Containers

Linux Kernel and Docker

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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

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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.

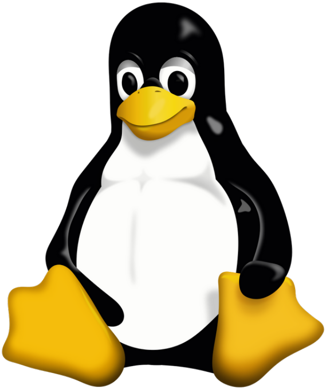

Figure 2: Tux

Containers in the Linux kernel

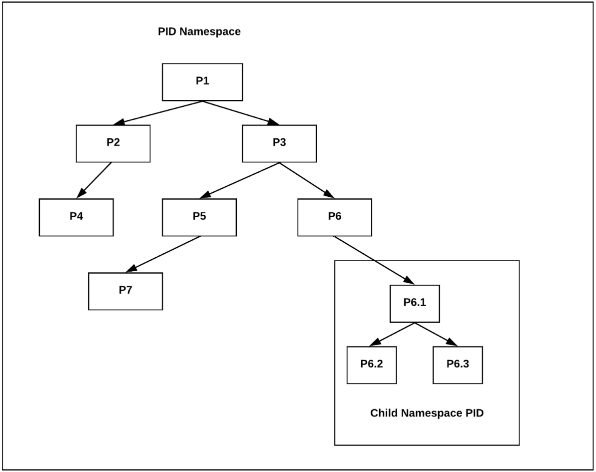

Figure 3: Nested PID namespaces

Roadmap

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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

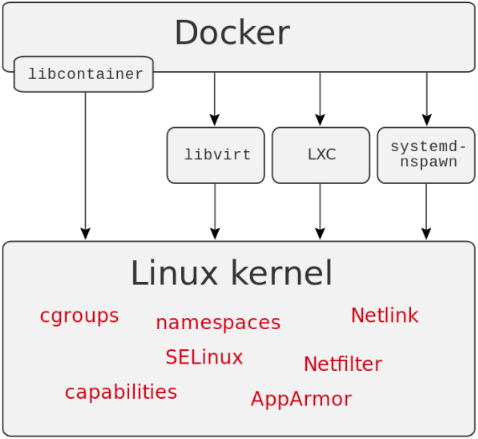

Figure 5: Docker Engine scheme

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

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

```
ARG VERSION=20.04
FROM ubuntu:$VERSION # Note the tag!

ENV DEBIAN_FRONTEND=noninteractive

RUN apt-get update && \
    apt-get install -y --no-install-recommends \
    build-essential \
    git && \
    rm -rf /tmp/*

ENV DEBIAN_FRONTEND=dialog
LABEL maintainer.name="Roberto Masocco"
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** containers by parsing all such settings from **YAML configuration files**.

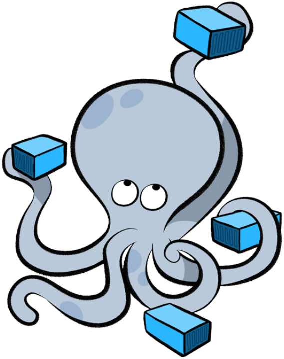

Figure 6: Docker Compose logo

Compose Files

```yaml
services:
  development:
    build:
      context: .
      args:
        TARGET: dev
    image: devenv:latest
    environment:
      TERM: xterm-256color
    network_mode: host
    command: ["/bin/zsh"]
    volumes:
      - ~/.ssh:/home/user/.ssh
```

Listing 2: Minimal example of a Compose file

Refer to the Compose reference for more.