Middleware Architectures 2

Lecture 3: Cloud Native and Microservices

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Evropský sociální fond
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Overview

- Cloud Native
- Microservices
- Containers
- Kubernetes

Overview

- The Cloud Native Computing Foundation (CNFS)
  - *Motto: Building sustainable ecosystems for cloud native software*
  - *CNFS is part of the nonprofit Linux Foundation*
- Cloud Native = scalable apps running in modern cloud environments
  - *containers, service mashes, microservices*
  - *Apps must be usually re-built from scratch or refactored*
  - *Benefits:*
    - → *loosely coupled systems that are resilient, manageable, and observable*
    - → *automation allowing for predictable and frequent changes with minimal effort*
  - *Trail Map*
    - → *provides an overview for enterprises starting their cloud native journey*
- Lift and Shift
  - *Cloud transition program in organizations*
  - *Move app from on-premise to the cloud*
  - *Benefits*
    - → *Infrastructure cost cutting (OPEX vs. CAPEX)*
    - → *Improved operations (scaling up/down if possible can be faster)*

CNFS Trail Map

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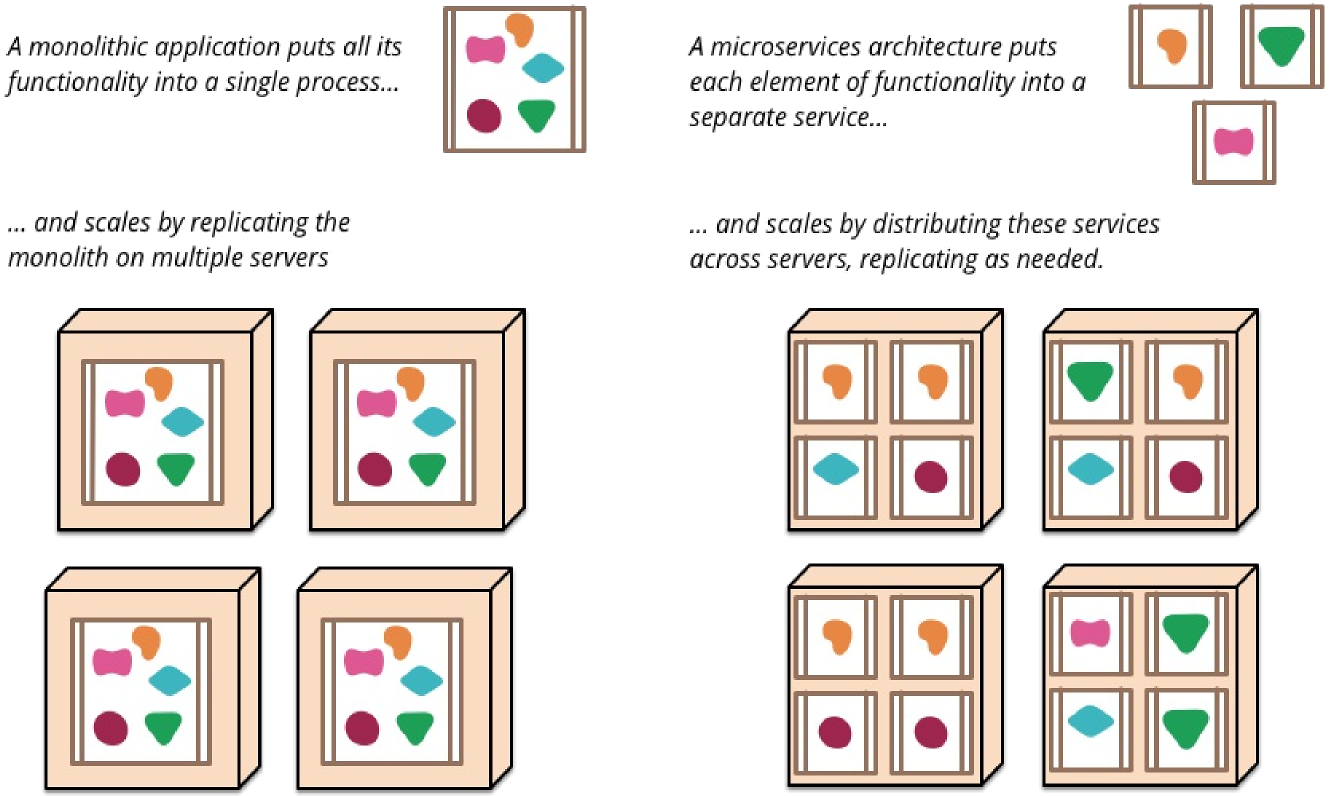
Overview

- Emerging software architecture
  - *monolithic vs. decoupled applications*
  - *applications as independenly deployable services*



Major Characteristics

- Loosely coupled
  – *Integrated using well-defined interfaces*
- Technology-agnostic protocols
  – *HTTP, they use REST architecture*
- Independently deployable and easy to replace
  – *A change in small part requires to redeploy only that part*
- Organized around capabilities
  – *such as accounting, billing, recommendation, etc.*
- Impplemented using different technologies
  – *polyglot – programming languages, databases*

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  - *Linux Namespaces*
  - *Images*
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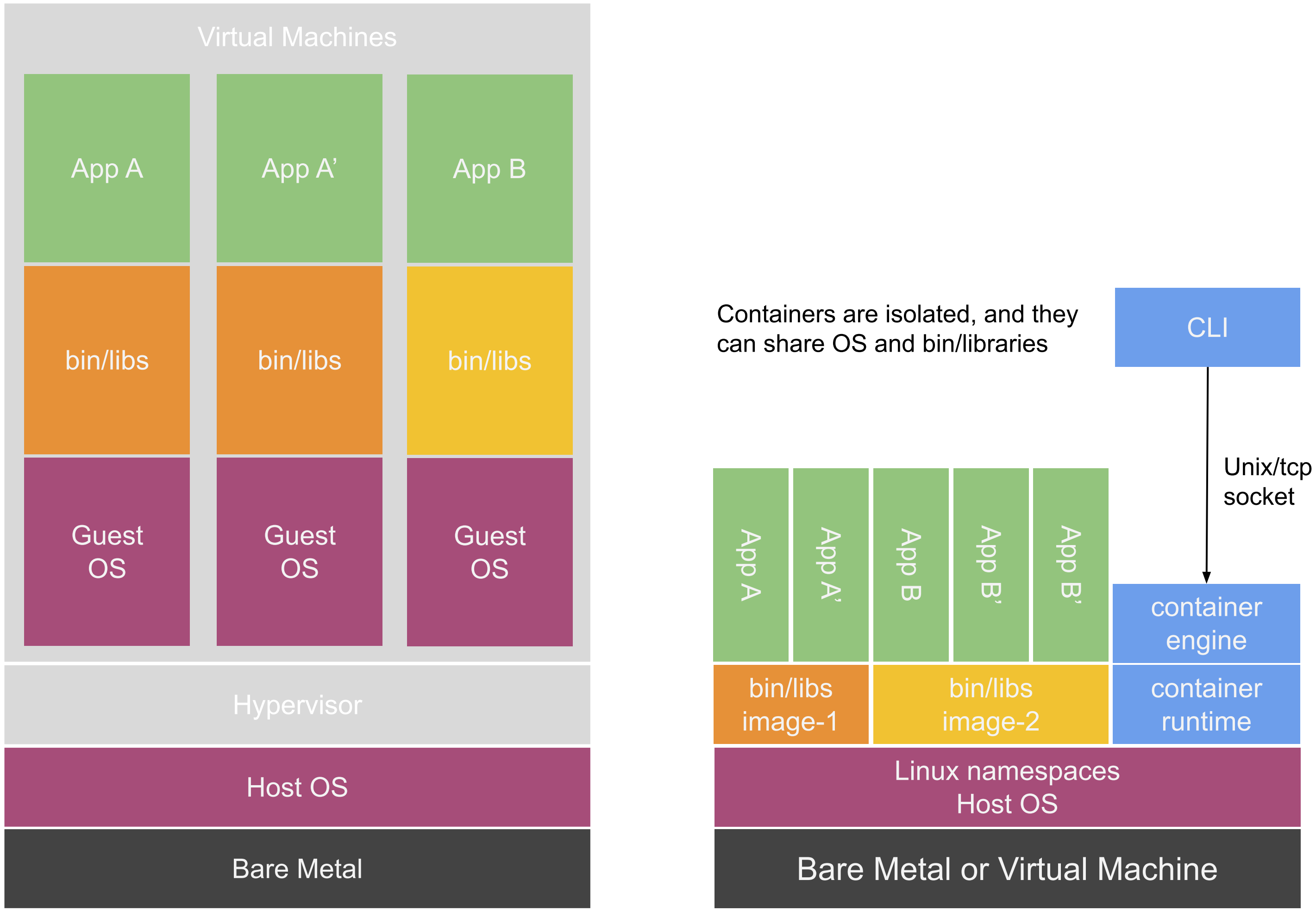
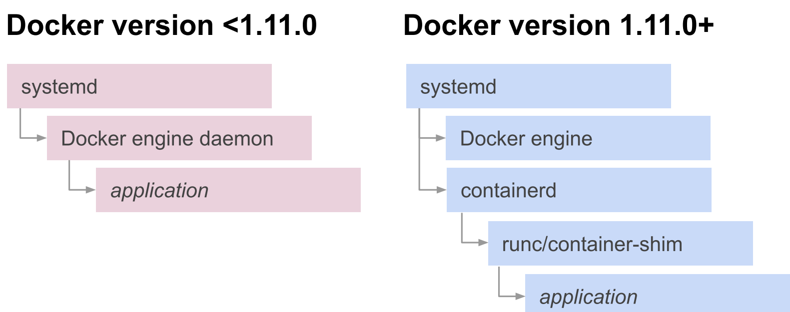
Virtual Machines vs. Containers

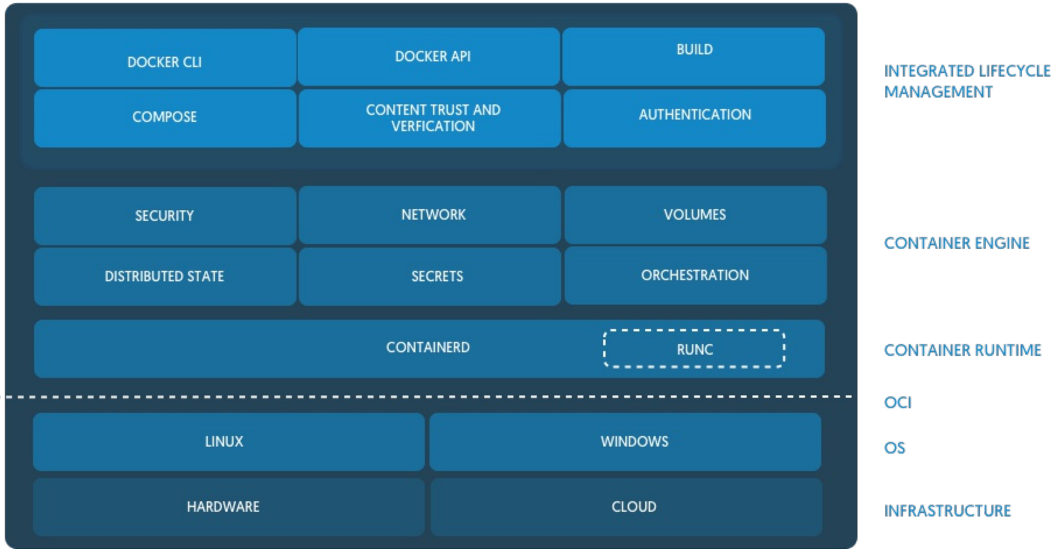


Overview

- Linux Containers
  - *Introduced in 2008*
  - *Allow to run a process tree in a isolated system-level "virtualization"*
  - *Use much less resources and disk space than traditional virtualization*
- Implementations
  - *LXC – default implementation in Linux*
  - *Docker Containers*
    - → *Builds on Linux namespaces and union file system (OverlayFS)*
    - → *A way to build, commit and share images*
    - → *Build images using a description file called Dockerfile*
    - → *Large number of available base and re-usable images*
- Monolithic design originally
  - *Now several layers*
  - *container runtime*
  - *container engine*



Containerd



- Container engine
  – *Accepts user inputs (via CLI or API), pulling images from registry, preparing metadata to be passed to container runtime*
- Container runtime
  – *Abstraction from syscalls or OS specific functionality to run containers on linux, windows, solaris, etc.*
  – *Uses* `runc` *and* `container-shim`
  – *Communicates with kernel to start containerized processes*

Terminology

- Image
  - *An image contains a union of layered filesystems stacked on top of each other*
  - *Immutable, it does not have state and it never changes*
- Container
  - *One or more processes running in one or more isolated namespaces in a filesystem provided by the image*
- Container Engine/Runtime
  - *The core processes providing container capabilities on a host*
- Client
  - *An app (e.g. CLI, custom app), communicates with a container engine by its API*
- Registry
  - *A hosted service containing repository of images*
  - *A registry provides a registry API to search, pull and push images*
  - *Docker Hub is the default Docker registry*
- Swarm
  - *A cluster of one or more docker engines*

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Linux Namespaces

- Isolation of Linux processes, there are **7 namespaces**
  – *Mount, UTS, IPC, PID, Network, User, Cgroup*
  – *By default, every process is a member of a default namespace of each type*
  – *In case no additional namespace configuration is in place, processes and all their direct children will reside in this exact namespace*
  – *Run* `lsns` *to check namespaces the process is in*

```
$ lsns
NS         TYPE   NPROCS   PID USER   COMMAND
4026531836 pid         2 30873 oracle -bash
4026531837 user      108  1636 oracle /bin/bash /u01/oracle/scripts/startWebLogicContainer.sh
4026531838 uts         2 30873 oracle -bash
4026531839 ipc         2 30873 oracle -bash
4026531840 mnt         2 30873 oracle -bash
4026531956 net       108  1636 oracle /bin/bash /u01/oracle/scripts/startWebLogicContainer.sh
4026532185 mnt        13 13542 oracle /bin/bash /u01/oracle/scripts/startNM_ohs.sh
4026532192 pid        13  2798 oracle /bin/bash /u01/oracle/scripts/startNM_ohs.sh
...
```

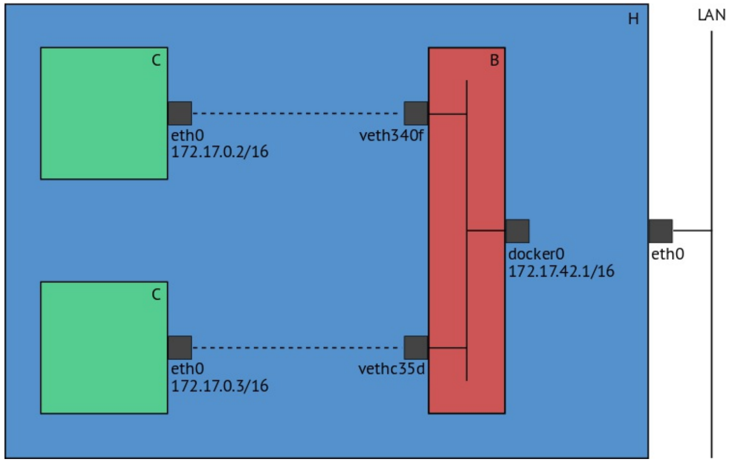
- Flexible configuration, for example:
  – *You can run two apps that only share the network namespace, e.g.* `4026531956`
  – *The apps can talk to each other*
  – *Any other app (not in this namespace) won't be able to talk to the apps*

Types: mnt, uts, ipc and pid

- `mnt` namespace
  - *Isolates filesystem mount points*
  - *Restricts the view of the global file hierarchy*
  - *Each namespace has its own set of mount points*
- `uts` namespace
  - *The value of the hostname is isolated between different UTS namespaces*
- `ipc` namespace
  - *Isolates interprocess communication resources*
  - *message queues, semaphore, and shared memory*
- `pid` namespace
  - *Isolates PID number space*
  - *A process ID number space gets isolated*
    - → *Processes can have PIDs starting from the value 1*
    - → *Real PIDs outside of the namespace of the same process is a different number*
  - *Containers have their own init processes with a PID value of 1*

Types: net

- `net` namespace
  - *Processes have their own private network stack (interfaces, routing tables, sockets)*
  - *Communication with external network stack is done by a virtual ethernet bridge*



  - *On the host there is a* ***userland proxy*** *or* ***NAT***
    - → *NAT is a prefered solution over userland proxy (*`/usr/bin/docker-proxy`*)*
    - → *Lack of NAT hairpinning may prevent to use NAT*
  - *Use case*
    - → *Multiple services binding to the same port on a single machine, e.g.* `tcp/80`
    - → *A port in the host is mapped to the port exposed by a process in the NS*

Types: user

- `user` namespace
  – *Isolates UID/GID number spaces*
- `cgroup` namespace
  – *Isolate cgroup root directory*

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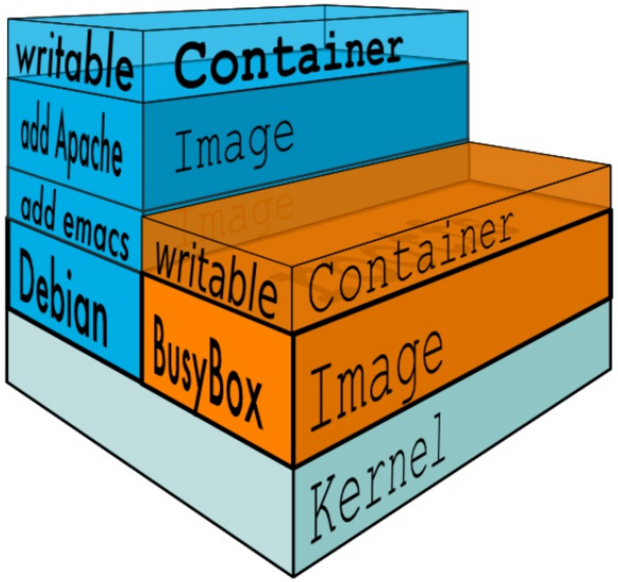
Container Images



- *Containers are made up of R/O layers via a storage driver (OverlayFS, AUFS, etc.)*
- *Containers are designed to support a single application*
- *Instances are ephemeral, persistent data is stored in bind mounts or data volume containers.*

Image Layering with OverlayFS

- OverlayFS
  - *A filesystem service implementing a **union mount** for other file systems.*
  - *Docker uses* `overlay` *and* `overlay2` *storage drivers to build and manage on-disk structures of images and containers.*
- Image Layering
  - *OverlayFS takes two directories on a single Linux host, layers one on top of the other, and provides a single unified view.*
  - *Only works for two layers, in multi-layered images hard links are used to reference data shared with lower layers.*

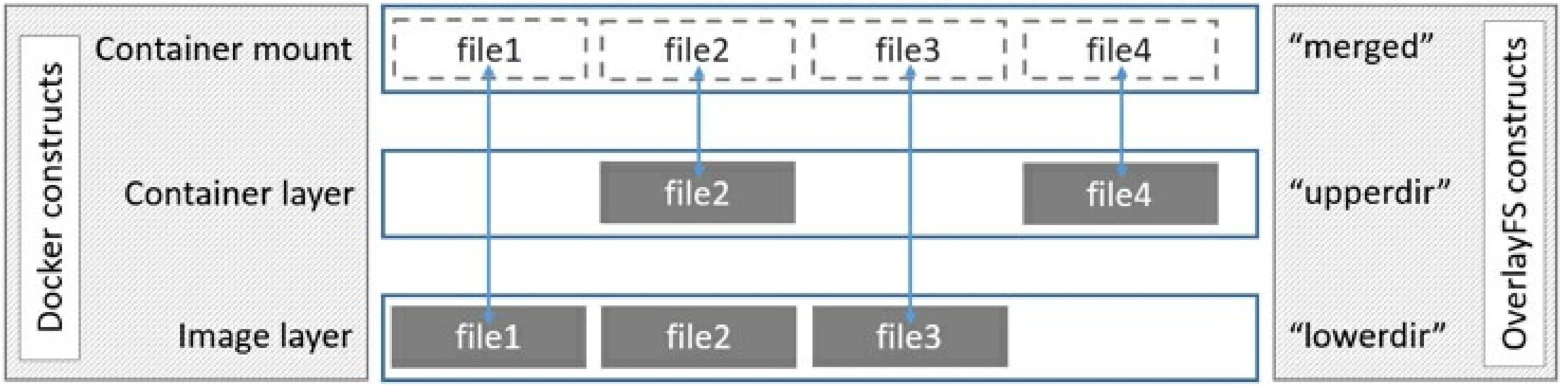


Image Layers Example

- Pulling out the image from the registry

```
$ docker pull ubuntu

Using default tag: latest
latest: Pulling from library/ubuntu

5ba4f30e5bea: Pull complete
9d7d19c9dc56: Pull complete
ac6ad7efd0f9: Pull complete
e7491a747824: Pull complete
a3ed95caeb02: Pull complete
Digest: sha256:46fb5d001b88ad904c5c732b086b596b92cfb4a4840a3abd0e35dbb6870585e4
Status: Downloaded newer image for ubuntu:latest
```

  – *Each image layer has its own directory under* `/var/lib/docker/overlay/`.
  – *This is where the contents of each image layer are stored.*

- Directories on the file system

```
$ ls -l /var/lib/docker/overlay/

total 20
drwx------ 3 root root 4096 Jun 20 16:11 38f3ed2eac129654acef11c32670b534670c3a06e483fce313d72e3e0a15baa
drwx------ 3 root root 4096 Jun 20 16:11 55f1e14c361b90570df46371b20ce6d480c434981cbda5fd68c6ff61aa0a535
drwx------ 3 root root 4096 Jun 20 16:11 824c8a961a4f5e8fe4f4243dab57c5be798e7fd195f6d88ab06aea92ba93165
drwx------ 3 root root 4096 Jun 20 16:11 ad0fe55125ebf599da124da175174a4b8c1878afe6907bf7c78570341f30846
drwx------ 3 root root 4096 Jun 20 16:11 edab9b5e5bf73f2997524eebeac1de4cf9c8b904fa8ad3ec43b3504196aa380
```

  – *The organization of files allows for efficient use of disk space.*
  – *There are* ***files unique to every layer*** *and* ***hard links to files*** *shared with lower layers*

Dockerfile

- Dockerfile is a script that creates a new image

```
# This is a comment
FROM oraclelinux:7
MAINTAINER Tomas Vitvar <tomas@vitvar.com>
RUN yum install -q -y httpd
EXPOSE 80
CMD httpd -X
```

- A line in the Dockerfile will create an intermediary layer

```
$ docker build -t tomvit/httpd:v1 .
Sending build context to Docker daemon 2.048 kB
Step 1 : FROM oraclelinux:7
 ---> 4c357c6e421e
Step 2 : MAINTAINER Tomas Vitvar <tomas@vitvar.com>
 ---> Running in 35feebb2ffab
 ---> 95b35d5d793e
Removing intermediate container 35feebb2ffab
Step 3 : RUN yum install -q -y httpd
 ---> Running in 3b9aee3c3ef1
 ---> 888c49141af9
Removing intermediate container 3b9aee3c3ef1
Step 4 : EXPOSE 80
 ---> Running in 03e1ef9bf875
 ---> c28545e3580c
Removing intermediate container 03e1ef9bf875
Step 5 : CMD httpd -X
 ---> Running in 3c1c0273a1ef
```

If processing fails at some step, all preceeding steps will be loaded from the cache on the next run.

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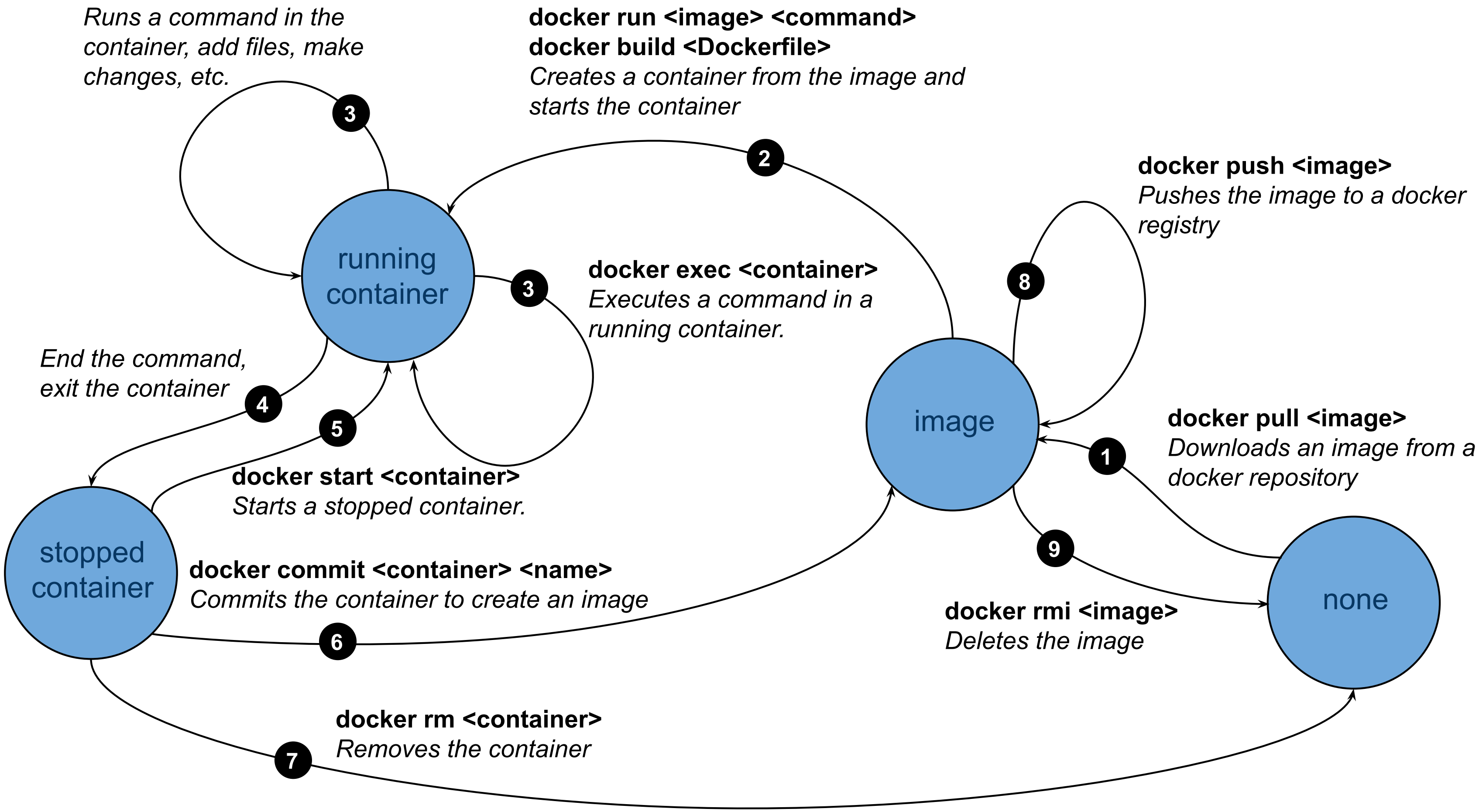
Docker Container State Diagram



Commands (1)

`docker version`

list current version of docker engine and client

`docker search <image>`

search for an image in the registry

`docker pull <image[:version]>`

download an image of a specific version from the registry
if the version is not provided, the latest version will be downloaded

`docker images`

list all local images

`docker run -it <image[:version]> <command>`

start the image and run the command inside the image
if the image is not found locally, it will be downloaded from the registry
option `-i` *starts the container in interactive mode*
option `-t` *allocates a pseudo TTY*

`docker ps [-as]`

list all running containers
option `-a` *will list all containers including the stopped ones.*
option `-s` *will list the container's size.*

Commands (2)

`docker rm <container>`

remove the container

`docker rmi <image>`

remove the image

`docker commit <container> <name[:version]>`

create an image from the container with the name and the version

`docker history <image>`

display the image history

Networking and Linking

- There are 3 docker networks by default
  - ***bridge*** *– container can access host's network (default)*
    - → *Docker creates subnet* `172.17.0.0/16` *and gateway to the network*
    - → *When a container is started, it is automatically added to this network*
    - → *All containers in this network can communicate with each other*
  - ***host*** *– all host's network interfaces will be available in the container.*
  - ***none*** *– container will be placed on its own network and no network interfaces will be configured.*
- Custom Network configuration
  - *You can create a new network and add containers to it*
  - *Containers in the new network can communicate with each other but the network will be isolated from the host network*
- Linking containers (legacy)

```
$ docker run -d --name redmine-db postgres
$ docker run -it --link redmine-db:db postgres /bin/bash
root@c4b12143ebe8:/# psql -h db -U postgres
psql (9.6.1)
Type "help" for help.
postgres=# SELECT inet_server_addr();
postgres=# SELECT * FROM pg_stat_activity \x\g\x
```

Networking Commands

`docker network ls`

lists all available networks

`docker network inspect <network-id>`

Returns the details of specific network

`docker network create --driver bridge isolated_nw`

creates a new isolated network

`docker run -it --network=isolated_nw ubuntu bin/bash`

starts the container ubuntu and attaches it to the isolated network

Data Volumes

- Data Volume
  - *A directory that bypass the union file system*
  - *Data volumes can be shared and reused among containers*
  - *Data volume persists even if the container is deleted*
  - *It is possible to mount a shared sotrage volume as a data volue by using a volume plugin to mount e.g. NFS*
- Adding a data volume

  ```
  docker run -d -v /webapp training/webapp python app.py
  ```

  will create a new value with name `webapp`*,*

  the location of the volume can be determined by using `docker inspect`*.*
- Mount a host directory as a data volume

  ```
  docker run -d -v /src/webapp:/webapp training/webapp python app.py
  ```

  if the path exists in the container, it will be overlayed (not removed),

  if the host directory does not exist, the docker engine creates it.
- Data volume container
  - *Persistent data to be shared among two or more containers*

  ```
  docker create -v /dbdata --name dbstore training/postgres /bin/true
  docker run -d --volumes-from dbstore --name db1 training/postgres
  docker run -d --volumes-from dbstore --name db2 training/postgres
  ```

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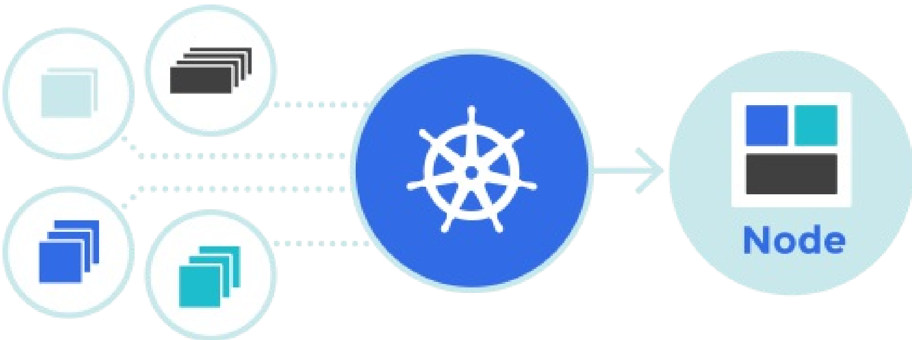
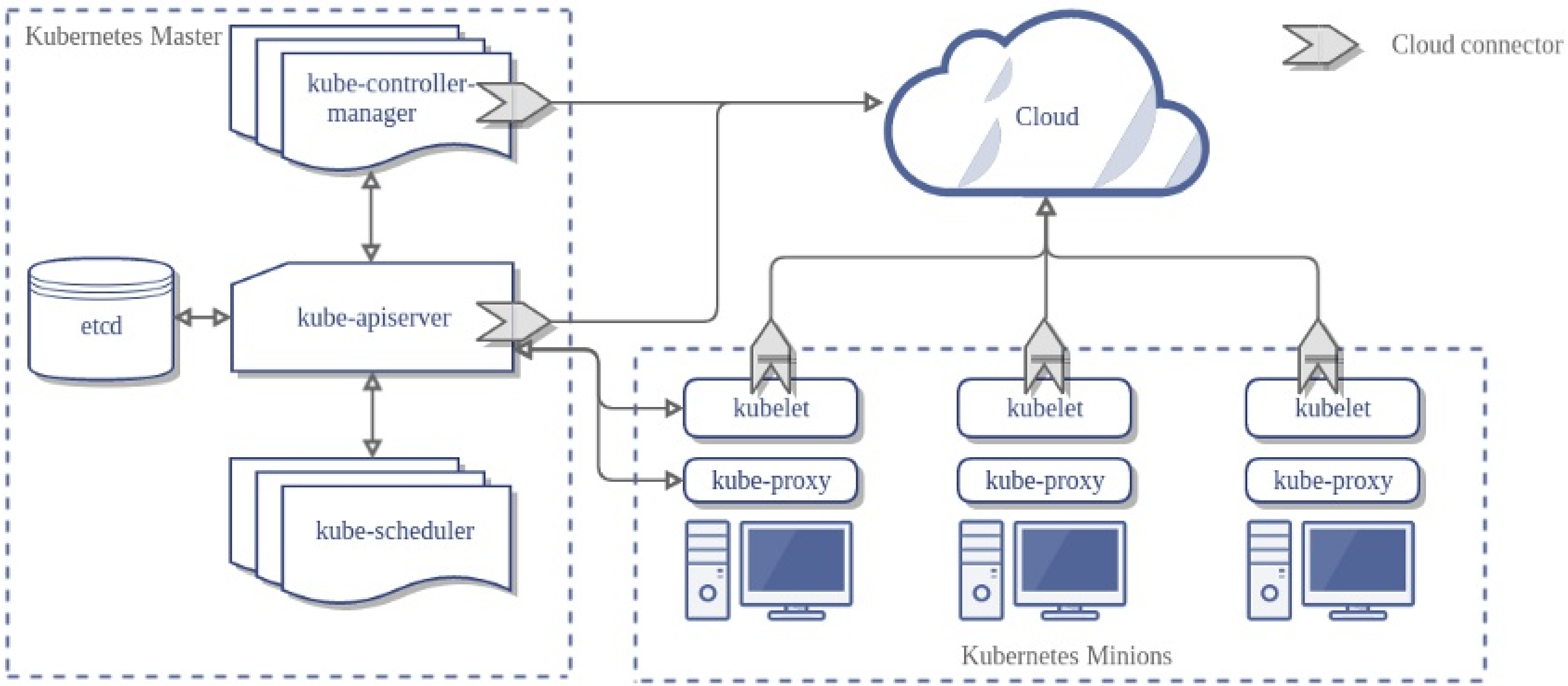
- In your architecture...
  - *Containers are atomic pieces of application architecture*
  - *Containers can be linked (e.g. web server, DB)*
  - *Containers access shared resources (e.g. disk volumes)*
- Kubernetes
  - *Automation of deployments, scaling, management of containerized applications across number of nodes*
  - *Based on Borg, a parent project from Goolge*



System Architecture



Major Terms

- Node
  - *a worker machine in Kubernetes, previously known as a minion (a VM or physical machine). It uses* `kubelet` *and* `kube-proxy` *to communicate with the master and other nodes/services.*
- Master
  - *A node that manages the cluster of nodes.*
- Pod
  - *The basic building block of Kubernetes, one or more dependant containers.*
- Service
  - *A set of pods with rules allowing pods to talk to each other, such as:*
    - → `NodePort` *exposes the pod under a cluster IP.*
    - → `LoadBalancer` *exposes the pod for load balancing by external load balancer*
- Controllers
  - *Worker units to ensure a desired state, such as:*
    - → `ReplicaSet` *ensures that a specified number of pod replicas are running.*
    - → `Deployment` *manages ReplicaSets, provides declarative updates to pods.*
    - → `StatefulSet` *manages deployment and scaling of a set of Pods.*
    - → `DeamonSet` *ensures that all (or some) Nodes run a copy of a Pod.*

Features

- Automatic binpacking
  - *Automatically places containers onto nodes based on their resource requirements and other constraints.*
- Horizontal scaling
  - *Scales your application up and down with a simple command, with a UI, or automatically based on CPU usage.*
- Automated rollouts and rollbacks
  - *Progressive rollout out of changes to application/configuration, monitoring application health and rollback when something goes wrong.*
- Storage orchestration
  - *Automatically mounts the storage system (local or in the cloud)*
- Self-healing
  - *Restarts containers that fail, replaces and reschedules containers when nodes die, kills containers that don't respond to user-defined health checks.*
- Service discovery and load balancing
  - *Gives containers their own IP addresses and a single DNS name for a set of containers, and can load-balance across them.*

Demo

- Environment Setup

  `minikube` – *a local virtual machine (running a master and a single node)*

  `kubectl` – *CLI to access Kubernetes cluster*

- Steps

  1. *create* `hello-node` *app in node.js and test it [see server.js]*

     `node server.js`

  2. *create docker image for the app [see Dockerfile]*

     `docker build -t hello-node:v1 .`

  3. *deploy the app to Kubernetes by using* `kubectl`

     `kubectl run hello-node --image=hello-node:v1 --port=8080`

  4. *Expose the app as a load balancer service.*

     `kubectl expose deployment hello-node --type=LoadBalancer`

  5. *Explore the app in minikube dashboard.*

     `minikube dashboard`

  6. *Fire requests at the service and count them [see test.sh]*

     `./test.sh`.

  7. *Change the number of replicas by using the dashboard or* `kubectl`.