Container Technology and Software Delivery

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Application Containers

Standard Surface for Applications

- Packaging and deployment
- Composability
- Reuse

Déjà-Vu: Virtual Machines?

Containers seem to tip the balance because they are more efficient and more convenient to use.

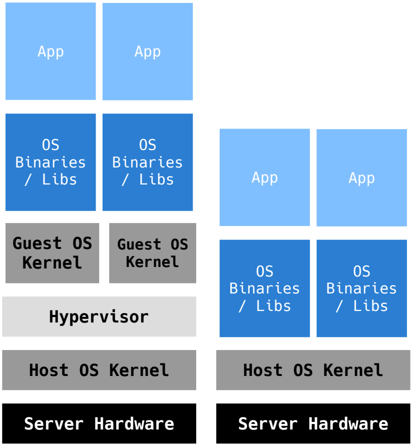
Idealised Container: Wraps a Slim Service

For instance: A Python application including dependencies to render https://phonebook.cern.ch

Virtual Machines vs. Container Virtualization

Container pros and cons:

- ☺ Smaller virtualization overhead for system calls, I/O, memory translation
- ☺ Better at overcommitting with idle services
- ☺ Boots faster (with caveats)
- ☺ Orchestration tools available
- ☹ Weaker isolation
- ☹ No “priviliged operations”, e.g. `mount`
- ☹ Linux only
- ☹ More moving parts



Name Spaces

Virtualization of individual kernel resources
Useful utilities: `unshare`, `nsenter`, `/proc/PID/ns`, `/proc/PID/mountinfo`

pid : Virtual process identifiers:

```
sudo unshare -fork -pid /bin/bash
echo $$ → 1
```

user : Virtual uid/gid mappings. Enables fake root:

```
unshare -U -r /bin/bash
```

net : detach network adapters

mount : detach directory tree from parent process
mount points can be

- **private** : complete isolation between process groups
- **shared** : mounts are propagated upwards and downwards
- **slave** : mounts are only propagated downwards

more : inter-process communication, host name, . . .

Powerful, but: complex to handle manually, hard to diagnose!

CGroups

Hierarchical resource containers, confines applications

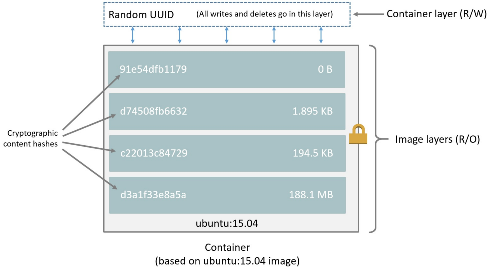
- Steered through the cgroups file system:

```
$ mkdir /sys/fs/cgroup/memory/small
$ echo $((1024*1024)) >
/sys/fs/cgroup/memory/small/memory.limit_in_bytes
$ echo $$ > /sys/fs/cgroup/memory/small/tasks
$ cat /sys/fs/cgroup/memory/small/tasks
13600
13658
$ firefox
Killed
```

- Higher level interfaces: `cgconfig`, `cgcreate`, `cgdelete`, . . .
- Controllers for memory, cpu pinning, device access, freezing, dots

Useful in its own right, e.g. HTCondor, benchmarks

chroot, layers, and union file systems



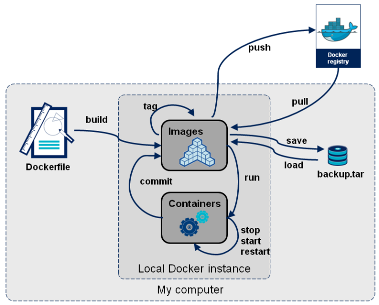
Source: Docker

- The "image" is usually a tarball with the root file system of the container
- Docker can assemble images from multiple tarballs in "layers"
- The layered approach requires a union file system to create a single root mount point
- Another option: bind mount of writable parts into a read-only root file system (/var, /tmp, /home, ...)

Container Ecosystem: Engines

Container Engines

- Docker: most influential one, introduced the push-pull model for containers



Source: `http://blog.octo.com/en/docker-registry-first-steps`

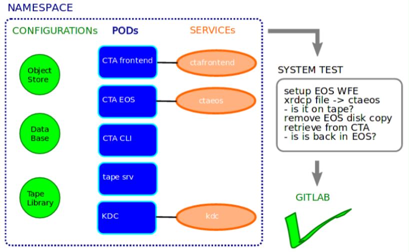
- Singularity: interesting new engine from the HPC world, very lightweight
- lxc, rkt, systemd-nspawn

Container Ecosystem: Clusters

Container Orchestration

- Mesos and DC/OS: two-level cluster scheduler, good for production services
- Kubernetes: container orchestration, good for running ensembles of containers
- Docker Swarm

Example: Test cluster with Kubernetes



Source: Julien Leduc

Container Ecosystem: Clusters

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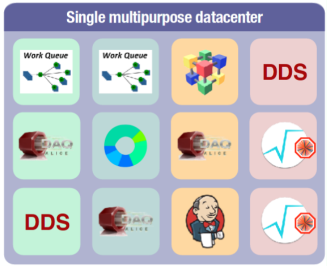
Example: Production Services Cluster on Mesos



Source: Dario Berzano

Reality: Container Images are Big

Image Distribution Problem:

iPhone App	Docker "App"
20 MB changes every month phones update staggered	1 GB changes twice a week servers update synchronized

Example: R in Docker

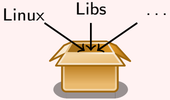
```
$ docker pull r-base
```

⟶ 1 GB image

```
$ docker run -it r-base
$ ...
```

(fitting tutorial)

⟶ only 30 MB used



Container ("App")

CernVM-FS In Containers

Bind Mount

```
docker run -v /cvmfs:/cvmfs:shared ... or
docker run -v /cvmfs/sft.cern.ch:/cvmfs/sft.cern.ch ...
```

- Cache shared by all containers on the same host

Docker Volume Driver

https://gitlab.cern.ch/cloud-infrastructure/docker-volume-cvmfs/

```
docker run --volume-driver cvmfs -v
cms.cern.ch:/cvmfs/cms.cern.ch ...
```

- Integrates with Kubernetes

From Inside Container

```
docker run --privileged ...
```

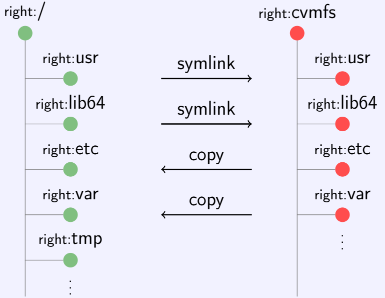
- Probably not very much used in practice

CernVM as a Container

Options for CernVM-FS

1. Fuse, mapped from host
   - Shared cache
   - Requires privileges on the host
2. Using Parrot-Cvmfs
   - Pure user-space (`ptrace`)
   - Can impact performance and stability

Root file system (/) layout

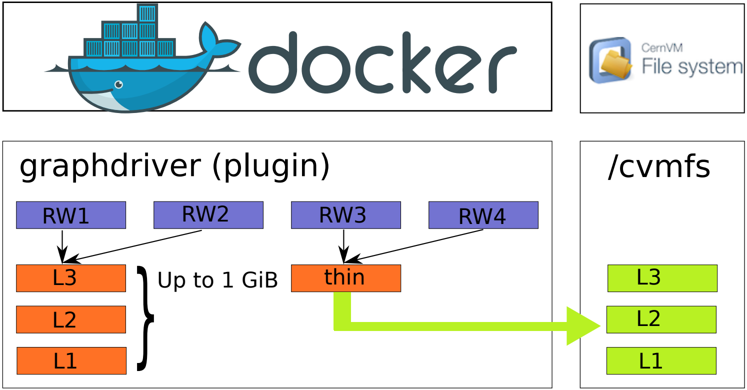


Limitations

Can be used to run tasks, does not allow derived containers

Docker Graph Driver Plugin

Work in Progress by Nikola Hardi



docker

CernVM File system

graphdriver (plugin)

RW1 RW2 RW3 RW4

L3

L2

L1

Up to 1 GiB

thin

/cvmfs

L3

L2

L1

L	Read-Only layer. ~ 300 MiB Fetched from network as whole.
RW	Read-Only layer. Created locally per container.
L	Read-Only layer stored on CVMFS. Fetched per file, on demand.
thin	RO layer, only metadata. ~ 100 KiB List of parent layers stored in CVMFS.

getParentLayers(RW1)
getParentLayers(thin)

Summary

- Containers used for
  - Isolation: e.g. replacing glexec, resource containment
  - Virtual environments:
    CentOS on Ubuntu, SL4 on CentOS7 (data preservation)
  - Unit of scheduling in distributed systems: Kubernetes, Mesos
- Docker/Singularity for isolation + CernVM-FS for image distribution:
  - Works out of the box with Singularity
  - Bind mounts and volume driver for experiment software in Docker
  - Full support for Docker's pull – commit – push lifecycle:
    CernVM-FS graph driver (expected H2/17)
- There are certain dangers with containers
  - More moving parts (and moving targets) in your system
  - Containers foster an attitude of "capturing the mess"
  - Requires automation: containers need to be disposable items
    (e.g. no carriers for storage, databases)