerfile` (for details refer to *Section 4.2.4, "Adding SLE Extensions and Modules to Images"*.

You do not need to add any credentials to the Docker image because the machine credentials are automatically injected into the container by the `docker` daemon. They are injected inside of the `/run/secrets` directory. The same applies to the `/etc/SUSEConnect` file of the host system, which is automatically injected into the `/run/secrets` directory.

Note: Credentials and Security

The contents of the `/run/secrets` directory are never committed to a Docker image, hence there is no risk of your credentials leaking.

Note: Building Images on Systems Registered with RMT

When the host system used for building Docker images is registered with RMT, the default behavior allows only building containers of the same code base as the host. For example, if your Docker host is an SLE 15 system, you can only build SLE 15-based images on that host by default. To build images for a different SLE version, for example SLE 12 on an SLE 15 host, the host machine credentials for the target release can be injected into the container as outlined below.

When the host system is registered with SUSE Customer Center, this restriction does not apply.

Note: Building Container Images in On-Demand SLE Instances in the Public Cloud

When building container images on SLE instances that were launched as so-called "on-demand" or "pay as you go" instances on a Public Cloud (AWS, GCE, or Azure), some additional steps have to be performed. For installing packages and updates, the "on-demand" public cloud instances are connected to a public cloud-specific update infrastructure, which is based around RMT servers operated by SUSE on the various Public Cloud Providers. Some additional steps are required to locate the required services and authenticate with them.

A new service was introduced to enable this, called `containerbuild-regionsrv`. This service is available in the public cloud images provided through the Marketplaces of the various Public Cloud Providers. So before building an image, this service has to be started on the public cloud instance by running the following command:

```
> sudo systemctl start containerbuild-regionsrv
```

To start it automatically after system startup, enable it with **`systemctl`**:

```
> sudo systemctl enable containerbuild-regionsrv
```

The Zypper plugins provided by the SLE base images will then connect to this service for retrieving authentication details and information about which update server to talk to. In order for that to work the container has to be built with host networking enabled, like the following example:

```
> docker build --network host build-directory/
```

Since update infrastructure in the Public Clouds is based upon RMT, the same restrictions with regard to building SLE images for SLE versions differing from the SLE version of the host apply here as well (see *Note: Building Images on Systems Registered with RMT*).

To obtain the list of repositories, use the following command:

```
> sudo zypper ref -s
```

It will automatically add all the repositories to your container. For each repository added to the system a new file will be created under `/etc/zypp/repos.d`. The URLs of these repositories include an access token that automatically expires after 12 hours. To renew the token call the **`zypper ref -s`** command. It is secure to commit these files to a Docker image.

If you want to use a different set of credentials, place a custom `/etc/zypp/credentials.d/SCCcredentials` file inside of the Docker image. It contains the machine credentials that have the subscription you want to use. The same applies to the `SUSEConnect` file: to override the file available on the host system that is running the Docker container, add a custom `/etc/SUSEConnect` file inside of the Docker image.

Now you can create a custom Docker image by using a `Dockerfile` as described in *Section 4.2.1* and *Section 4.2.2*. In case you would like to move your application to a Docker container, refer to *Chapter 5, Creating Docker Images of Applications*. After you have edited the `Dockerfile`, build the image by running the following command in the same directory in which the `Dockerfile` resides:

```
> docker build .
```

4.2.1 Creating a Custom SLE 12 Image

The following `Dockerfile` creates a simple Docker image based on SLE 12 SP4:

```
FROM registry.suse.com/suse/sles12sp4
```

```
RUN zypper ref -s
RUN zypper -n in vim
```

When the Docker host machine is registered against an internal RMT server, the Docker image requires the SSL certificate used by RMT:

```
FROM registry.suse.com/suse/sles12sp4

# Import the crt file of our private SMT server
ADD http://smt.test.lan/smt.crt /etc/pki/trust/anchors/smt.crt
RUN update-ca-certificates

RUN zypper ref -s
RUN zypper -n in vim
```

4.2.2 Creating a Custom SLE 15 Image

The following `Dockerfile` creates a simple Docker image based on the latest Service Pack released for SLE 15:

```
FROM registry.suse.com/suse/sle15

RUN zypper ref -s
RUN zypper -n in vim
```

When the Docker host machine is registered against an internal RMT server, the Docker image requires the SSL certificate used by RMT:

```
FROM registry.suse.com/suse/sle15

# Import the crt file of our private SMT server
ADD http://smt.test.lan/smt.crt /etc/pki/trust/anchors/smt.crt
RUN update-ca-certificates

RUN zypper ref -s
RUN zypper -n in vim
```

4.2.3 Meta Information in SLE Container Images

Starting from SUSE Linux Enterprise 12 SP3, all base container images include information such as a build time stamp and description. This information is provided in the form of labels attached to the base images and is thus available for derived images and containers as well. It can be displayed with **`docker inspect`**:

```
> docker inspect registry.suse.com/suse/sle15
[...]
            "Labels": {
                "com.suse.sle.base.created": "2019-06-20T18:21:37.729383880Z",
                "com.suse.sle.base.description": "Image containing a minimal environment
 for containers based on SUSE Linux Enterprise Server 15 SP1.",
                "com.suse.sle.base.disturl": "obs://build.suse.de/SUSE:SLE-15-
SP1:Update:CR/images/20efed47827dc48da9537c1aeed4dbe2-sles15-image",
                "com.suse.sle.base.reference": "registry.suse.com/suse/
sle15:15.1.6.2.31",
                "com.suse.sle.base.title": "SUSE Linux Enterprise Server 15 SP1 Base
 Container",
                "com.suse.sle.base.url": "https://www.suse.com/products/server/",
                "com.suse.sle.base.vendor": "SUSE LLC",
                "com.suse.sle.base.version": "15.1.6.2.31",
                "org.openbuildservice.disturl": "obs://build.suse.de/SUSE:SLE-15-
SP1:Update:CR/images/20efed47827dc48da9537c1aeed4dbe2-sles15-image",
                "org.opencontainers.image.created": "2019-06-20T18:21:37.729383880Z",
                "org.opencontainers.image.description": "Image containing a minimal
 environment for containers based on SUSE Linux Enterprise Server 15 SP1.",
                "org.opencontainers.image.title": "SUSE Linux Enterprise Server 15 SP1
 Base Container",
                "org.opencontainers.image.url": "https://www.suse.com/products/server/",
                "org.opencontainers.image.vendor": "SUSE LLC",
                "org.opencontainers.image.version": "15.1.6.2.31",
                "org.opensuse.reference": "registry.suse.com/suse/sle15:15.1.6.2.31"
            }
[...]
```

All labels are shown twice. This is necessary to ensure that in derived images the information about the original base image is still visible and not overwritten.

4.2.4 Adding SLE Extensions and Modules to Images

You may have subscriptions to SLE extensions or modules that you would like to use in your custom image. To add them to the Docker image, proceed as follows:

PROCEDURE 4.1: ADDING EXTENSION AND MODULES

1. Add the following into your `Dockerfile`:

   ```
   ADD *.repo /etc/zypp/repos.d/
   ADD *.service /etc/zypp/services.d
   RUN zypper refs && zypper refresh
   ```

2. Copy all `.service` and `.repo` files that you will use into the directory where you will build the Docker image from the `Dockerfile`.

5 Creating Docker Images of Applications

Docker Open Source Engine is a technology that can help minimize resources used to run or build applications. There are several types of applications that are suitable to run inside a Docker container like daemons, Web pages or applications that expose ports for communication. You can use Docker Open Source Engine to automate building and deployment processes by adding the build process into a Docker image, then building the image and then running containers based on that image.

Running an application inside a Docker container has the following advantages:

- You can minimize the runtime environment of the application as you can add to the Docker image of the application just the required processes and applications.
- The image with your application is portable across machines also with different Linux host systems.
- You can share the image of your application by using a repository.
- You can use different versions of required packages in the container than the host system uses without having problems with dependencies.
- You can run several instances of the same application that are completely independent from each other.

Using Docker Open Source Engine to build applications has the following advantages:

- You can prepare a complete building image.
- Your build always runs in the same environment.
- Developers can test their code in the same environment as used in production.
- You can set up an automated building process.

The following section provides examples and tips on creating Docker images for applications. Prior to reading further, make sure that you have activated your SLES base Docker image as described in *Section 4.1, "Obtaining Base SLES Images"*.

5.1 Running an Application with Specific Package Versions

You may face the problem that your application uses a specific version of a package that is different from the package installed on the system that should run your application. You can modify your application to work with another version or you can create a Docker image with that particular package version. The following example of a `Dockerfile` shows an image based on a current version of SLES but with an older version of the `example` package

```
FROM registry.suse.com/suse/sles12sp4
MAINTAINER Tux

RUN zypper ref && zypper in -f example-1.0.0-0
COPY application.rpm /tmp/

RUN zypper --non-interactive in /tmp/application.rpm

ENTRYPOINT ["/etc/bin/application"]

CMD ["-i"]
```

Build the image by running the following command in the directory that the `Dockerfile` resides in:

```
> docker build --tag tux_application:latest .
```

The `Dockerfile` example shown above performs the following operations during the **`docker build`**:

1. Updates the SLES repositories.
2. Installs the desired version of the `example` package.
3. Copies the application package to the image. The source RPM must be placed in the build context.
4. Unpacks the application.
5. The last two steps run the application after a container is started.

After a successful build of the `tux_application` image, you can start a container based on the new image:

```
> docker run -it --name application_instance tux_application:latest
```

You have created a container that runs a single instance of the application. Bear in mind that after closing the application, the Docker container exits as well.

5.2 Running Applications with Specific Configuration

You may need to run an application that is delivered in a standard package accessible through SLES repositories but you may need to use a different configuration or use specific environment variables. In case you would like to run several instances of the application with non-standard configuration, you can create your own image that will pass the custom configuration to the application.

An example with the *example* application follows:

```
FROM registry.suse.com/suse/sles12sp4
RUN zypper ref && zypper --non-interactive in example

ENV BACKUP=/backup

RUN mkdir -p $BACKUP
COPY configuration_example /etc/example/

ENTRYPOINT ["/etc/bin/example"]
```

The above example `Dockerfile` results in the following operations:

1. Refreshing of repositories and installation of the *example*.
2. Sets a `BACKUP` environment variable (the variable persists to containers started from the image). You can always overwrite the value of the variable with a new one while running the container by specifying a new value.
3. Creates the directory `/backup`.
4. Copies the `configuration_example` to the image.
5. Runs the *example* application.

You can now build the image. After a successful build, you can run a container based on your image.

5.3 Sharing Data Between an Application and the Host System

You may run an application that needs to share data between the application's container and the host file system. Docker Open Source Engine enables you to do data sharing by using volumes. You can declare a mount point directly in the `Dockerfile`. But you cannot specify a directory on the host system in the `Dockerfile` as the directory may not be accessible at the build time. You can find the mounted directory in the `/var/lib/docker/volumes/` directory on the host system.

Note: Discarding Changes to the Directory to Be Shared

After you declare a mount point by using the `VOLUME` instruction, all changes performed (by using the `RUN` instruction) to the directory will be discarded. After the declaration, the volume is part of a temporary container that is then removed after a successful build. For example, to change permissions, perform the change before you declare the directory as a mount point in the `Dockerfile`.

You can specify a particular mount point on the host system when running a container by using the `-v` option:

```
> docker run -it --name testing -v /home/tux/data:/data sles12sp4:latest /bin/bash
```

Note

Using the `-v` option overwrites the `VOLUME` instruction if you specify the same mount point in the container.

Now create an example image with a Web server that will read Web content from the host's file system. The `Dockerfile` could look as follows:

```
FROM registry.suse.com/suse/sles12sp4
RUN zypper ref && zypper --non-interactive in apache2
COPY apache2 /etc/sysconfig/
RUN chown -R admin /data
EXPOSE 80
VOLUME /data
ENTRYPOINT ["apache2ctl"]
```

The example above installs the Apache Web server to the image and copies all configuration to the image. The `data` directory will be owned by the *admin* user and will be used as a mount point to store Web pages.

5.4 Applications Running in the Background

Your application may need to run in the background as a daemon or as an application exposing ports for communication. In that case, the Docker container can be run in the background.

An example `Dockerfile` for an application exposing a port looks as follows:

EXAMPLE 5.1: BUILDING AN APACHE2 WEB SERVER DOCKER CONTAINER (`Dockerfile`)

```
FROM registry.suse.com/suse/sle15 ❶
MAINTAINER tux ❷

ADD etc/ /etc/zypp/ ❸
RUN zypper refs && zypper refresh ❹
RUN zypper --non-interactive in apache2 ❺

RUN echo "The Web server is running" > /srv/www/htdocs/test.html ❻
# COPY data/* /srv/www/htdocs/ ❼

EXPOSE 80 ❽

ENTRYPOINT ["/usr/sbin/httpd"]
CMD ["-D", "FOREGROUND"]
```

❶ Base image, taken from *Section 4.1, “Obtaining Base SLES Images”*.

❷ Maintainer of the image (optional).

❸ The repositories and service files. These are copied to `/etc/zypp/repos.d` and `/etc/zypp/services.d` to make these files available on the host in the Docker container too.

❹ Command to refresh repositories and services.

❺ Command to install Apache2.

❻ Test line for debugging purposes, can be removed if everything works as expected.

❼ The copy instruction to copy own data to the server's directory. The leading hash character (`#`) marks this line as a comment, so it is not executed.

❽ The exposed port for the Apache Web server.

Note: Check for Running Apache2 Instances on the Host

Make sure there are no Apache2 server instances running on the host. Otherwise, the Docker container will not serve any data. Remove or stop any Apache2 servers on your host.

To use the container, proceed as follows:

PROCEDURE 5.1: TESTING THE APACHE2 WEB SERVER

1. Prepare the host system for the build process:

   a. Make sure the host system is subscribed to the *Server Applications Module* of SUSE Linux Enterprise Server. To see installed modules or install additional modules, open YaST and select *Add System Extensions or Modules*.

   b. Make sure the SUSE Linux Enterprise images from the SUSE registry are installed, as described in *Section 4.1, “Obtaining Base SLES Images”*.

   c. Save the `Dockerfile` from *Example 5.1, “Building an Apache2 Web Server Docker Container (`Dockerfile`)”* into the `docker` directory.

   d. Within the Docker container, you need access to software repositories and services that are registered on the host. To make them available, copy repositories and service files from the host to the `docker/etc` directory:

      ```
      > cd docker
      > mkdir etc
      > sudo cp -a /etc/zypp/{repos.d,services.d} etc/
      ```

      Instead of copying all repository and service files, you can also copy only the subset that is required by the Docker container.

   e. Add Web site data (such as HTML files) into the `docker/data` directory. The contents of this directory are copied to the Docker image and are thus published by the Web server.

2. Build the container. Set a tag for your image with the `-t` option (here `tux/apache2`, but you can use any name you want):

   ```
   > sudo docker build -t tux/apache2 .
   ```

Docker Open Source Engine will now execute the instructions provided in `Dockerfile`: It will take the base image, copy content, refresh repositories and install the Apache2, etc.

3. Create a Docker container instance from the Docker image created in the previous step:

```
> docker run --detach --interactive --tty tux/apache2
```

Docker Open Source Engine returns the container ID, for example:

```
7bd674eb196d330d50f8a3cfc2bc61a243a4a535390767250b11a7886134ab93
```

4. Point a browser at `http://localhost:80/test.html`. You should see the message `The Web server is running.`

5. To see an overview of running containers, use:

```
> docker ps --latest
CONTAINER ID        IMAGE               COMMAND                  [...]
7bd674eb196d        tux/apache2         "/usr/sbin/httpd -..."   [...]
```

To stop and delete the Docker container, use the following command:

```
> docker rm --force 7bd674eb196d
```

The above procedure describes building an image containing the Apache2 Web server. You can use the resulting container to serve your data with the Apache2 Web server by following these steps:

PROCEDURE 5.2: **CREATING A DOCKER CONTAINER WITH YOUR OWN DATA**

1. In `Dockerfile`:

   - Convert the line starting with `RUN echo` into a comment by adding a `#` character at its beginning (6 in *Example 5.1, "Building an Apache2 Web Server Docker Container (`Dockerfile`)"*).
   - Convert the line starting with `COPY` to a command by removing the leading `#` in it (7 in *Example 5.1, "Building an Apache2 Web Server Docker Container (`Dockerfile`)"*).

2. Rebuild the image as described in *Step 2* of *Procedure 5.1*.

3. Run the image in detached mode:

```
> docker run --detach --interactive --tty tux/apache2
```

Docker Open Source Engine responds with the container ID, for example:

```
e43fff4ae9832ecdb7677c058a73039d7610c32145a1d9b6ad0a4ed52b5c4dc7
```

To view the published data, point a browser at `http://localhost:80/test.html`.

To avoid copying Web site data into the Docker container, share a directory of the host with the container. For information, see https://docs.docker.com/storage/volumes/ ↗.

6 Working with Containers

After you have created your images, you can start your containers based on that image. You can run an instance of the image by using the **`docker run`** command. Docker Open Source Engine then creates and starts the container. The command **`docker run`** takes several arguments:

- A container name - it is recommended to name your container.
- Specify a user to use in your container.
- Define a mount point.
- Specify a particular host name, etc.

The container typically exits if its main process finishes. For example, if your container starts a particular application, as soon as you quit the application, the container exits. You can start the container again by running:

```
> docker start -ai <container name>
```

You may need to remove unused containers, you can achieve this by using:

```
> docker rm <container name>
```

6.1 Linking Containers

Docker Open Source Engine enables you to link containers together which allows for communication between containers on the same host server. If you use the standard networking model, you can link containers by using the `--link` option when running containers:

First, create a container to link to:

```
> docker run -d --name sles sles12sp4 /bin/bash
```

Then create a container that will link to the *sles* container:

```
> docker run --link sles:sles sles12sp4 /bin/bash
```

The container that links to *sles* has defined environment variables that enable connecting to the linked container.

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