

Containers

Linux Kernel and Docker

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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

Why Containers?

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**.

Why Containers?

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.

Why Containers?

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.

Why Containers?

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.

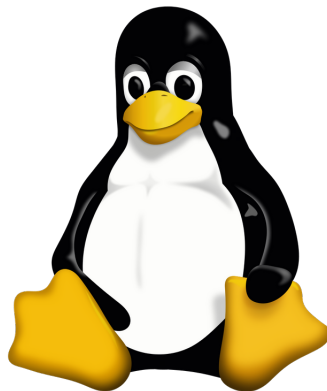


Figure 2: Tux

Containers in the Linux kernel

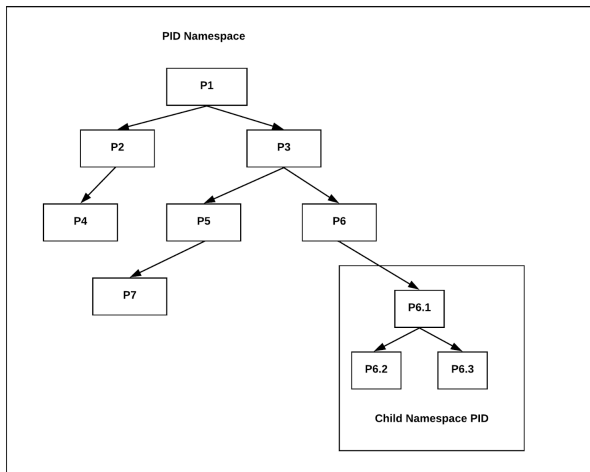


Figure 3: Nested PID namespaces

Roadmap

1 Containers

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3 Docker Compose

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.

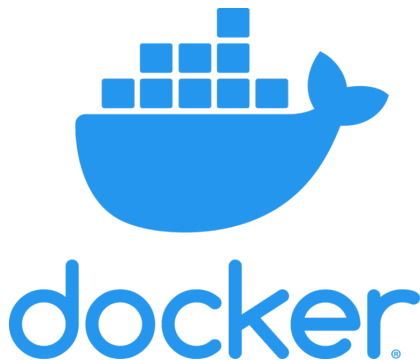


Figure 4: Docker logo

Docker Engine

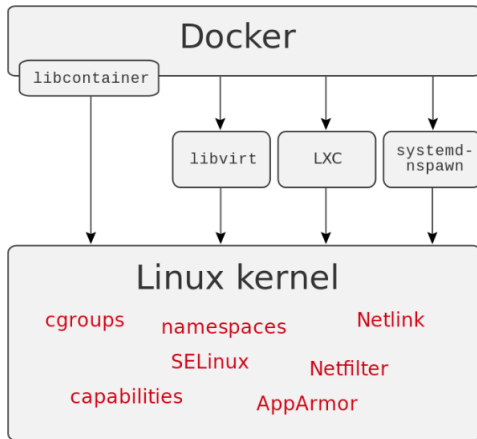


Figure 5: Docker Engine scheme

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

- ① A **Dockerfile** specifies a set of rules to build an **image**, just like a script.
- ② **Images** are the binary archives from which a **container** can be started: they can be stored, pulled or simply built locally.
- ③ A **container** can be built from an image and then started, stopped and managed by the Docker daemon.
- ④ 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
4 ENV DEBIAN_FRONTEND=noninteractive
5
6 RUN apt-get update && \
7     apt-get install -y --no-install-recommends \
8     build-essential \
9     git && \
10    rm -rf /tmp/*
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**.

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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**.

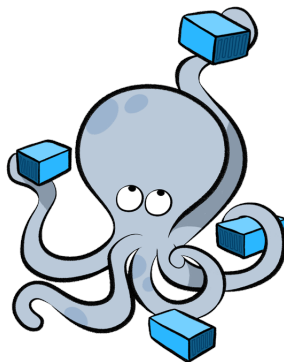


Figure 6: Docker Compose logo

Compose Files

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

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 [ros2-examples](#)?

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