

# Web 2.0

## Lecture 9: Cloud Architecture

**doc. Ing. Tomáš Vitvar, Ph.D.**

tomas@vitvar.com • @TomasVitvar • <http://vitvar.com>



Czech Technical University in Prague

Faculty of Information Technologies • Software and Web Engineering • <http://vitvar.com/courses/w20>



Modified: Wed Mar 22 2017, 19:38:47  
Humla v0.3

## Overview

- Introduction
- Cloud Architecture
- Docker Containers

## What is a Cloud?

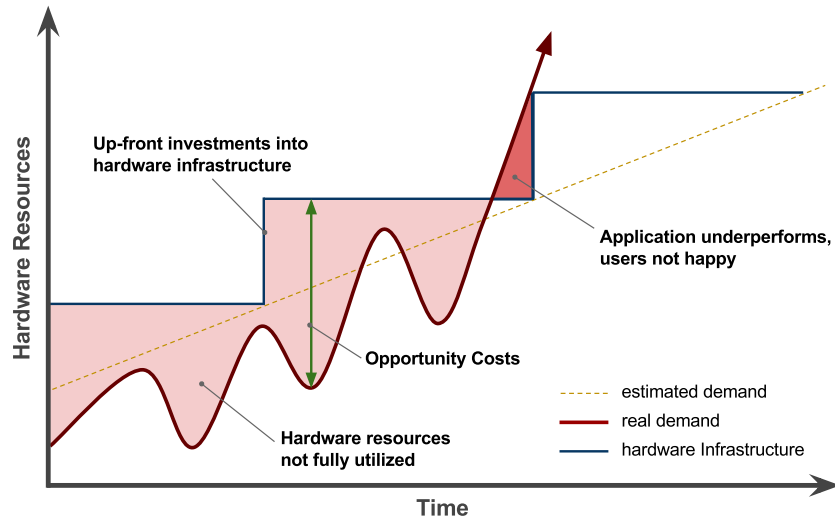
- A different way of thinking
  - Got your grand mum's savings under your pillow?  
→ probably not, you better have them in your bank
  - Data is your major asset
  - you better have them in a "bank" too
  - Someone can abuse your data?
  - banks bankrupt too, sometimes – it is a risk you take
  - there is a market and a competition
- Outsourcing of application infrastructure
  - Reliability and availability
  - Low costs – pay-per-use
  - Elasticity – can dynamically grow with your apps

## What is a Cloud?

- Any app you access over the web?
- A datacenter?
  - Offers virtualization
  - Any company having a datacenter wants to move to
- Cloud provider should also offer services, such as:
  - scalability, storage
  - Possible to configure programmatically
    - integration to enterprise administration processes
    - usually REST interface

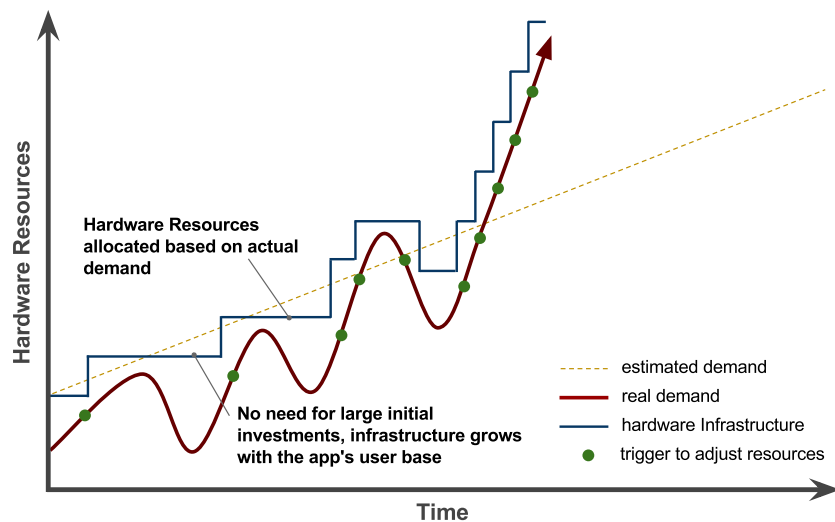
## Traditional Solution to Infrastructure

- Traditional hardware model
  - Up-front hardware investments
  - Hardware not optimally utilized



## Good Performance – Cloud Solution

- Cloud Computing model
  - No up-front hardware investments
  - Hardware optimally utilized



## Cloud Computing Concepts

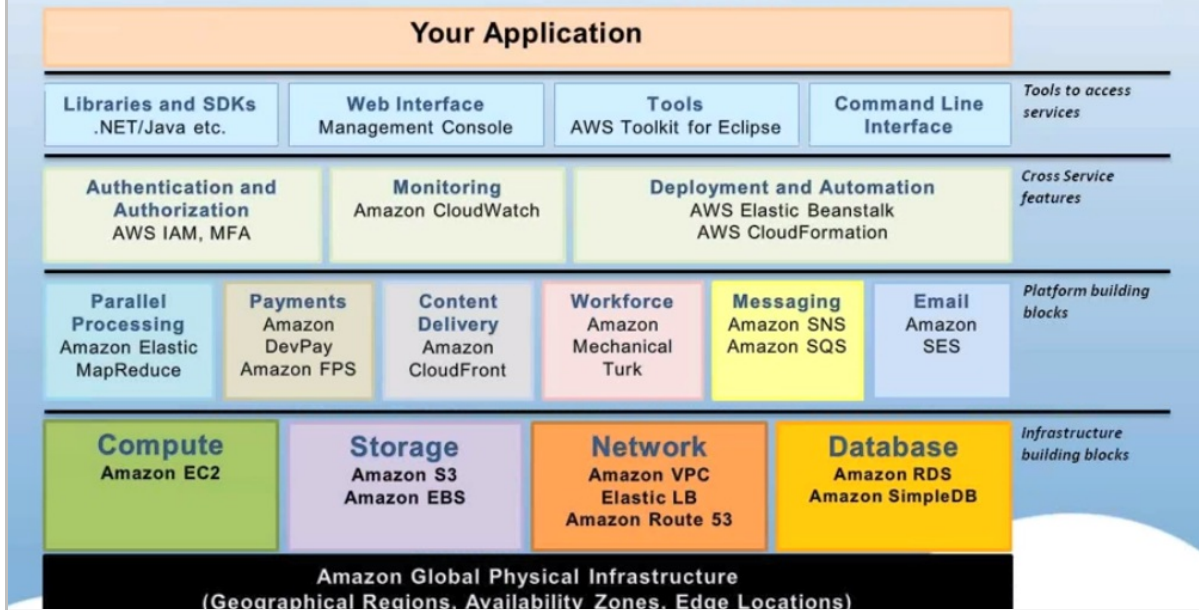
- **Resource Pooling**
  - *Resources reused by multiple tenants (multitenancy)*
  - *Resources: CPU, memory, storage, network*
- **On-demand and Self-service**
  - *Resources are provisioned as they are requested and when they are required*
  - *No human interaction, automatic*
- **Scalability and Elasticity**
  - *Infrastructure may grow and shrink according to needs*
  - *Automatic or manual*
- **Pay-per-use**
  - *Consumers only pay for resources when they use them*

## Cloud Computing Concepts (Cont.)

- **Service Models (aka Cloud Layers)**
  - *IaaS – Infrastructure as a Service*
  - *PaaS – Platform as a Service*
    - *MWaaS, DBaaS, ...*
  - *SaaS – Software as a Service*
- **Deployment Models**
  - *Public Cloud*
  - *Private Cloud*
  - *Hybrid Cloud*

# Cloud Provider Example – Amazon AWS

## The “Living and Evolving” AWS Cloud



Lecture 9: Cloud Architecture, CTU Summer Semester 2016/2017, @TomasVitvar

– 9 –

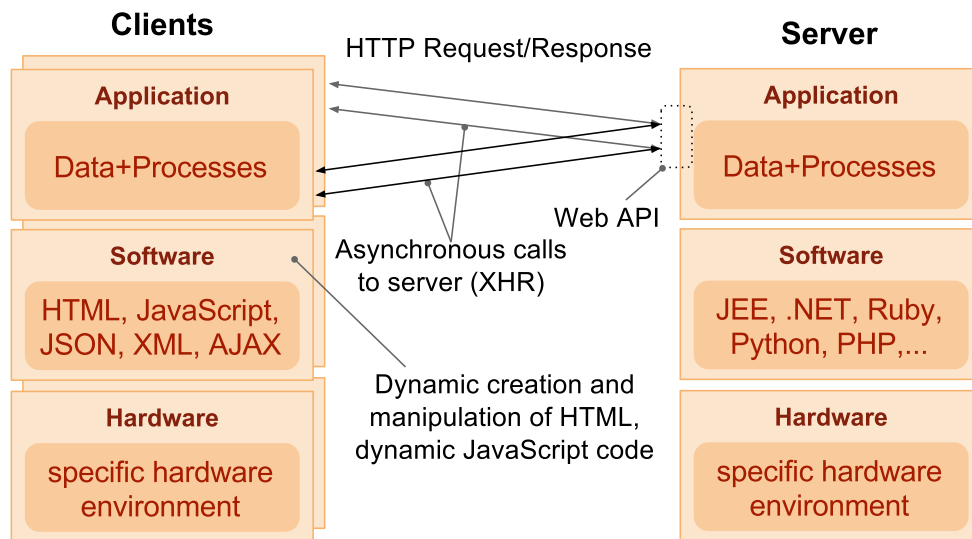
## Overview

- Introduction
- Cloud Architecture
  - *Service Models*
  - *Multitenancy*
- Docker Containers

Lecture 9: Cloud Architecture, CTU Summer Semester 2016/2017, @TomasVitvar

– 10 –

## Web 2.0 Web Architecture

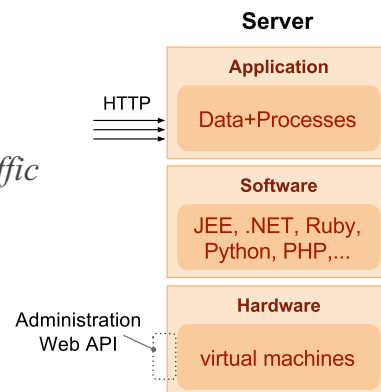


## IaaS: Infrastructure as a Service

- Provides basic computing resources and services for application providers
  - *Services for application providers*
  - *A consumer is able to deploy and run arbitrary software*
- Infrastructure implications
  - *Exposing of infrastructure resources through abstraction*
  - *Support for infrastructure resources – compute (hardware/OS/VM), storage, network, etc.*
  - *Supports isolation for multitenant environments*

## IaaS: Infrastructure as a Service

- Usage
  - *Predefined machine instances (micro, small, large, extra-large)*
    - *Linux OS, 613 MB of memory, 30 GB of Storage, Load Balancer, etc.*
  - *Pay-per-use – pay for resources you use (time or amount); no up-front costs*
- IaaS Services Examples
  - *Elastic Storage*
  - *Monitoring resources*
    - *Amazon CloudWatch*
  - *Auto Scalling of running instances*
  - *Load Balancing – distributing incoming traffic across multiple instances*
- IaaS providers
  - *Amazon EC2, GoGrid, Rackspace, OpenNebula, ...*

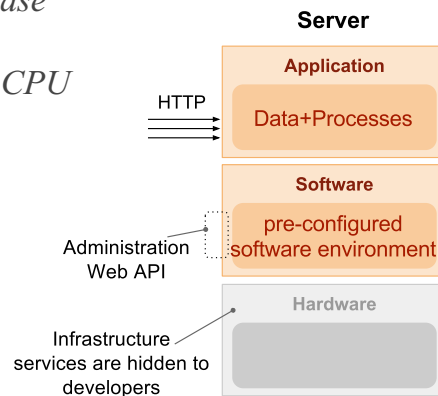


## PaaS: Platform as a Service

- Provides scalable platform for applications
  - *Services for application providers*
  - *No costs of buying and managing underlying infrastructure*
    - *hardware and software*
- Infrastructure implications
  - *Scalable platform, deploy on-demand*
  - *Self service interface to deploy applications and services*
  - *Support for monitoring and measuring platform usage*
  - *Model supporting isolation in multi-tenant environments*

## PaaS: Platform as a Service

- Usage
  - Choose software platform, e.g., JEE, .NET, Python, etc.
  - Pay-per-use – pay for the resources you use; no up-front costs
- PaaS features
  - Auto Scalling and Load Balancing of applications
  - Persistent Storage - usually NoSQL database
  - Local development environment
  - Backends – for app instances with higher CPU and memory demands
  - Administration APIs for its services
- PaaS providers
  - Google App Engine, Heroku, Windows Azure, etc.
- Limitations
  - HTTP request limit (30 - 60 sec)
  - No writes to file system, no thread support



## SaaS: Software as a Service

- Software delivery model for applications hosted in the cloud
  - typically software for end-users
  - services accessed using a web browser
  - provides API for programmatic access
- SaaS characteristics
  - Typically build on top of IaaS or PaaS
  - Configurable and customizable modern Web applications
  - Usually basic version for free, need to pay for pro version
  - Global availability - any computer, any device
  - Easy management - automatic and fast updates
  - Pay-per-use – pay for the time you use
- SaaS providers
  - Google Apps, Salesforce, iCloud, Flickr, Picasa, ...



## Overview

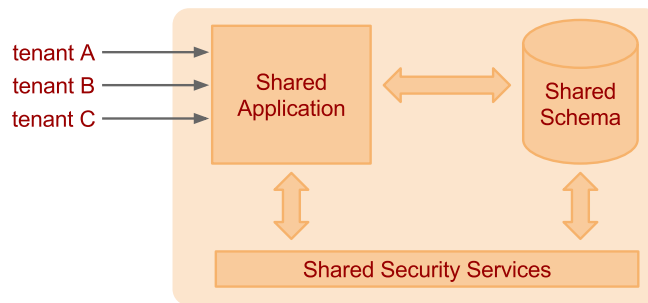
- Introduction
- Cloud Architecture
  - *Service Models*
  - *Multitenancy*
- Docker Containers

## Multitenancy

- Architectural approach where resources are shared between multiple tenants or consumers
- Implications
  - *Centralization of infrastructure in locations with lower costs*
  - *Peak-load capacity increases*
  - *Utilisation and efficiency improvements for systems that are not well utilised*
- Sharing options
  - *Shared Everything*
  - *Shared Infrastructure*
    - *Virtual Machines*
    - *O/S virtualization*

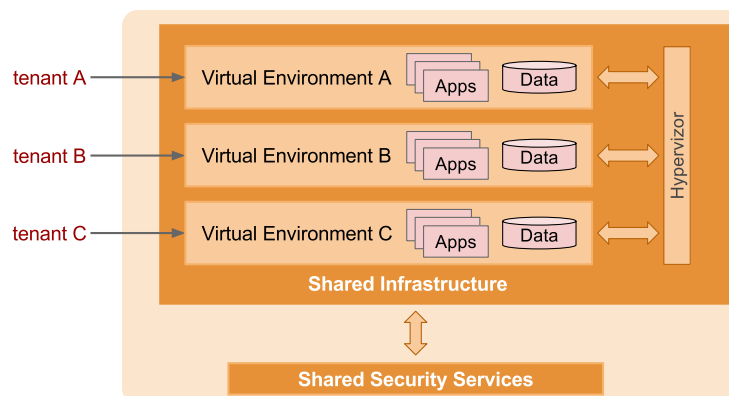
## Shared Everything

- Resources are shared between all tenants or consumers
  - *tenant: a service consumer*
- Common for the SaaS model
- The application should provide tenant isolation
- Data for multiple tenants is stored in the same database tables



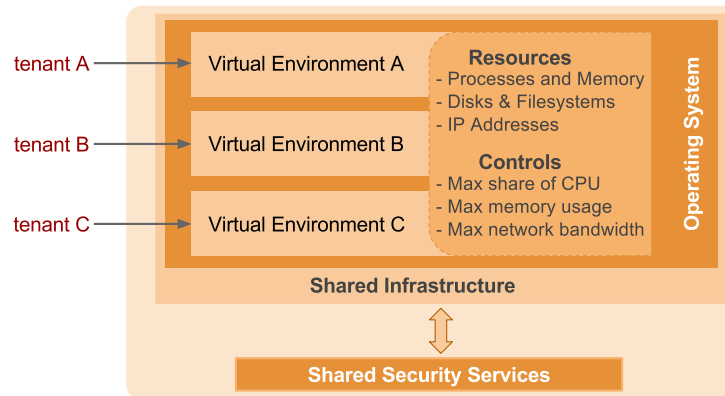
## Shared Infrastructure: Virtual Machines

- Infrastructure shared via virtual machines
  - *each tenant has its own virtual environment*
  - *Isolation provided by hypervisor*
    - *hypervisor: virtual machine manager, runs virtual machines*
  - *Resource contention depends on VM capability and configuration*
  - *Adds an additional layer and processes to run and manage*



## Shared Infrastructure: OS Virtualization

- Infrastructure shared via OS Virtualization
  - *Each tenant has its own processing zone*
  - *Isolation provided by the operating system*
  - *Resource contention depends on zone configuration*
  - *No VMs to run and manage, no abstraction layer between app & OS*



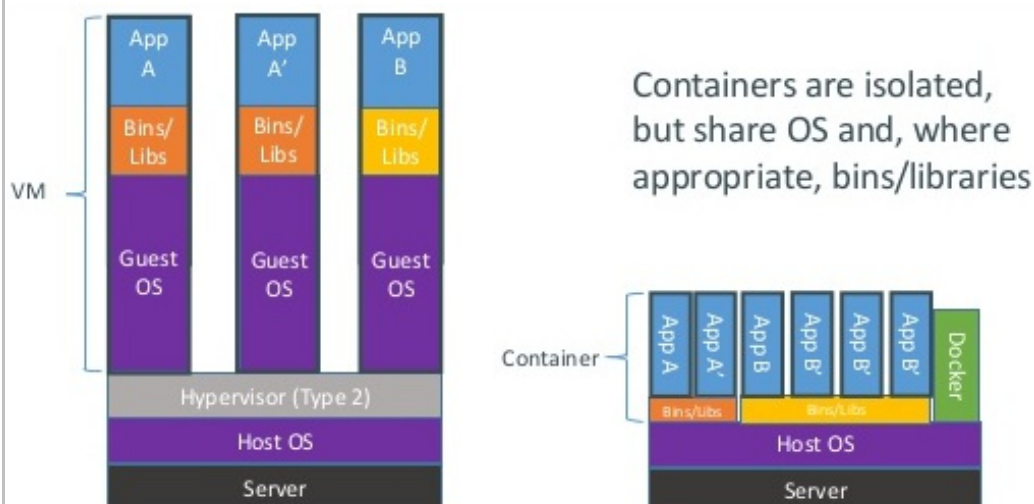
## Overview

- Introduction
- Cloud Architecture
- Docker Containers
  - *Overview*
  - *Image Layering*
  - *Working with Docker*
  - *Swarm*

## 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 new Kernel features: control groups (cgroups), kernel namespaces, union-capable file system (OverlayFS, AUFS, etc.)*
    - *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*

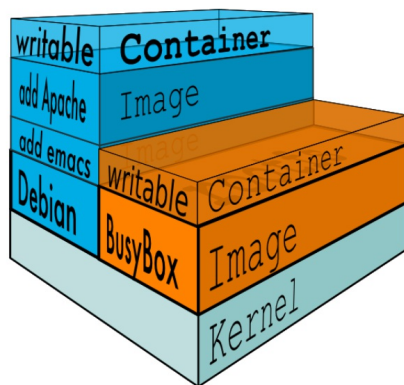
## VM vs. Docker Containers



## Docker Basic Terms

- Image
  - Basis for containers.
  - An image contains a union of layered filesystems stacked on top of each other.
  - An image does not have state and it never changes.
- Container
  - A runtime instance of a Docker image, a standard to "ship software".
- Docker Engine
  - The core process providing the Docker capabilities on a host.
- Docker Client
  - Interface that integrates with docker engine.
- 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.

## Docker 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.

## Overview

- Introduction
- Cloud Architecture
- Docker Containers
  - Overview
  - *Image Layering*
  - *Working with Docker*
  - *Swarm*

## 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

```
$ sudo docker pull ubuntu

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

5ba4f30e5bea: Pull complete
9d7d19c9dc56: Pull complete
ac6ad7efd0f9: Pull complete
e7491a747824: Pull complete
a3ed95cae02: 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/

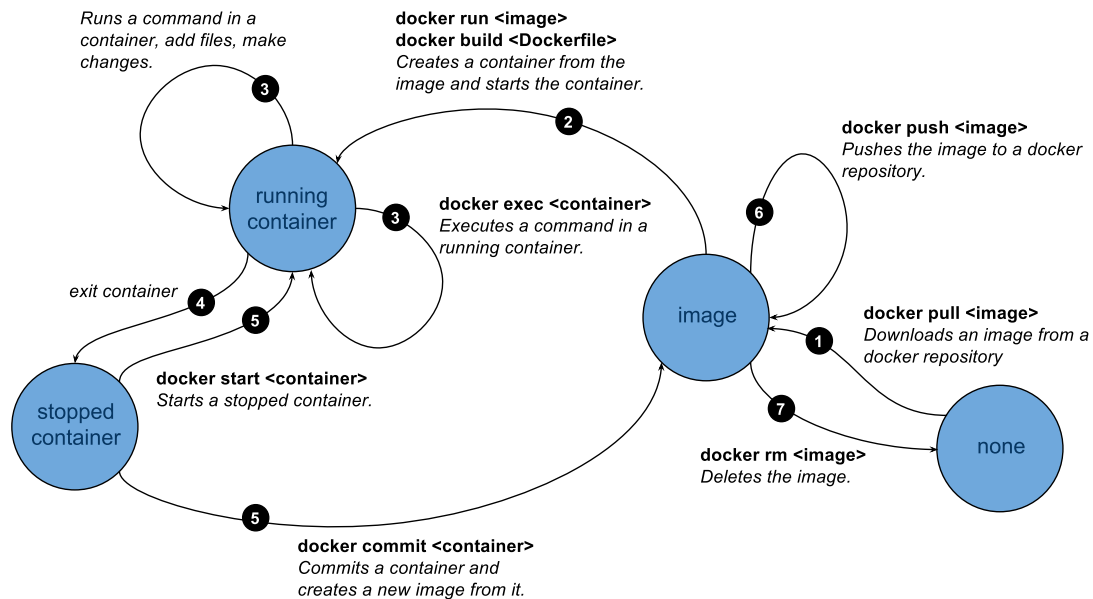
total 20
drwx----- 3 root root 4096 Jun 20 16:11 38f3ed2eac129654acef11c32670b534670c3a06e483fce313d72e3e
drwx----- 3 root root 4096 Jun 20 16:11 55f1e14c361b90570df46371b20ce6d480c434981cbda5fd68c6ff61
drwx----- 3 root root 4096 Jun 20 16:11 824c8a961a4f5e8fe4f4243dab57c5be798e7fd195f6d88ab06aea92
drwx----- 3 root root 4096 Jun 20 16:11 ad0fe55125ebf599da124da175174a4b8c1878afe6907bf7c7857034
drwx----- 3 root root 4096 Jun 20 16:11 edab9b5e5bf73f2997524eebeac1de4cf9c8b904fa8ad3ec43b35041
```

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

## Overview

- Introduction
- Cloud Architecture
- Docker Containers
  - *Overview*
  - *Image Layering*
  - ***Working with Docker***
  - *Swarm*

# Docker Container Lifecycle 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 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 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 storage volume as a data volume 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 volume 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`

# 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 the processing fails at some point, all preceding points will be loaded from the*

# Overview

- Introduction
- Cloud Architecture
- Docker Containers
  - *Overview*
  - *Image Layering*
  - *Working with Docker*
  - *Swarm*

# Swarm

