# Web 2.0 Lecture 2: Cloud Architectures

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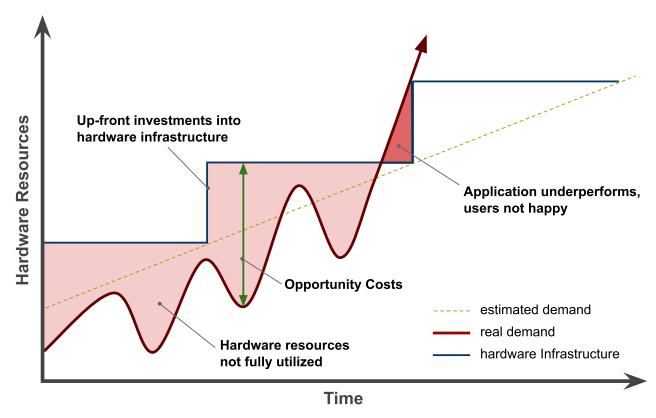




- Introduction
- Infrastructure as a Service
- Multitenancy
- Microservices Architecture
- Docker
- Kubernetes

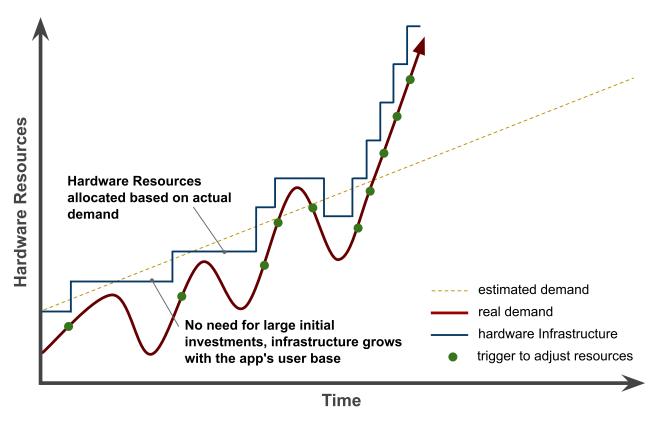
### **Traditional Solution to Infrastructure**

- 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
    - $\rightarrow$  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.

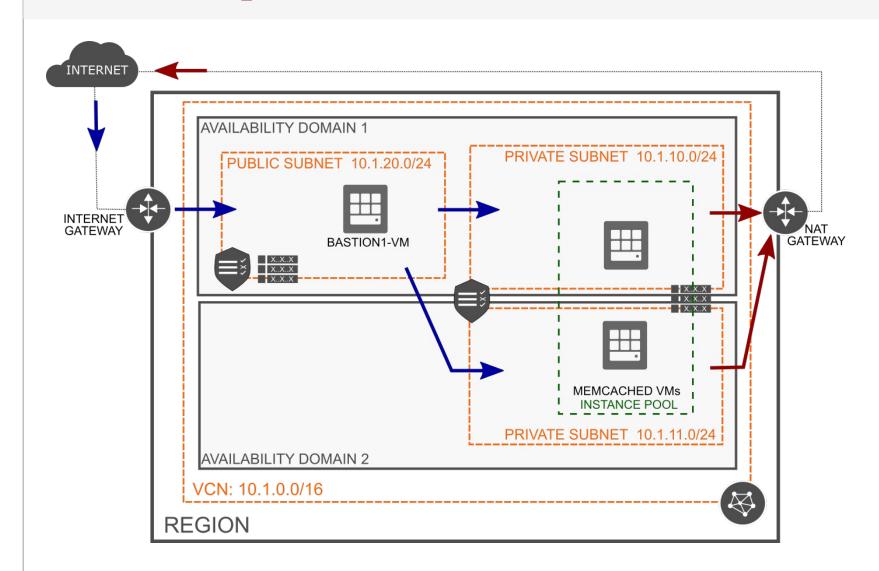
# Terminology (2)

- 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  $\rightarrow$  REST API  $\rightarrow$  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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- 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
    - $\rightarrow$  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

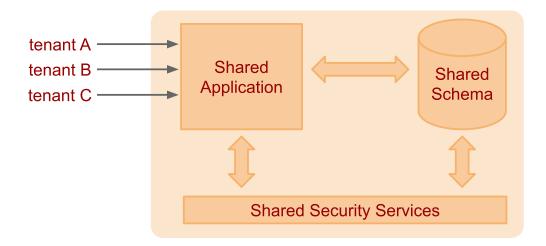
- Introduction
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- Multitenancy
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# **Multitenancy**

- 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
    - $\rightarrow$  O/S virtualization

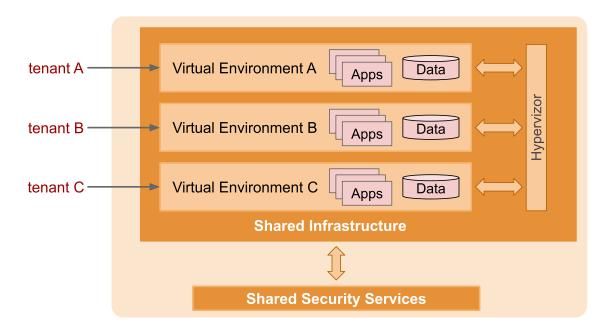
# **Shared Everything**

- 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



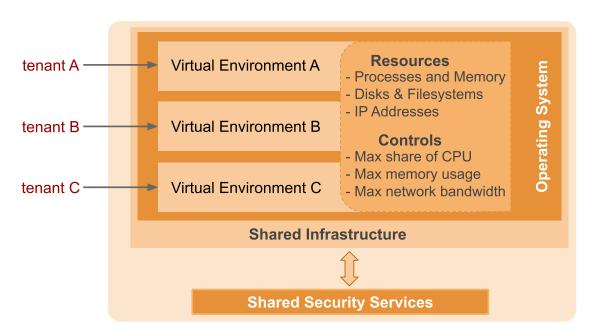
### **Shared Infrastructure: Virtual Machines**

- 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



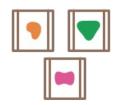
- Introduction
- Infrastructure as a Service
- Multitenancy
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- Emerging software architecture
  - monolithic vs. decoupled applications
  - applications as independenly deployable services

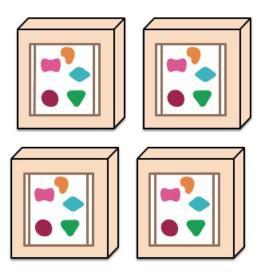
A monolithic application puts all its functionality into a single process...



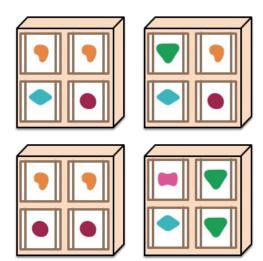
A microservices architecture puts each element of functionality into a separate service...



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



... 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.
- Impplemented using different technologies
  - polyglot programming languages, databases

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  - Overview
  - Image Layering
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  - Swarm
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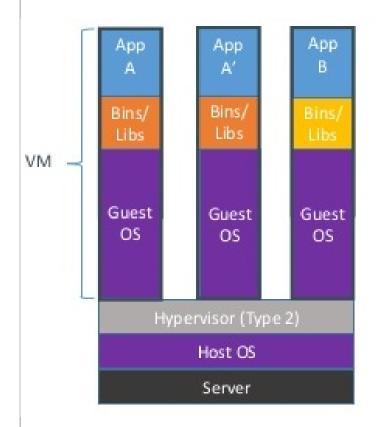
#### • Linux Containers

- 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

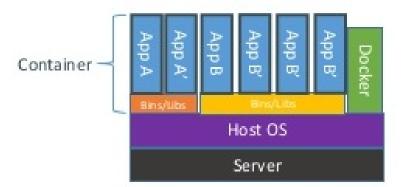
### Implementations

- LXC default implementation in Linux
- Docker Containers
  - → Builds on new Kernel features: control groups (cgroups), kernel namespaces, union-capable file system (OverlayFS, AUFS, etc.)
  - $\rightarrow$  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



Containers are isolated, but share OS and, where appropriate, bins/libraries



### **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.

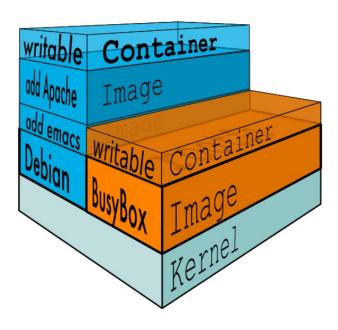
#### Registry

- 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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  - Overview
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  - Swarm
- Kubernetes

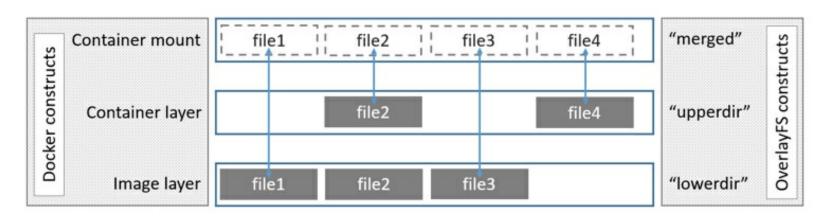
# Image Layering with OverlayFS

#### 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

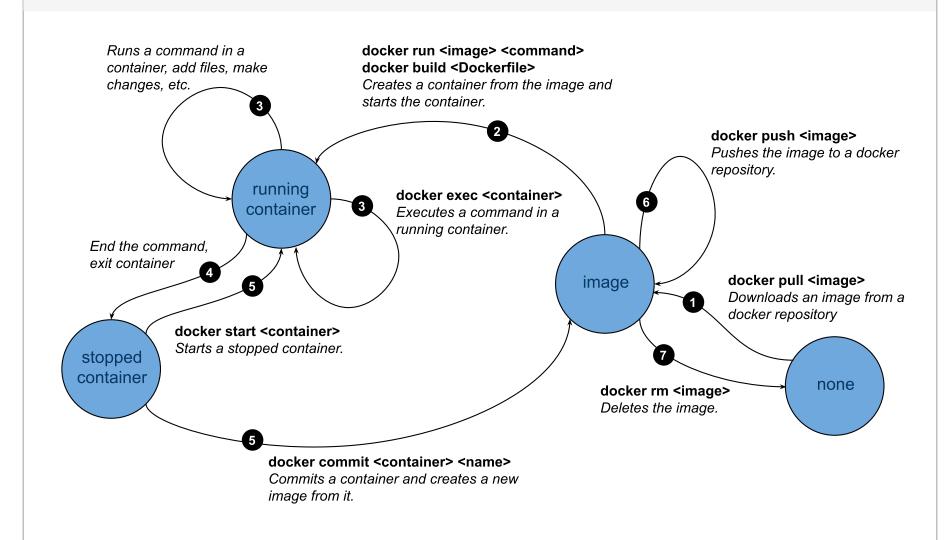
```
$ ls -l /var/lib/docker/overlay/
```

```
total 20
drwx----- 3 root root 4096 Jun 20 16:11 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

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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 1s

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
```

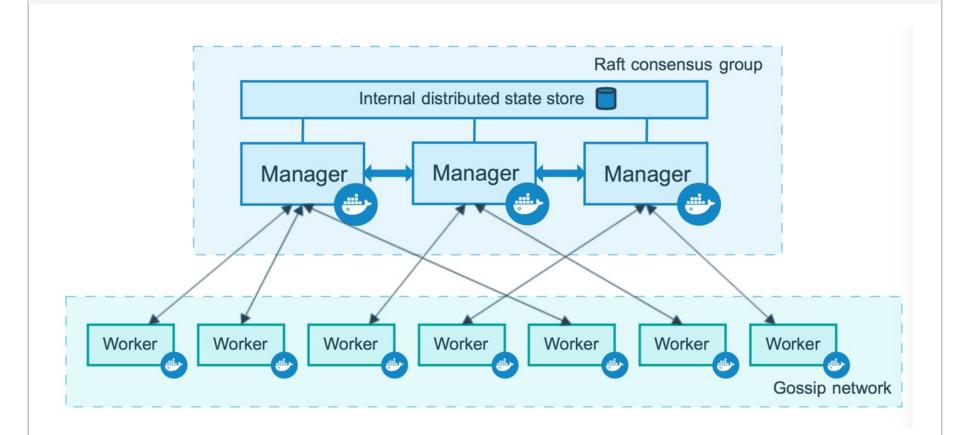
• A line in the Dockerfile will create an intermediary layer

```
$ 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 preceding steps will be loaded from the cache on the next run.

- Introduction
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  - Swarm
- Kubernetes

### Swarm

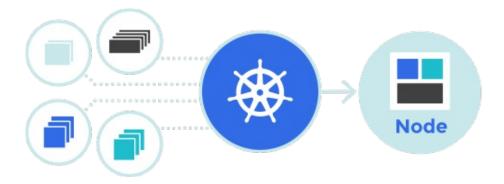


- Introduction
- Infrastructure as a Service
- Multitenancy
- Microservices Architecture
- Docker
- Kubernetes

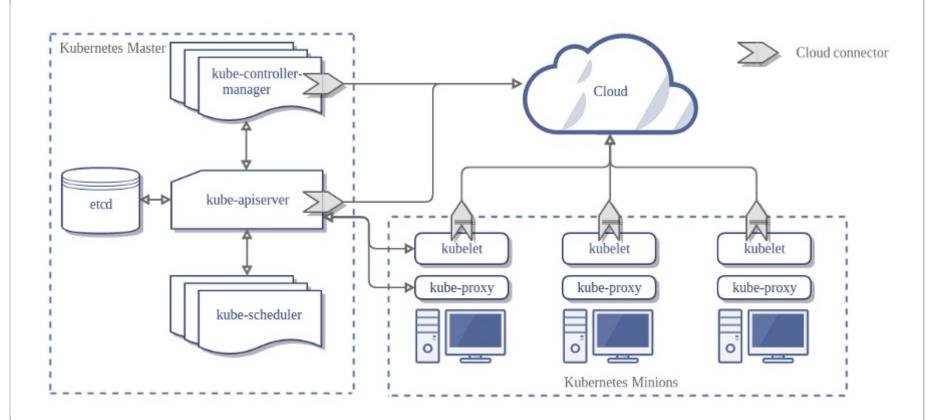
- In your architecture...
  - Containers are atomic pieces of application architecture
  - Containers can be linked (e.g. web server, DB)
  - Containers access shared resources (e.g. disk volumes)

#### 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:
  - $\rightarrow$  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:
  - $\rightarrow$  ReplicaSet ensures that a specified number of pod replicas are running.
  - $\rightarrow$  Deployment manages ReplicaSets, provides declarative updates to pods.
  - $\rightarrow$  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.