Web 2.0

Lecture 2: Cloud Architectures

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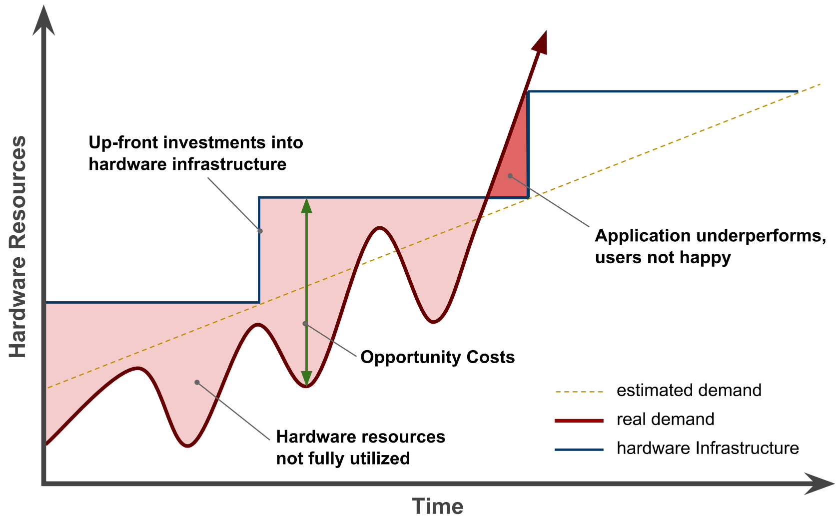
Modified: Sun Feb 24 2019, 23:08:11
Humla v0.3

Overview

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

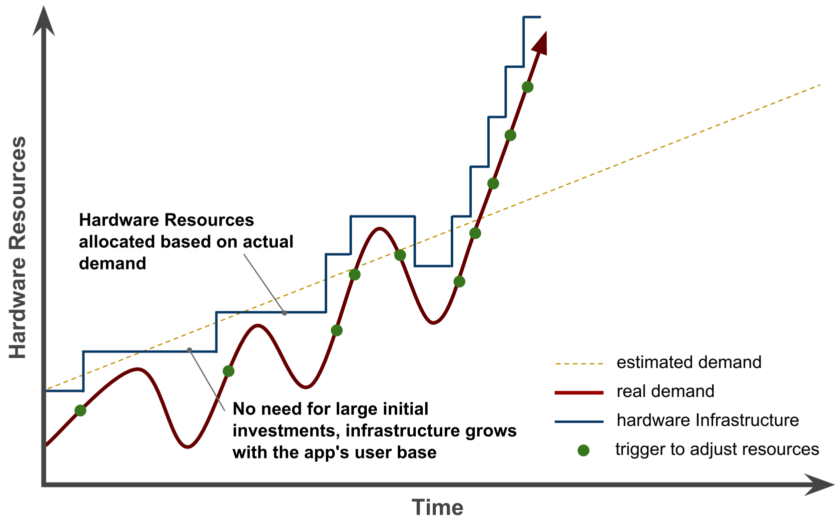
Traditional Solution to Infrastructure

- 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*

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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.*

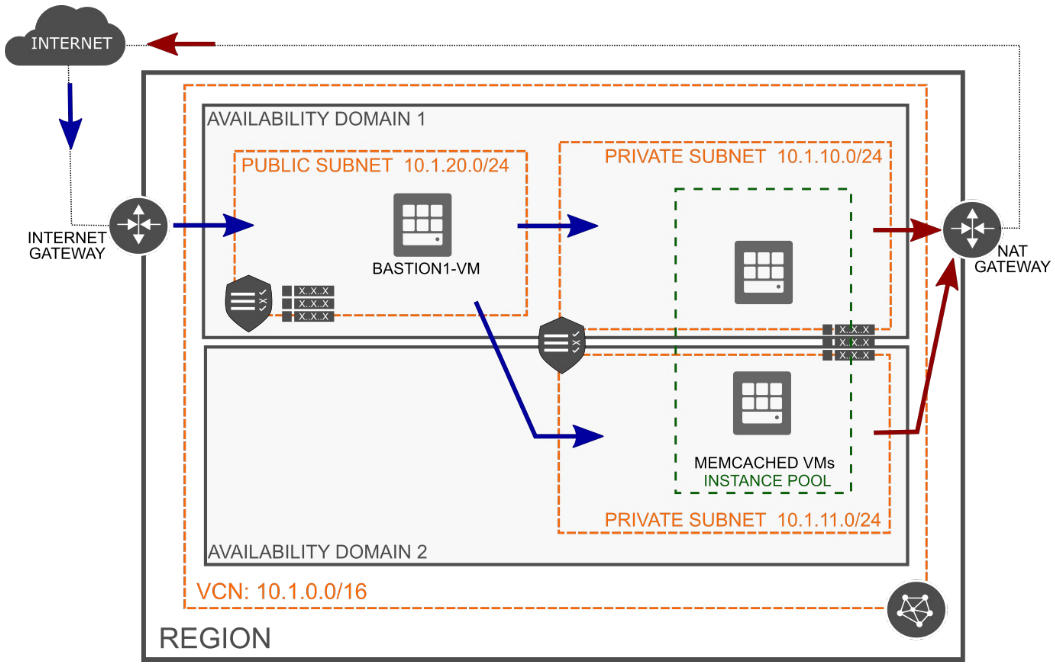
Terminology (2)

- 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 deamon running in Linux*

IaaS Example



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Overview

- Definition
  – *Application envs (in a cloud) managed via definition files*
  – *Version control, collaborative development, scripts, 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, fw rules, routing, etc.*
  2. *Terraform generates execution plan to reach the desired state*
  3. *Execution of the plan to reach the desired state; can generate incremental execution plan*

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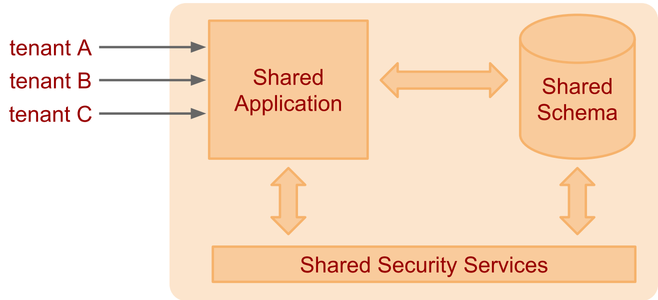
Multitenancy

- 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*

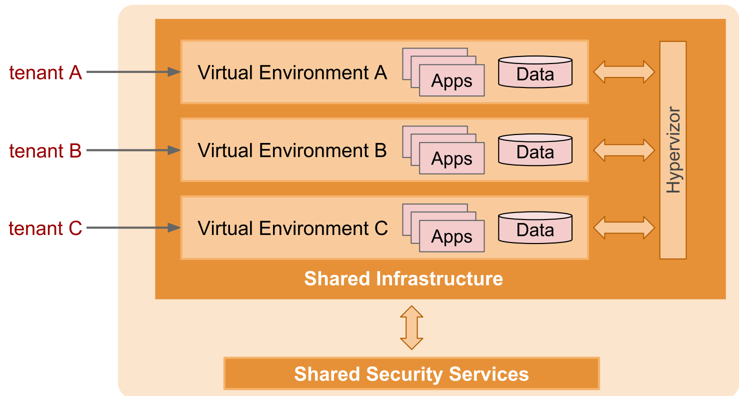
Shared Everything

- 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



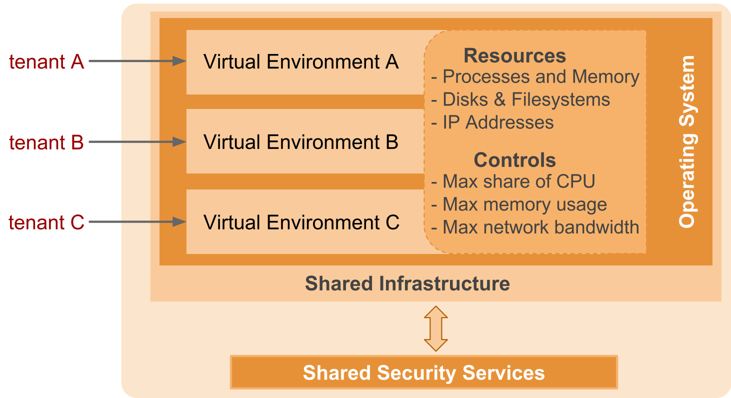
Shared Infrastructure: Virtual Machines

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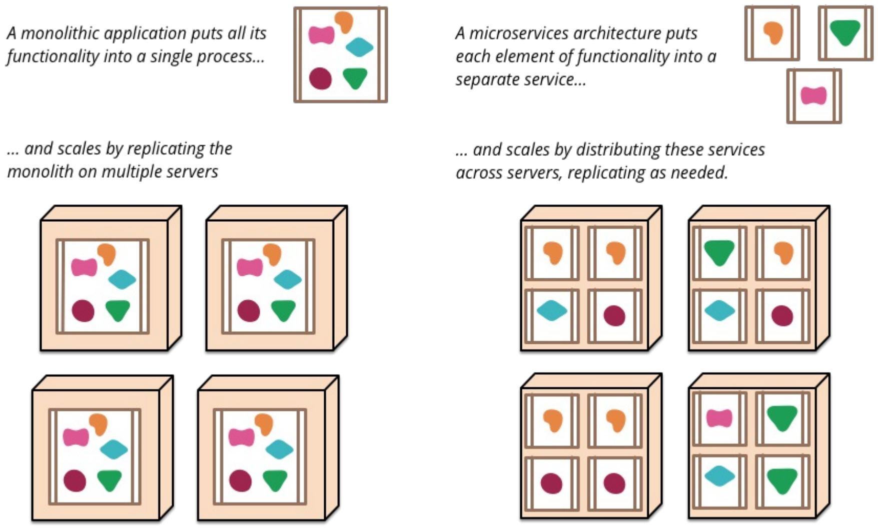
- Emerging software architecture
  - *monolithic vs. decoupled applications*
  - *applications as independently deployable services*



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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  – *Image Layering*
  – *Working with Docker*
  – *Swarm*
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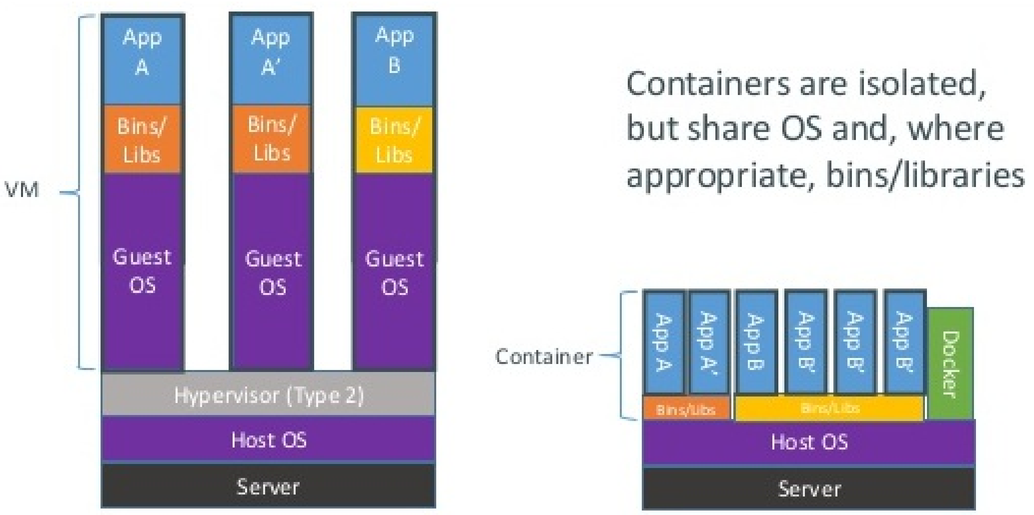
Overview

- 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*

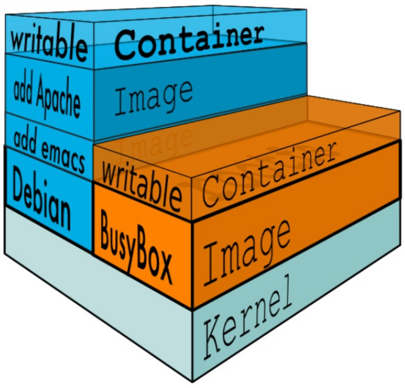
VM vs. Docker Containers



Docker Basic Terms

- Image
  - *Bssis 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.*

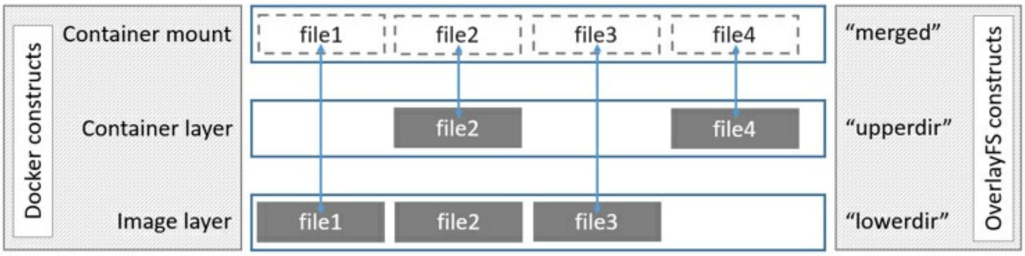

Image Layers Example

- 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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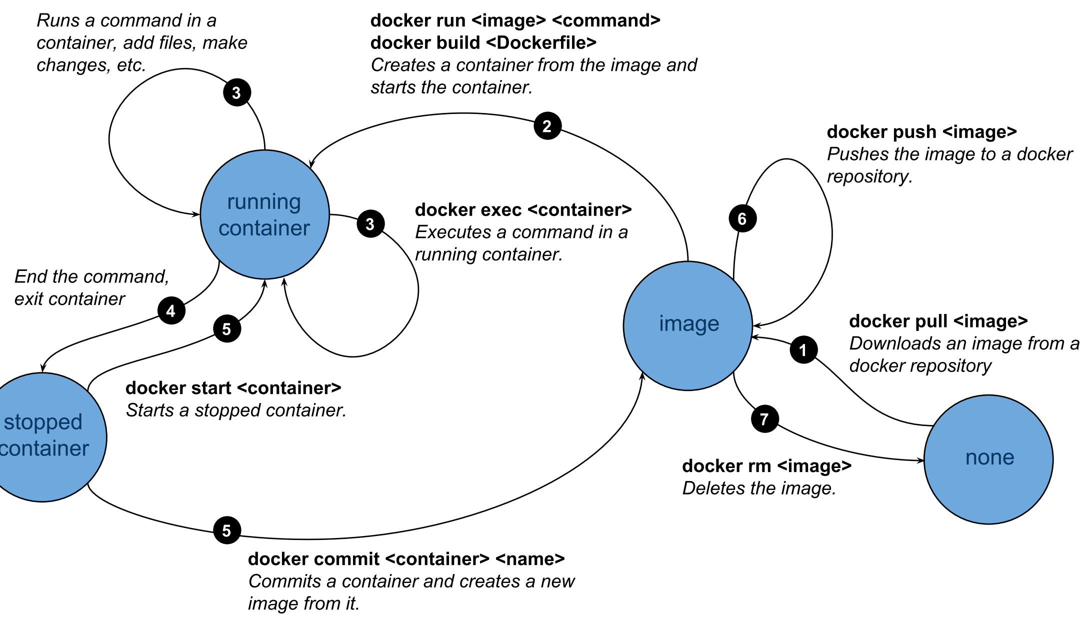
Docker Container Lifecycle State Diagram



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 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
  ```


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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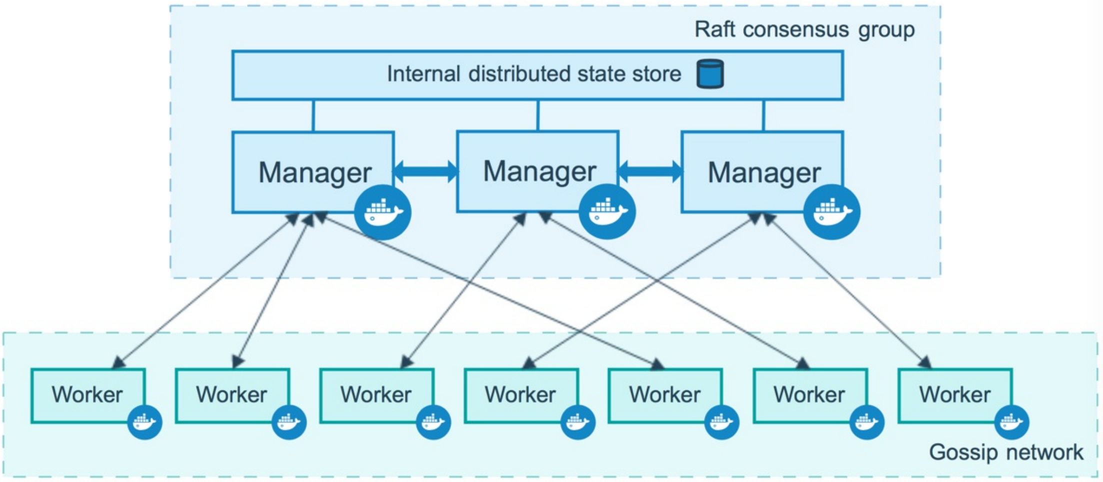
Swarm



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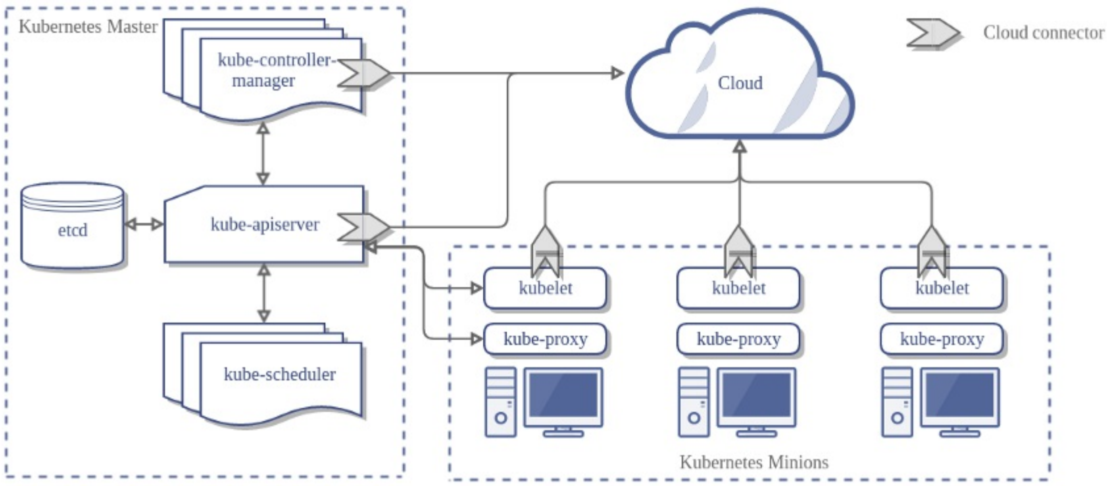
- In your architecture...
  - *Containers are atomic pieces of application architecture*
  - *Containers can be linked (e.g. web server, DB)*
  - *Containers access shared resources (e.g. disk volumes)*
- Kubernetes
  - *Automation of deployments, scaling, management of containerized applications across 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.*

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`.