Containers Linux Kernel and Docker

Roberto Masocco roberto.masocco@uniroma2.it

University of Rome "Tor Vergata"

Department of Civil Engineering and Computer Science Engineering
Intelligent Systems Lab

May 5, 2022



Disclaimer

What follows is heavily based on specific features of the Linux kernel.

Compatibility with different platforms cannot be guaranteed.

Roadmap

1 Containers

2 Docker

3 Docker Compose

Roadmap

1 Containers

2 Docker

3 Docker Compose

Example: Packaging Applications

Suppose you are ready to distribute your new application:

- you need to be sure that it is compatible with all the platforms you chose to support;
- you need to figure out a way to deal with dependencies;
- you want to publish some kind of self-contained, easily-identifiable package.

Example: Isolating Applications

Suppose you are deploying applications on a server:

- you want to define resource quotas and permissions for each;
- you want to be sure that each module has what it needs to operate, but nothing more;
- you want to **isolate** each module for security reasons, in case something goes wrong.

Example: Replicating Environments

Suppose you are developing applications for a specific system (maybe with a different architecture):

- you want to have a local copy of such system without carrying one with you;
- you want to have all libraries and dependencies installed without tainting your own system;
- you would like to deploy the entire installation with just a few commands, without running any script but simply copying data.

A possible solution to many of the previous situations could be a set of virtual machines.

However, virtual machines are slow, hypervisors take up system resources and guest kernels must always be tweaked.

In each of the above scenarios something simpler would be enough, especially since **the OS is not involved**, only applications are.

This is what a container is.



Figure 1: FreeBSD jail logo

Containers in the Linux kernel

Support for containers was added to the Linux kernel with a set of **features** starting from kernel 2.6 (2003), mainly:

- control groups (cgroups): defining different resource usage policies for groups of processes;
- namespaces: isolating processes and users in different "realms", both hardware (e.g. network stack) and software (e.g. PIDs);
- capabilities: defining what a process can do, with both hardware and software resources.



Figure 2: Tux

Containers in the Linux kernel

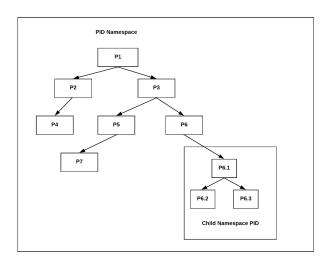


Figure 3: Nested PID namespaces

Roadmap

1 Containers

2 Docker

3 Docker Compose

Docker Engine

Docker is the currently de-facto standard for building, managing and distributing **multiplatform** containers.

It is an engine (i.e. a collection of daemons) that automates the management of the kernel subsystems in order to set up, store and run containers.

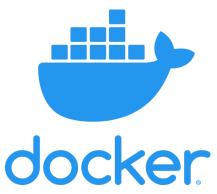


Figure 4: Docker logo

Docker Engine

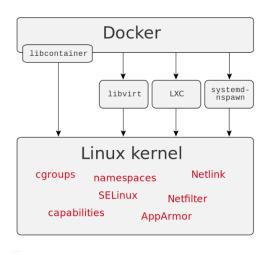


Figure 5: Docker Engine scheme

Containers in Robotics

Containers can be of help in some classic scenarios:

- deploying applications or whole control architectures, solving issues like dependencies and configurations;
- configuring and distributing development environments;
- expanding the capabilities of (partially) closed-source hardware solutions (e.g. Nvidia Jetson...);
- working with multiple architectures at the same time: Docker fully supports QEMU to build and run containers.

Building a Docker Container

- A Dockerfile specifies a set of rules to build an image, just like a script.
- Images are the binary archives from which a container can be started: they can be stored, pulled or simply built locally.
- A container can be built from an image and then started, stopped and managed by the Docker daemon.
- Processes started inside the container are subject to its limitations, e.g. filesystem jails prevent them to climb up to the hosts's filesystem.

Images are built **incrementally**: each Dockerfile directive defines a new **layer**, and the Docker engine stores the differences between each build step thanks to filesystem capabilities: this allows to efficiently **cache build stages**.

Dockerfiles

```
1 ARG VERSION=20.04
2 FROM ubuntu: $VERSION # Note the tag!
3
  ENV DEBIAN FRONTEND=noninteractive
5
  RUN apt-get update && \
      apt-get install -y --no-install-recommends \
8
      build-essential \
9
    git && \
      rm -rf /tmp/*
10
11
12 ENV DEBIAN_FRONTEND=dialog
13 LABEL maintainer.name="Roberto Masocco"
14 CMD ["bash"]
```

Listing 1: Minimal example of a Dockerfile running an Ubuntu image in a container

Dockerfile commands

Just to name a few (see the Dockerfile reference for more):

- FROM repository/image:tag Specifies a base image to pull.
- RUN command Runs the following command in a new shell inside the container.
- COPY source target Copies a file into the container.
- ENV variable=value Sets an environment variable inside the container.
- ARG name=value Declares a build argument.
- CMD ["command", "arg1", ...] Specifies the command to run when the container is started.

Docker Commands

Again, just a few (each with a gazillion of options):

- docker build
 Builds a new image from a Dockerfile.
- docker run
 Builds and starts a container.
- docker ps
 Lists active containers.
- docker exec
 Runs a command inside a container (e.g. a shell).
- docker start
 Starts a container.

Docker Commands

- docker stop
 Stops a container.
- docker images
 Lists available images.
- docker rm
 Removes a container.
- docker rmi
 Removes an image.

Active containers are usually referenced by their **ID**.

Roadmap

1 Containers

2 Docker

3 Docker Compose

Composing Services

Managing multiple, interdependent **containerized services** can become quite a tedious task.

Each container may take multiple options, some have to be started in sequence or built in a particular way...

Compose is a utility that helps to build, run and manage multiplatform containers by parsing all such settings from YAML configuration files.

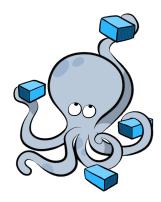


Figure 6: Docker Compose logo

Compose Files

```
services:
    development:
       build:
4
         context: .
5
         args:
6
           TARGET: dev
       image: devenv:latest
8
       environment:
9
         TERM: xterm-256color
10
       network mode: host
       command: ["/bin/zsh"]
11
12
       volumes:
         - ~/.ssh:/home/user/.ssh
13
```

Listing 2: Minimal example of a Compose file

Refer to the Compose reference for more.

Compose Commands

Pretty much the same that Docker has, but invoked with docker-compose and oriented only towards services specified in the local Compose file. Consult the CLI reference for more info.

Example: ROS 2 Development Environment

Remember <u>ros2-examples</u>?

It is a self-contained ROS 2 development environment built with Docker! Go check it out!