

# Web 2.0

## Lecture 2: Cloud Architectures

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Evropský sociální fond  
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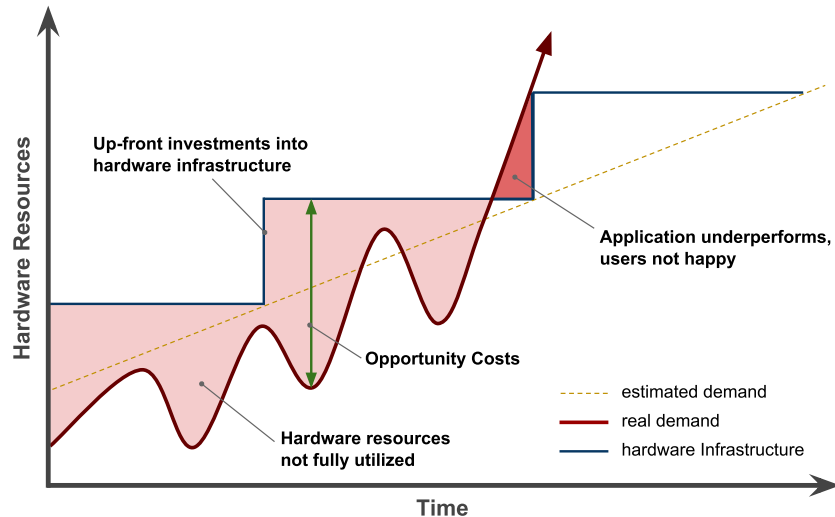
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## Overview

- **Introduction**
- Infrastructure as a Service
- Multitenancy
- Microservices Architecture
- Docker
- Kubernetes

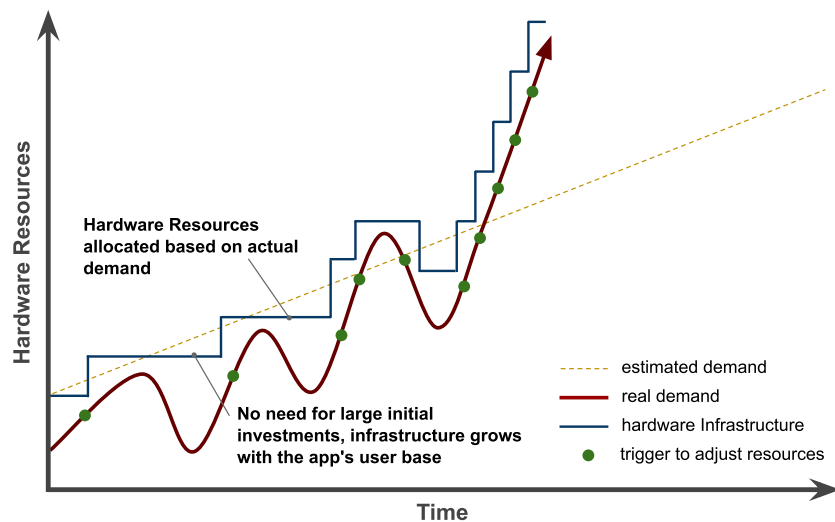
## Traditional Solution to Infrastructure

- 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 Service Concepts

- **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*
- **Usage**
  - *Cloud native applications*
  - *Moving existing applications from on-premise to cloud*

## Overview

- Introduction
- **Infrastructure as a Service**
  - *Infrastructure as Code*
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## Terminology (1)

- Region
  - *A localized geographical area*
  - *A cloud provider usually has multiple regions around the world.*
- Availability Domain
  - *A datacenter in a region; there can be more AD in a region*
- Tenancy
  - *Isolated partition where a customer creates and organizes cloud resources.*
- Instance
  - *Compute host running in the cloud*
- Bare Metal
  - *Physical host that run directly on bare metal servers without hypervisor*
- Shape/Class
  - *Amount of computing resources allocated to the instance*
  - *CPUs, Memory, Local Disk, Network Bandwidth, Number of VNICs*
- Image
  - *A template of a virtual hard drive that defines operating system and other software for an instance.*

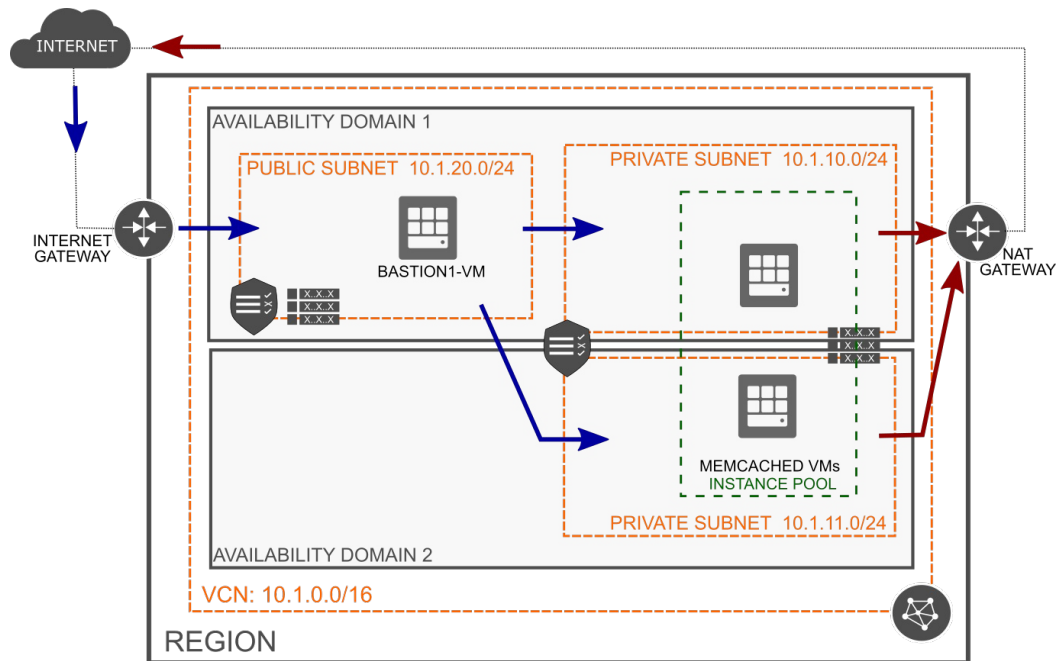
## Terminology (2)

- Instance Pool
  - *A group of instances*
- Virtual Cloud Network (VCN)
  - *A virtual network in which instances run*
  - *It includes: **subnets**, **route tables**, **firewall rules**, **gateways***
- Block Volume
  - *A virtual disk providing persistent storage*
  - *It can be used as a volume attached to the instance*
- Object Storage
  - *Allows to store and manage data as objects in logical containers (**buckets**)*
  - *The data can be of any type and are usually of large size*
  - *The data does not change frequently*
  - *Examples: data backup, storing unstructured data, sensor-generated data*

## Access and Usage

- Layers
  - *Cloud Infrastructure → REST API → CLI, Web Console, other tools*
- Key pair
  - *Authentication mechanism using **public** and **private** key*
  - *public key is uploaded to an instance, a client uses the private key to authenticate*
  - *Example: ssh using key authentication to access ssh daemon running in Linux*

## IaaS Example



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## Overview

- Definition
  - *Application envs (in a cloud) managed via definition files*
  - *Version control, team development, scripting, etc.*
- Major Technologies
  - **Configuration Management Tools**
    - *install and manage software on machines that already exist*
    - *Examples: Ansible, Chef, Puppet*
  - **Abstraction of cloud infrastructure**
    - *Terraform*

## Terraform

- Higher-level abstraction of the datacenter and associated services
- Supports many service providers
  - *Google, Microsoft, Oracle, AWS*
- Steps
  1. *Description of resources in Hashicorp Configuration Language (HCL)*
    - *instances, networks, firewall rules, routing tables, etc.*
  2. *Terraform generates execution plan to reach the desired state*
  3. *Terraform executes the plan to reach the desired state; can generate incremental execution plan*

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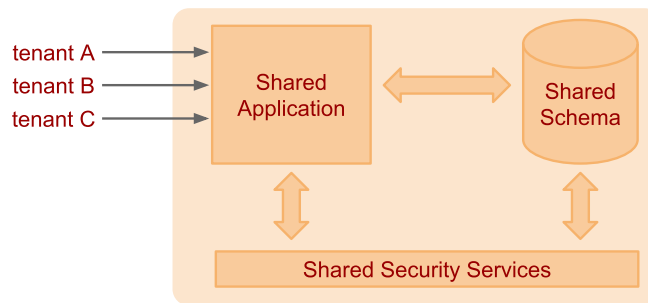
## Multitenancy

- 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*



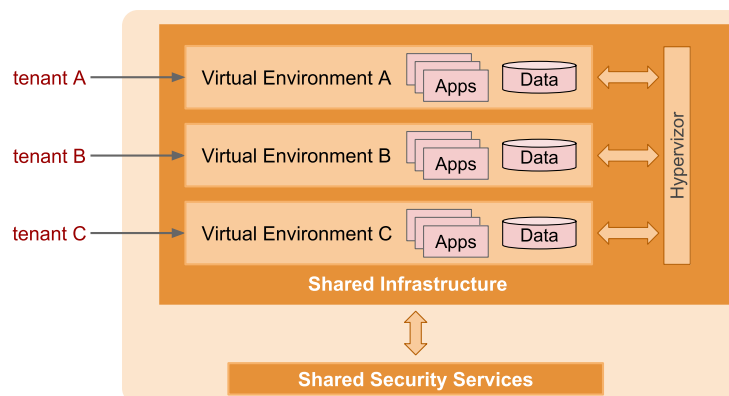
## Shared Everything

- 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



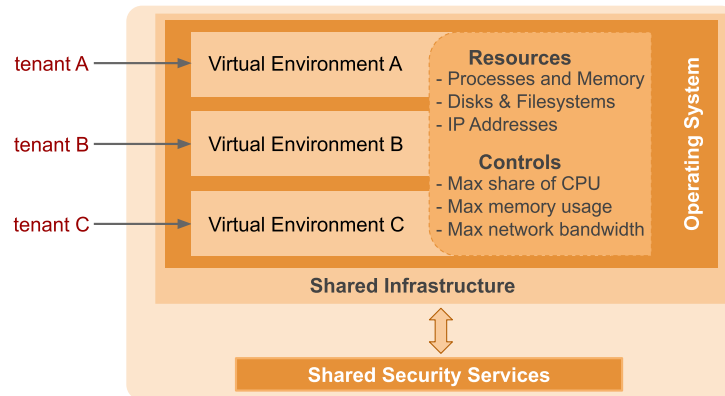
## Shared Infrastructure: Virtual Machines

- 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



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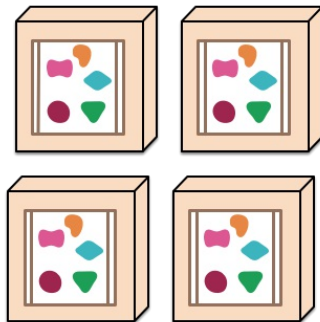
## Overview

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

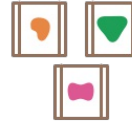
A monolithic application puts all its functionality into a single process...



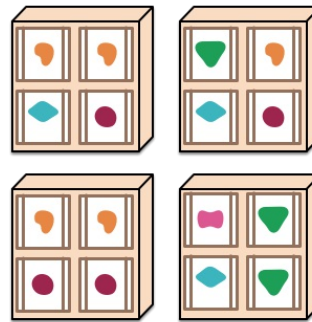
... and scales by replicating the monolith on multiple servers



A microservices architecture puts each element of functionality into a separate service...



... and scales by distributing these services across servers, replicating as needed.



## 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.*
- Implemented using different technologies
  - *polyglot – programming languages, databases*

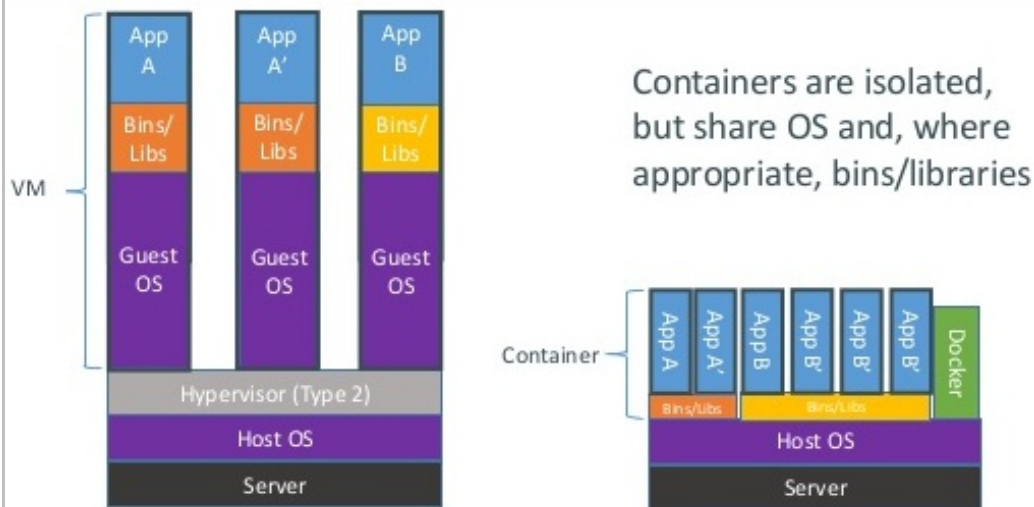
## Overview

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- Docker
  - *Overview*
  - *Image Layering*
  - *Working with Docker*
  - *Swarm*
- Kubernetes

## 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*

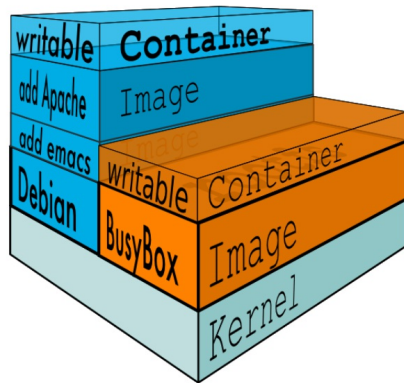
## VM vs. Docker Containers



## 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



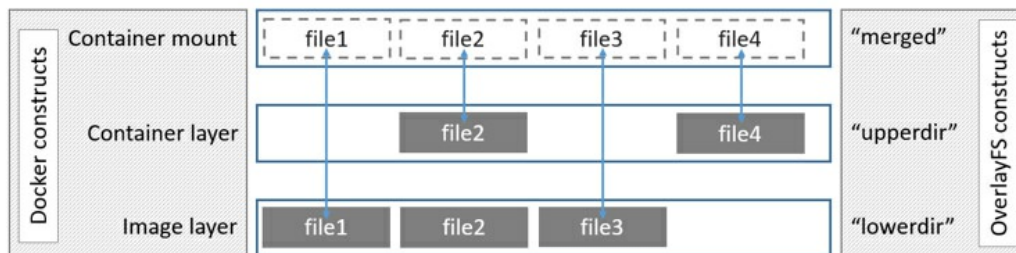
- Containers are made up of R/O layers via a storage driver (OverlayFS, AUFS, etc.)
- Containers are designed to support a single application
- Instances are ephemeral, persistent data is stored in bind mounts or data volume containers.

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# 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
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

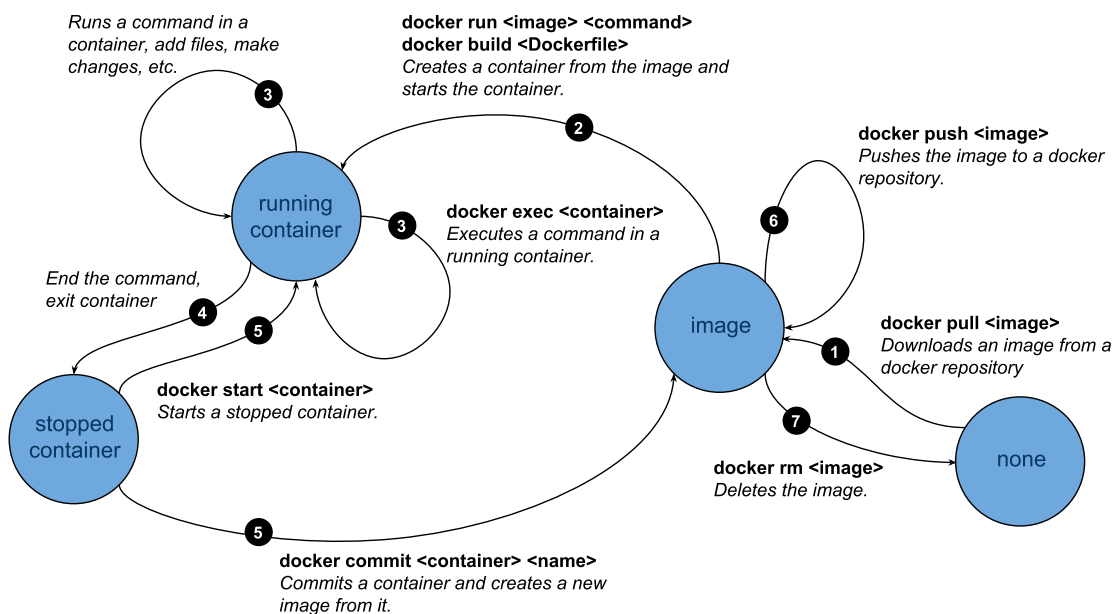
```
$ ls -l /var/lib/docker/overlay/
total 20
drwx----- 3 root root 4096 Jun 20 16:11 38f3ed2eac129654acef11c32670b534670c3a06e483fce313d72e3e
drwx----- 3 root root 4096 Jun 20 16:11 55f1e14c361b90570df46371b20ce6d480c434981cbda5fd68c6ff61
drwx----- 3 root root 4096 Jun 20 16:11 824c8a961a4f5e8fe4f4243dab57c5be798e7fd195f6d88ab06aea92
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 files** shared with lower layers

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## 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 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 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

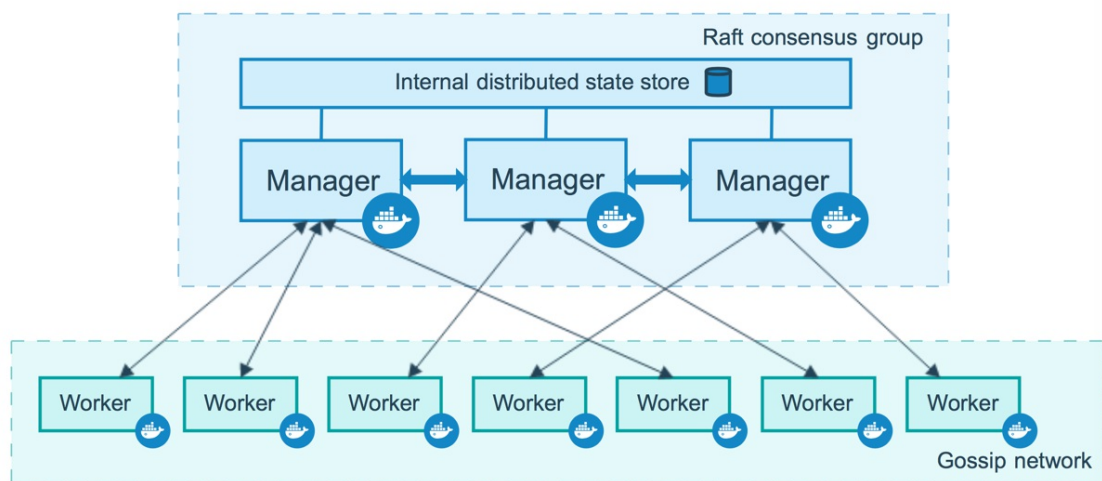
```
$ docker build -t tomvit/httpd:v1 .
Sending build context to Docker daemon 2.048 kB
Step 1 : FROM oraclelinux:7
----> 4c357c6e421e
Step 2 : MAINTAINER Tomas Vitvar <tomas@vitvar.com>
----> Running in 35feebb2ffab
----> 95b35d5d793e
Removing intermediate container 35feebb2ffab
Step 3 : RUN yum install -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 processing fails at some step, all preceding steps will be loaded from the cache on the next run.*

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## Swarm

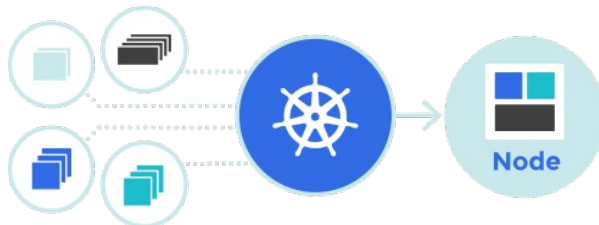


## Overview

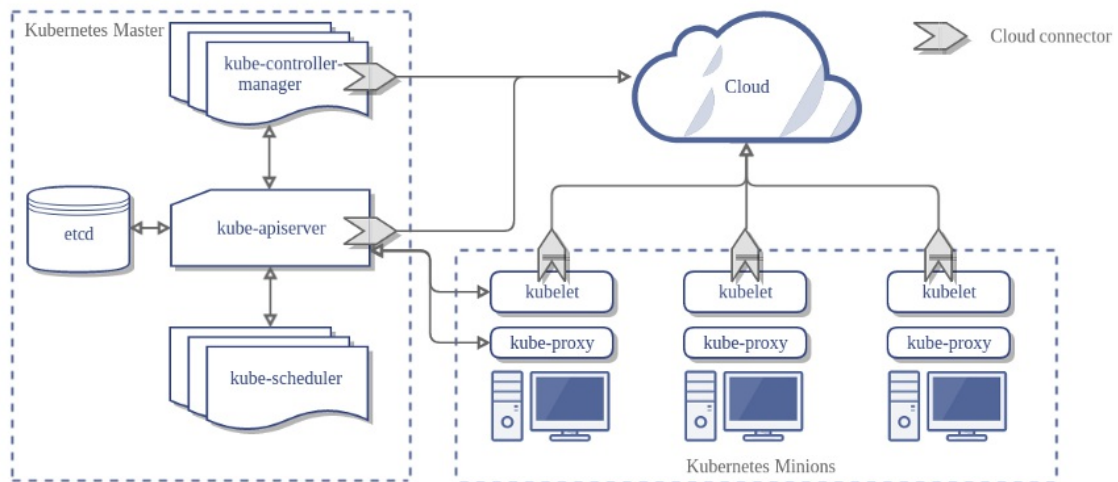
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## Overview

- 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 Google



# 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.

## 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`.