Kubernetes 101 for Python Programmers

Learn the ABCs of Kubernetes and how to get started on using managed containers for your python development on your local machine and also for production deployments on a cloud provider-managed Kubernetes cluster.

Sachin Agarwal <sachin@bigbitbus.com>

Download the latest version of these slides from
https://github.com/bigbitbus/k8s-tutorial-python

DRAFT v.07

Visit this GitHub repository for accompanying code and documentation

https://github.com/bigbitbus/k8s-tutorial-python

Tutorial Agenda

1. Background
   - Docker container runtime
2. Kubernetes Architecture & Components
3. Kubernetes for Managed Containers
   - Installation options – local laptop/cloud/DiY
   - Services and deployments
   - Operational constructs – scaling, updating code
   - State considerations, secrets and environment variables
4. Further reading pointers

Bare-metal, Virtual Machines, Containers

Bare Metal

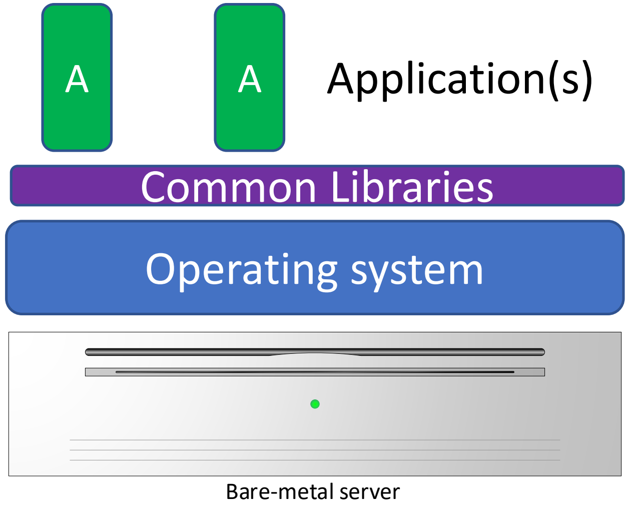
- Weak encapsulation
- Long install/start-up times
- Ideal for single application e.g. a Hadoop node
- Hard to right-size

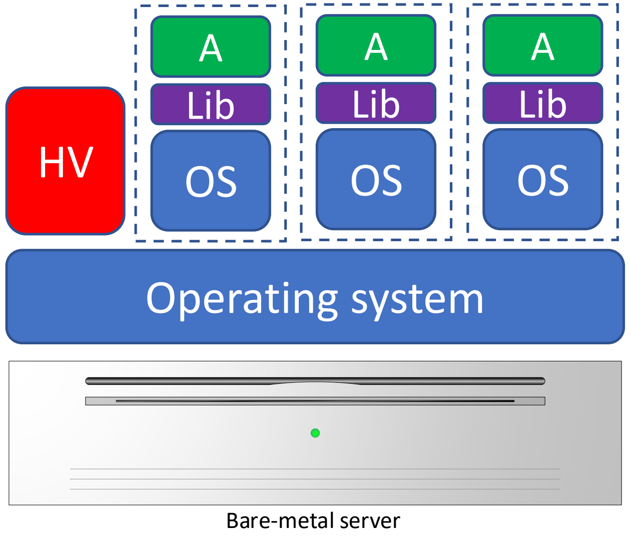
Virtual machines

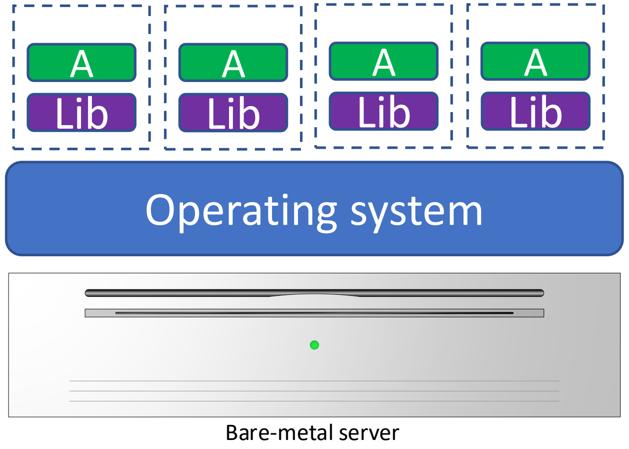
- Strong encapsulation
- Hardware emulation overhead (per VM)
- Per-VM operating system overhead
- Long install/start-up times

Containers

- Encapsulation *lite*
- Small overhead – only single kernel running
- Smaller deployment artifacts expressed as code
- Quick start-up times





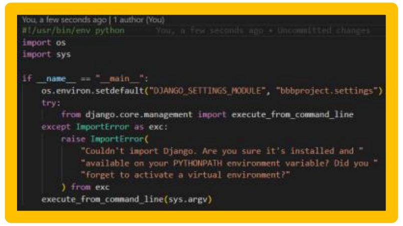


Docker – container runtime

Build

Base image

+



```
You, a few seconds ago | 1 author (You)
#!/usr/bin/env python        You, a few seconds ago • Uncommitted changes
import os
import sys

if __name__ == "__main__":
    os.environ.setdefault("DJANGO_SETTINGS_MODULE", "bbbproject.settings")
    try:
        from django.core.management import execute_from_command_line
    except ImportError as exc:
        raise ImportError(
            "Couldn't import Django. Are you sure it's installed and "
            "available on your PYTHONPATH environment variable? Did you "
            "forget to activate a virtual environment?"
        ) from exc
    execute_from_command_line(sys.argv)
```

Source code

+

Packages/libraries

Docker image

Upload

Docker Hub
Upload/Download
Images

Image repository

Run

- *Download immutable image*
- *Configure and run*

Application Code

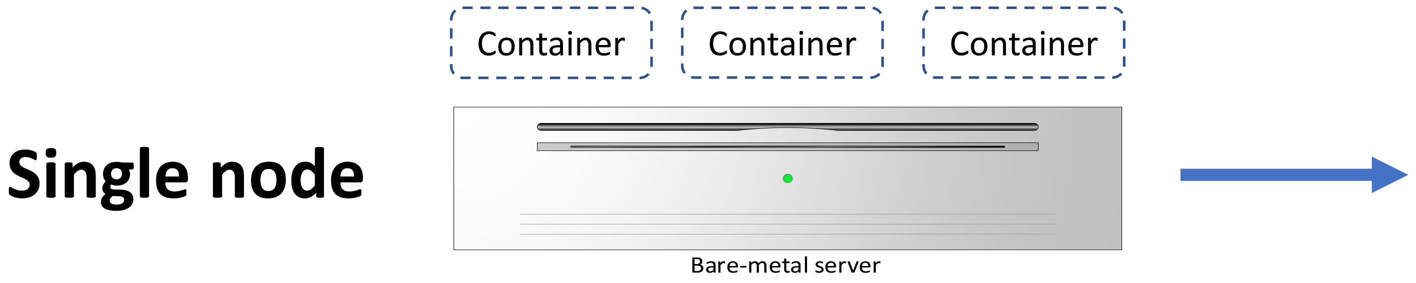
Packages

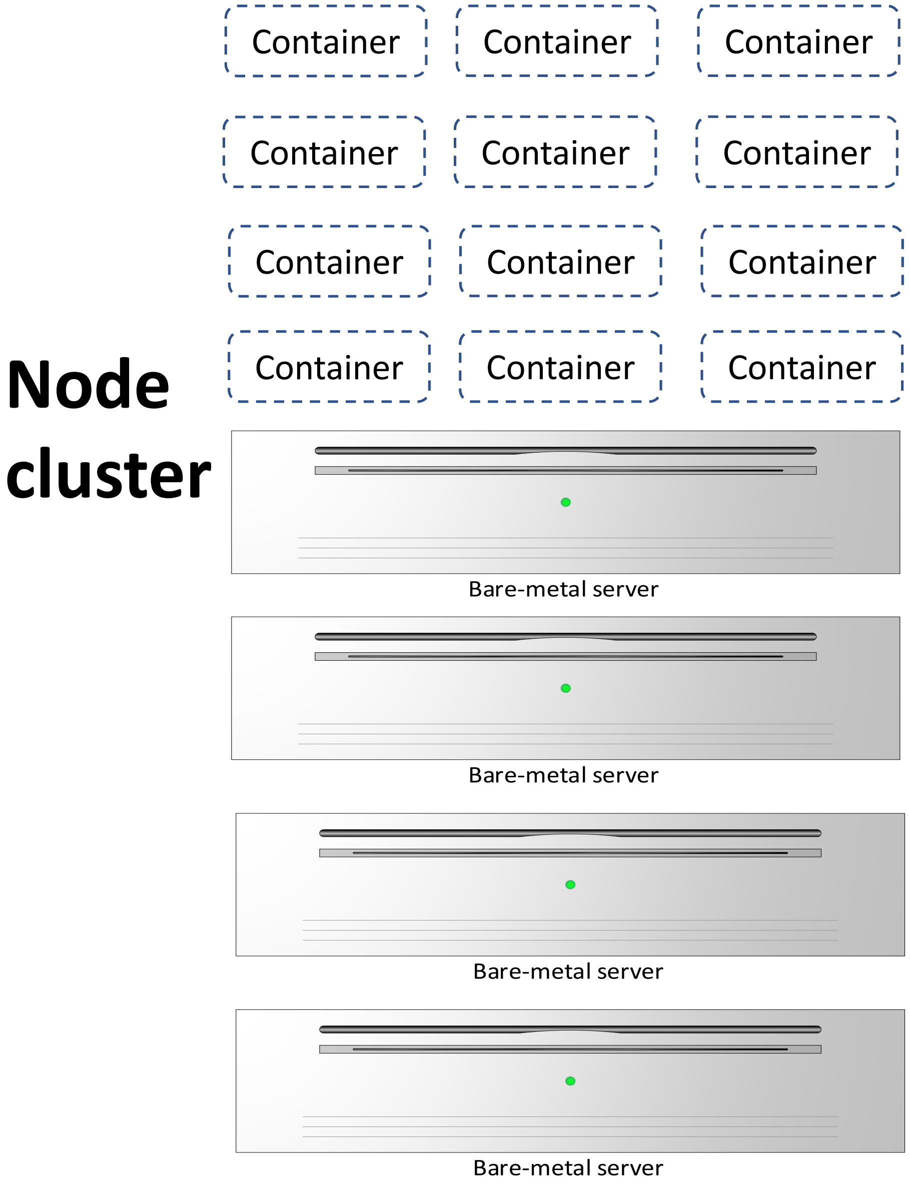
Libraries

Configuration

Inject environment and secrets at runtime

Beyond Single Node Docker





Multi-node production scale-out?

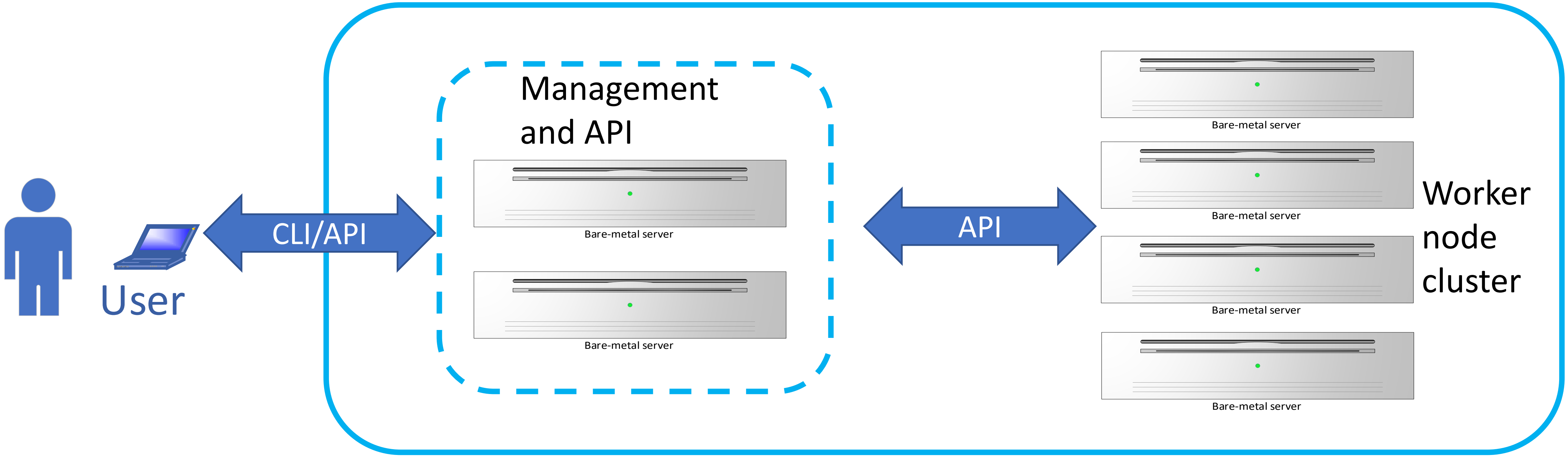
1. *High-availability*
2. *Horizontal scalability*

Beyond Manual Containers

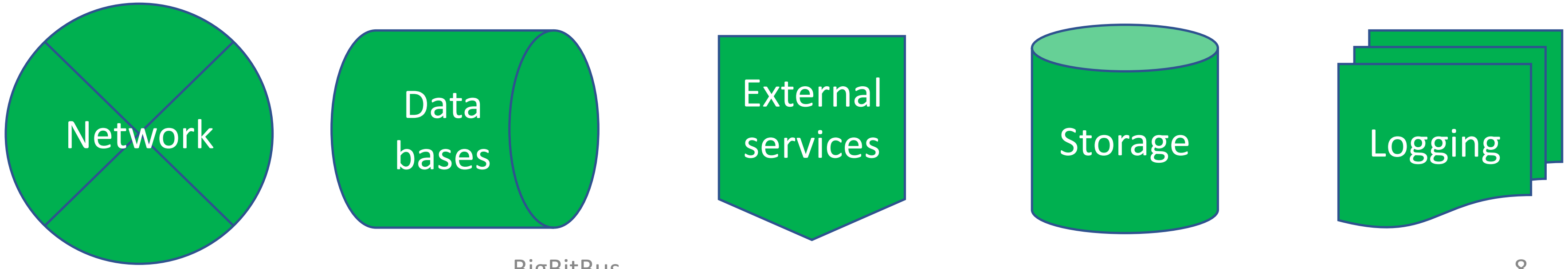
kubernetes

1. Multiple node container runtime cluster
    - Load-balancing across multiple containers
    - Service discovery
    - Fairness and resource sharing among different applications
2. Production Operations Management
    - Application updates & versioning
    - Monitoring for failures; auto-healing
    - Autonomous behavior – autoscaling and repairs
    - Dealing with Failures
    - Role based access controls
    - Zero-downtime upgrades

Kubernetes Cluster



External services

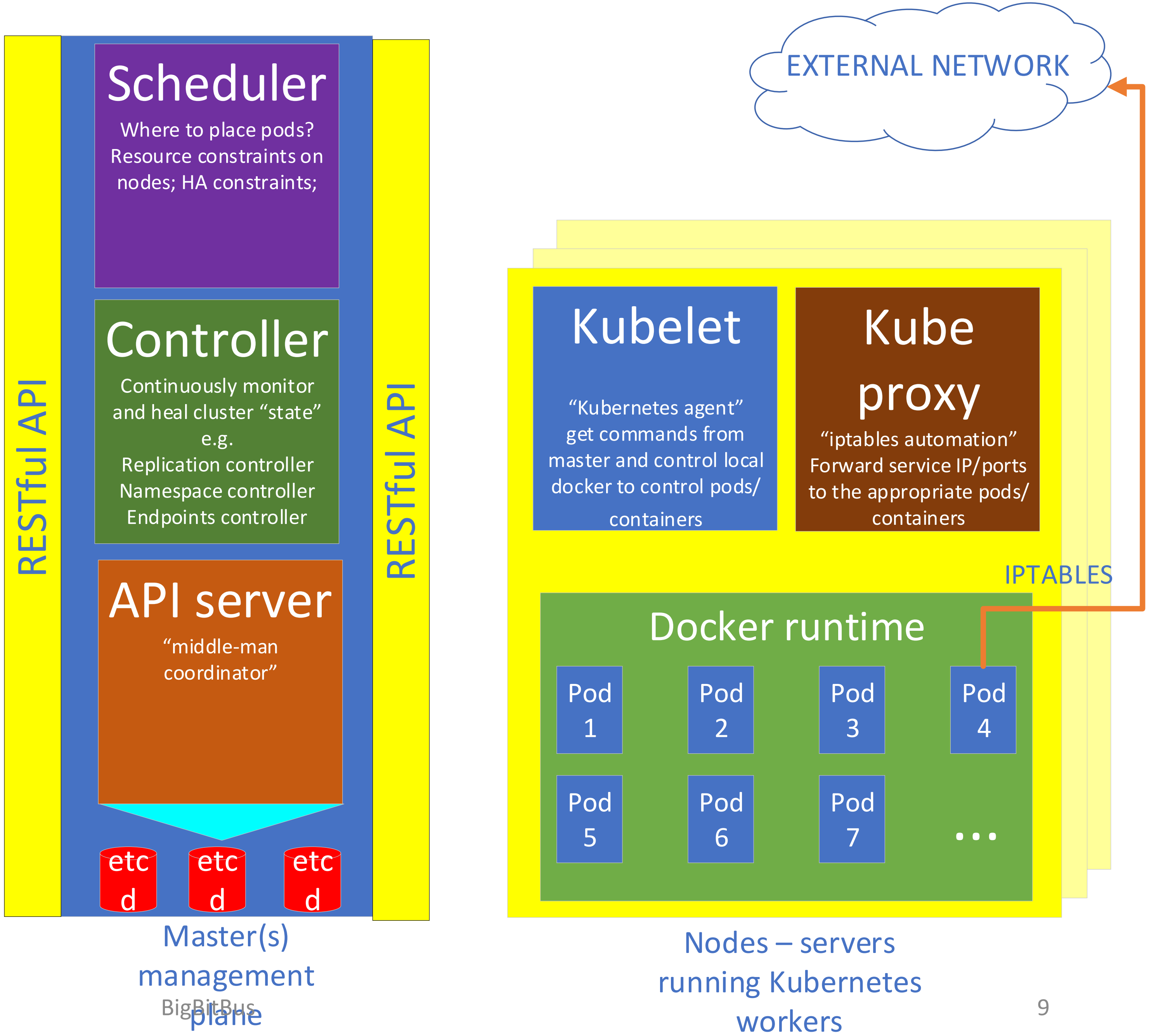


Kubernetes Architecture

Multiple components

- Management plane
- Worker plane

Worker nodes can be bare-metal or virtual machines



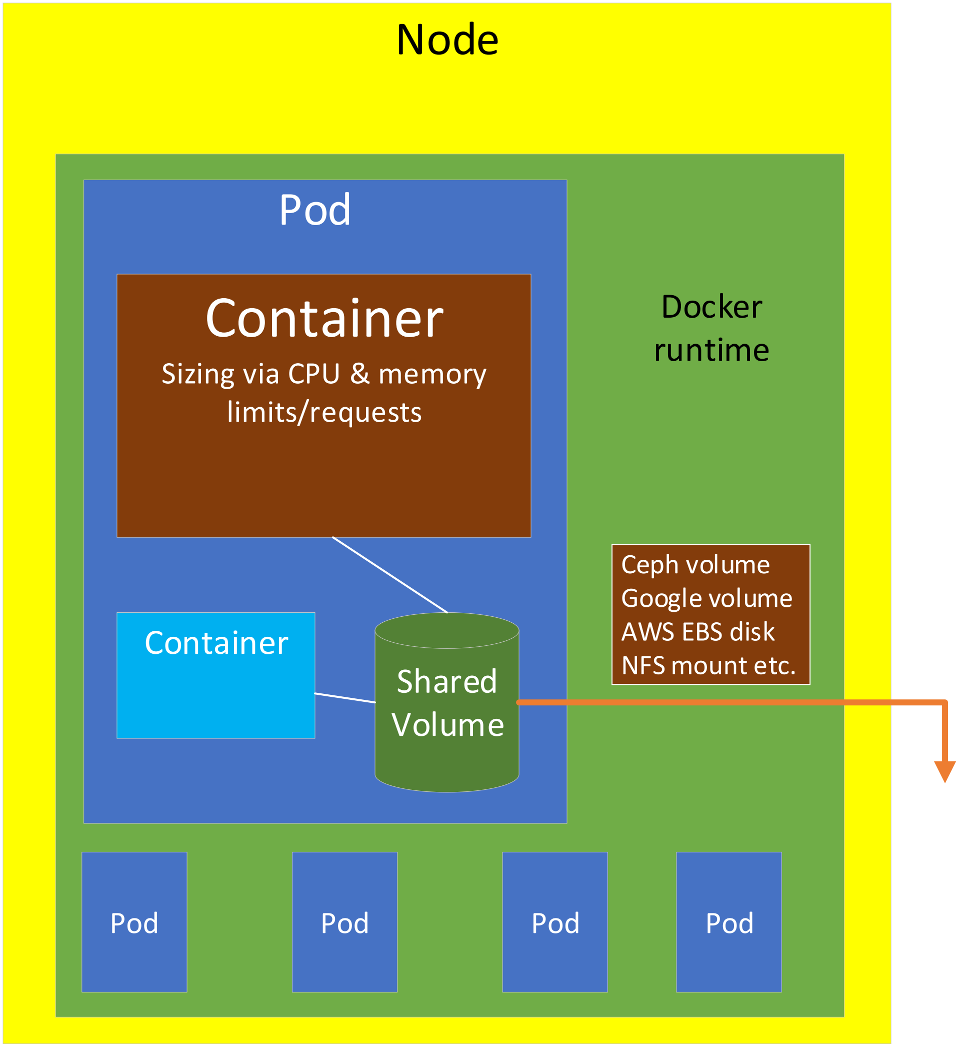
EXTERNAL NETWORK
RESTful API
Scheduler
Where to place pods? Resource constraints on nodes; HA constraints;
Controller
Continuously monitor and heal cluster "state" e.g.
Replication controller
Namespace controller
Endpoints controller
API server
"middle-man coordinator"
etcd
etcd
etcd
RESTful API
Master(s) management plane
Kubelet
"Kubernetes agent" get commands from master and control local docker to control pods/ containers
Kube proxy
"iptables automation" Forward service IP/ports to the appropriate pods/ containers
IPTABLES
Docker runtime
Pod 1
Pod 2
Pod 3
Pod 4
Pod 5
Pod 6
Pod 7
…
Nodes – servers running Kubernetes workers

Pod

- The smallest independent “unit” of infrastructure in K8s
  - Scaling/redundancy
- A logical “host”
- Multiple containers & volumes
- Localhost and IPC connectivity
- Cannot span nodes

Application server + log watcher

Application server + local cache



Node

Pod

Container

Sizing via CPU & memory limits/requests

Container

Shared Volume

Docker runtime

Ceph volume
Google volume
AWS EBS disk
NFS mount etc.

Pod

Pod

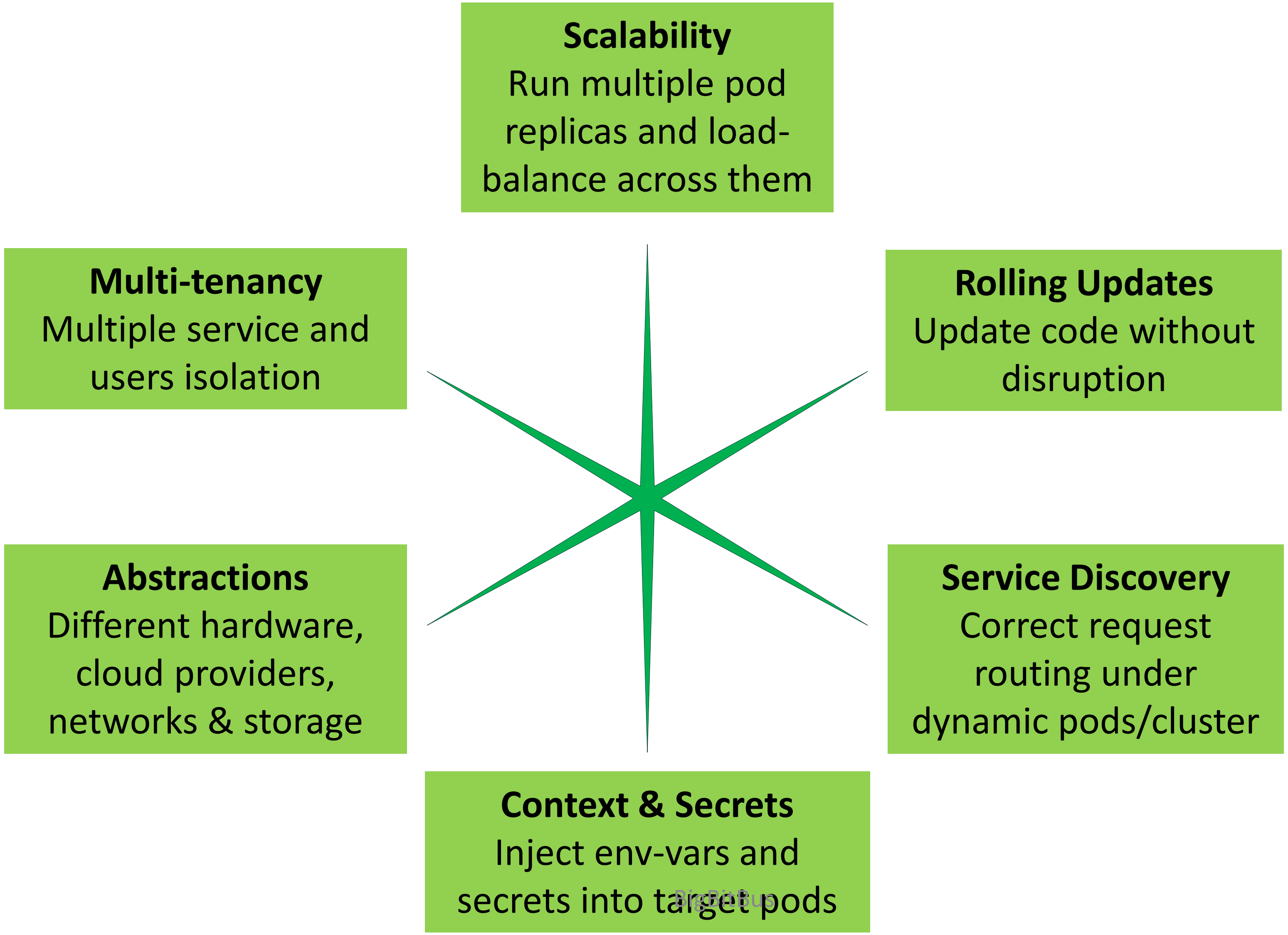
Pod

Pod

https://kubernetes.io/docs/concepts/workloads/pods/pod/

“Avoid the singleton”

Operational Requirements



Scalability
Run multiple pod replicas and load-balance across them

Multi-tenancy
Multiple service and users isolation

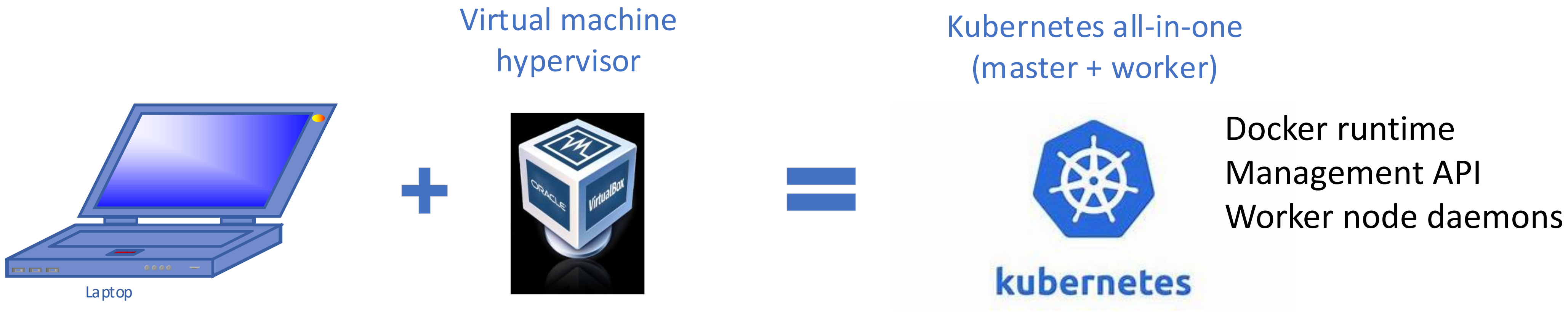
Rolling Updates
Update code without disruption

Abstractions
Different hardware, cloud providers, networks & storage

Service Discovery
Correct request routing under dynamic pods/cluster

Context & Secrets
Inject env-vars and secrets into target pods

Minikube: Kubernetes on your Laptop



Virtual machine hypervisor

Kubernetes all-in-one (master + worker)

Docker runtime
Management API
Worker node daemons

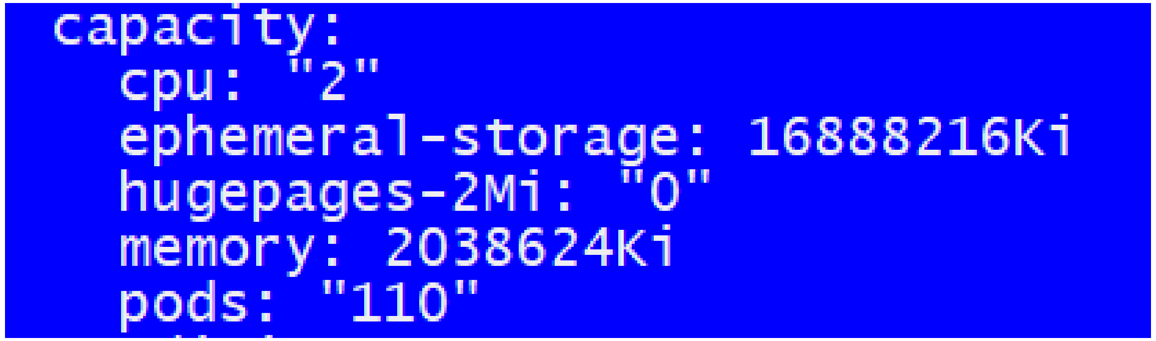
- Installation instructions for Windows, Mac and Linux
  https://kubernetes.io/docs/tasks/tools/install-minikube/

- Default: 2 cores + 2 GB RAM = capable of running a few containers

Starting minikube

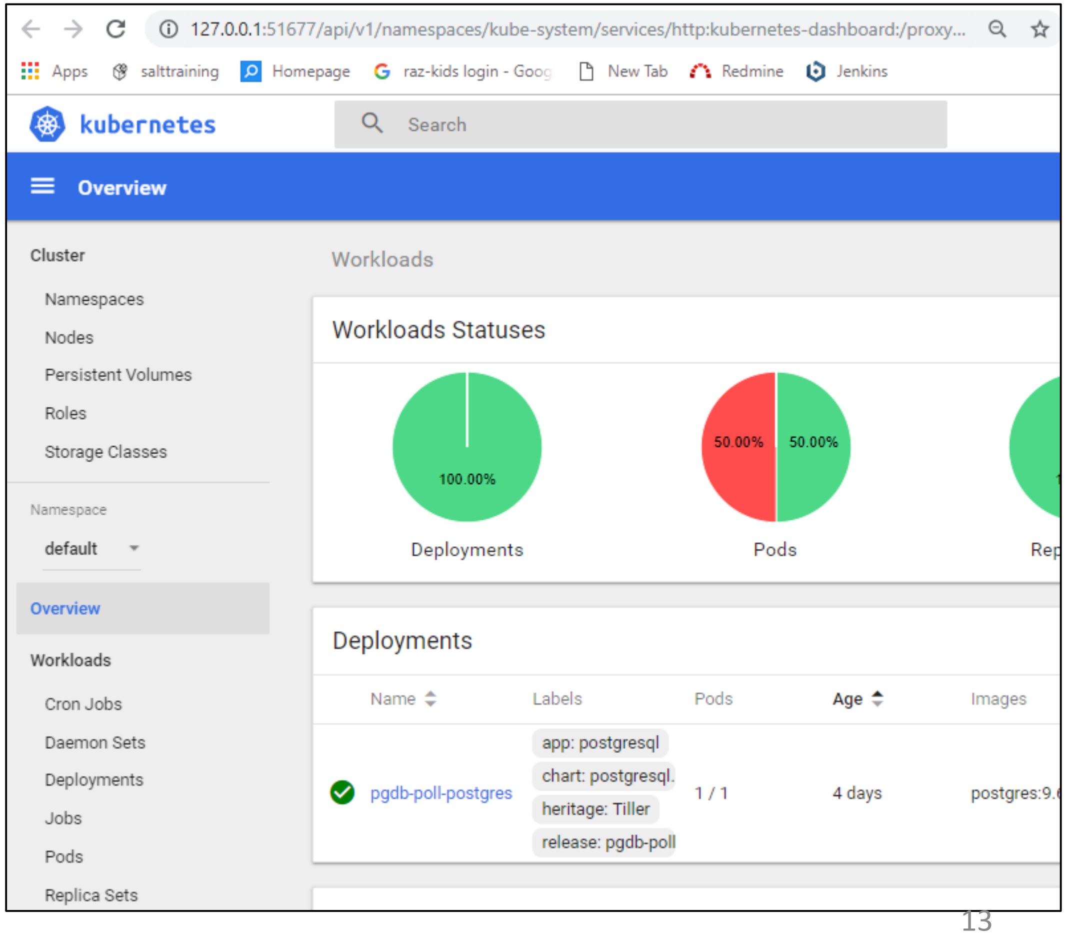
minikube cli

```
# start minikube, launch VM
$ minikube start
# check minikube status
$ minikube status
# start minikube GUI
$ minikube dashboard
```



```
capacity:
  cpu: "2"
  ephemeral-storage: 16888216Ki
  hugepages-2Mi: "0"
  memory: 2038624Ki
  pods: "110"
```

Dashboard
General-purpose web UI for Kubernetes clusters



127.0.0.1:51677/api/v1/namespaces/kube-system/services/http:kubernetes-dashboard:/proxy...

Deployments

	Name	Labels	Pods	Age	Images
✓	pgdb-poll-postgres	app: postgresql chart: postgresql. heritage: Tiller release: pgdb-poll	1 / 1	4 days	postgres:9.(

Kubectl – Kubernetes CLI

`kubectl --help`

- Wrapper around RESTful API: GET, CREATE, DEPLOY etc. action-words

```
kubectl get nodes
kubectl get nodes -o wide
kubectl get node minikube -o yaml
```

More information,
yaml or json

```
kubectl config get-contexts
kubectl config use-context aws
kubectl get nodes
```

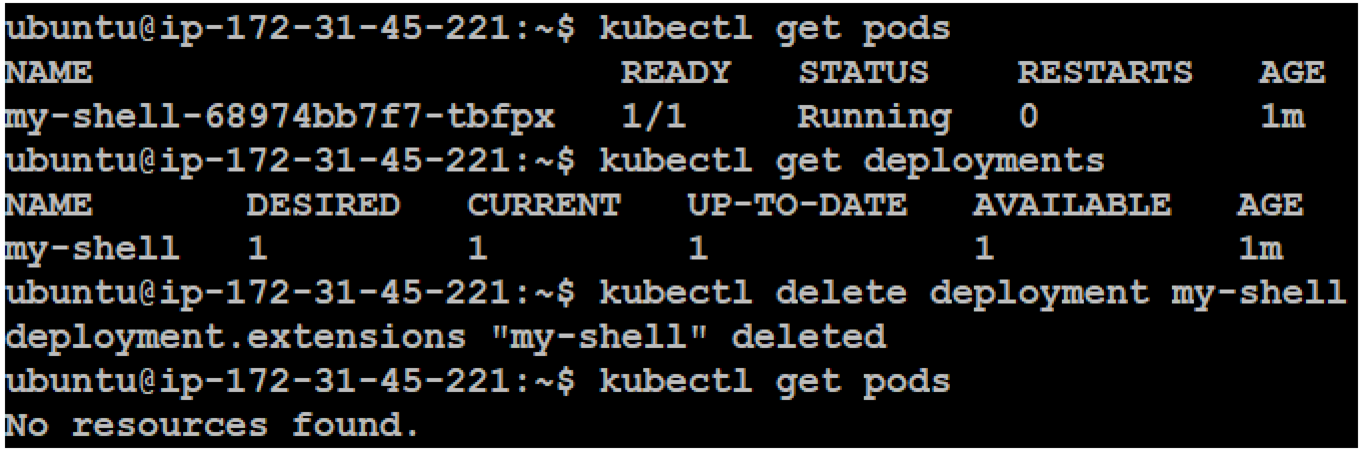
The same kubectl can point to multiple k8s clusters

```
kubectl create namespace development
kubectl get namespaces
kubectl --namespace development get pods
```

Virtual k8s cluster via namespaces

Run a one-off Pod

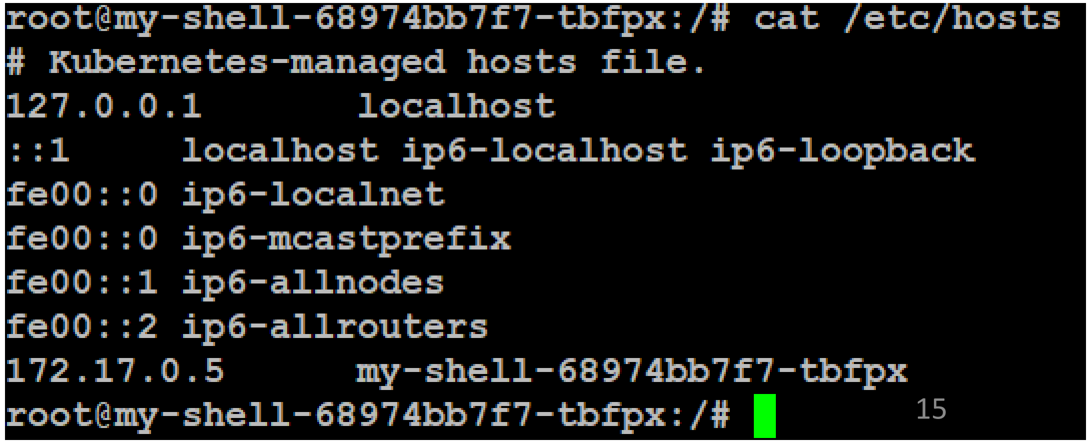
```
kubectl run my-shell --rm -i --tty --image ubuntu -- bash
```



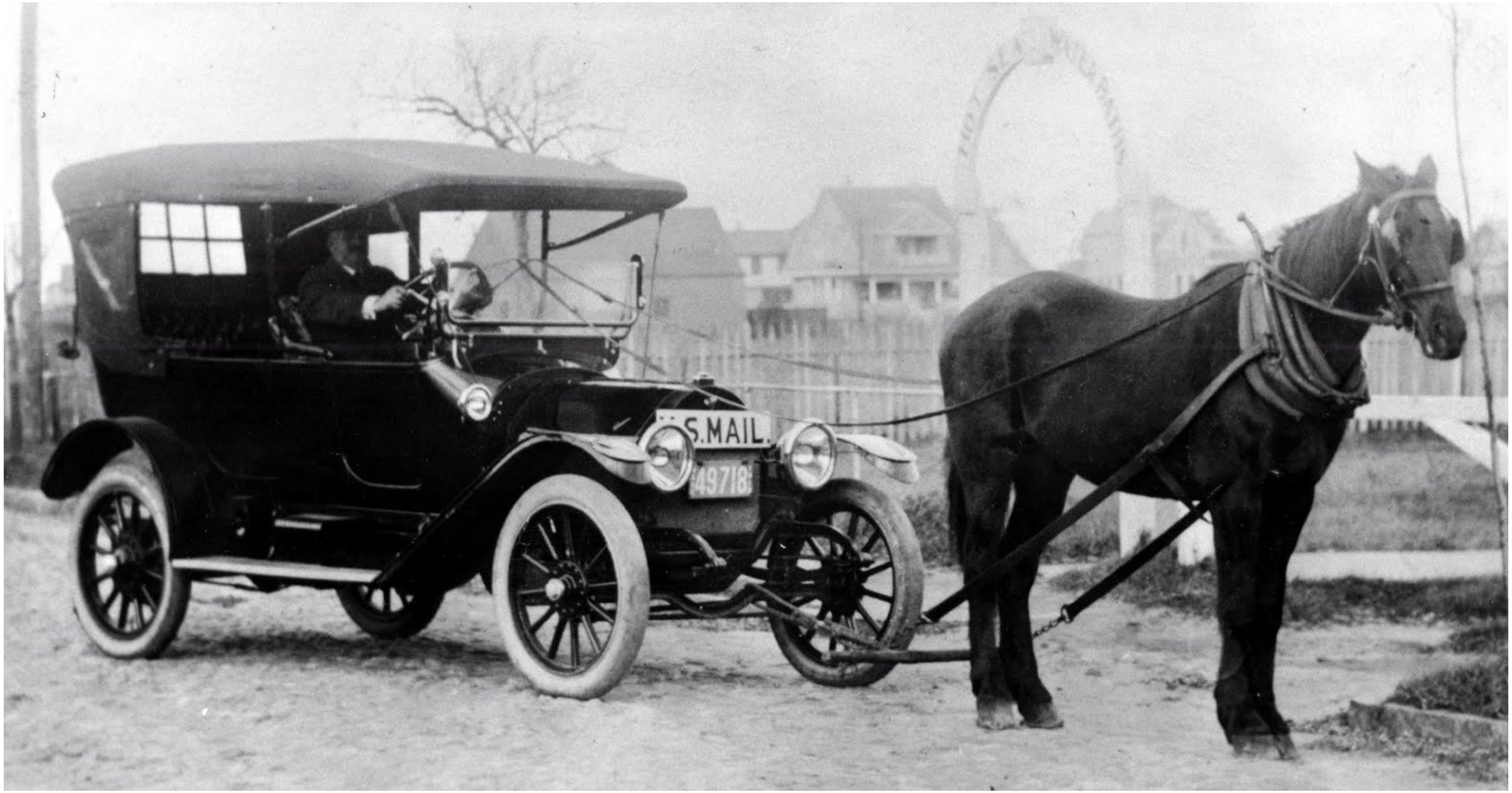
```
ubuntu@ip-172-31-45-221:~$ kubectl get pods
NAME                          READY     STATUS     RESTARTS    AGE
my-shell-68974bb7f7-tbfpx    1/1       Running    0           1m
ubuntu@ip-172-31-45-221:~$ kubectl get deployments
NAME         DESIRED    CURRENT    UP-TO-DATE    AVAILABLE    AGE
my-shell    1          1          1             1            1m
ubuntu@ip-172-31-45-221:~$ kubectl delete deployment my-shell
deployment.extensions "my-shell" deleted
ubuntu@ip-172-31-45-221:~$ kubectl get pods
No resources found.
```

A pod is created, a
A deployment is also created
Cascading delete – pod also deleted

Inside the pod
Just like a “normal” Linux box



```
root@my-shell-68974bb7f7-tbfpx:/# cat /etc/hosts
# Kubernetes-managed hosts file.
127.0.0.1       localhost
::1     localhost ip6-localhost ip6-loopback
fe00::0 ip6-localnet
fe00::0 ip6-mcastprefix
fe00::1 ip6-allnodes
fe00::2 ip6-allrouters
172.17.0.5      my-shell-68974bb7f7-tbfpx
root@my-shell-68974bb7f7-tbfpx:/# 
```

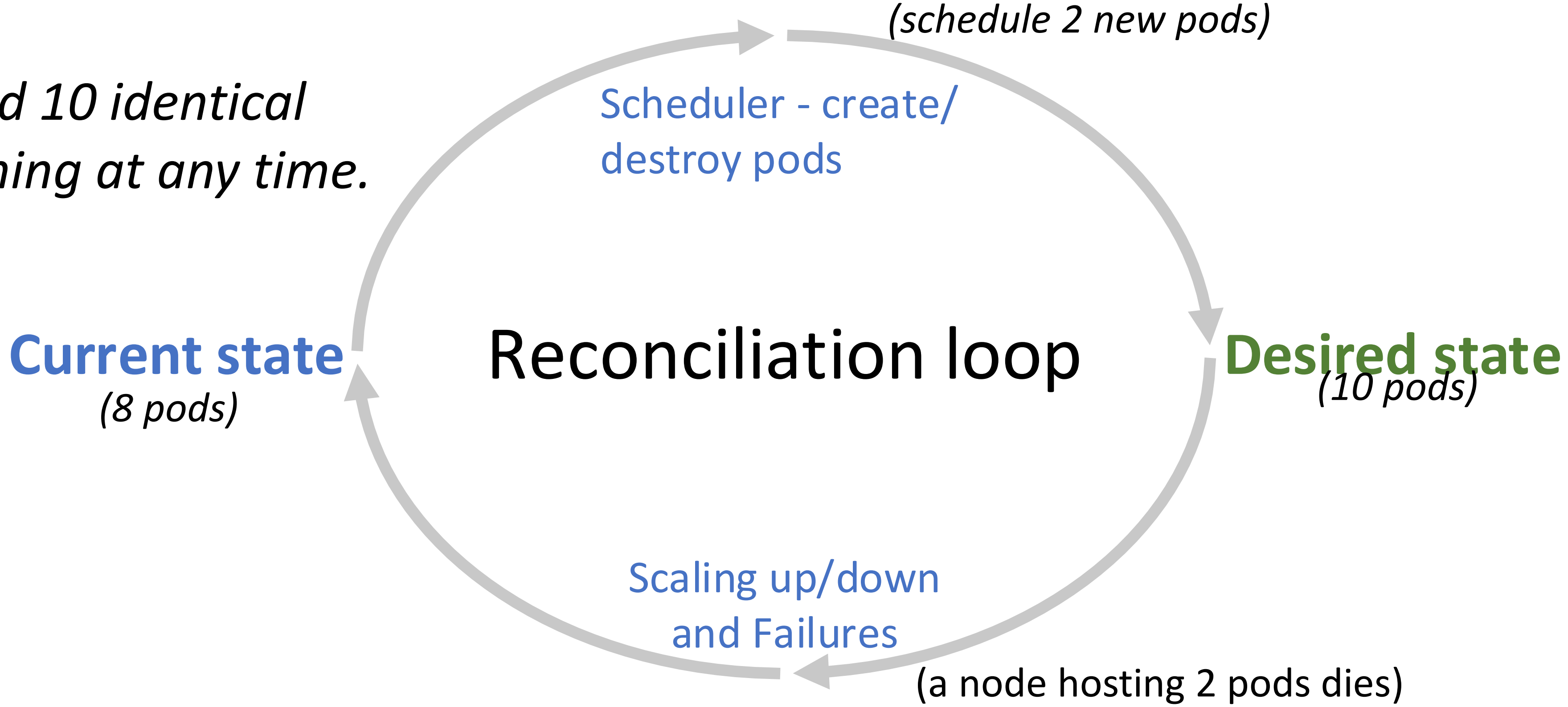


Running one-off pods is not the Kubernetes use-case

Replicasets (of pods)

- Keep a defined number of identical pod replicas running in the Kubernetes cluster

Example: We need 10 identical Django pods running at any time.



(schedule 2 new pods)

Scheduler - create/ destroy pods

Current state

(8 pods)

Reconciliation loop

Desired state

(10 pods)

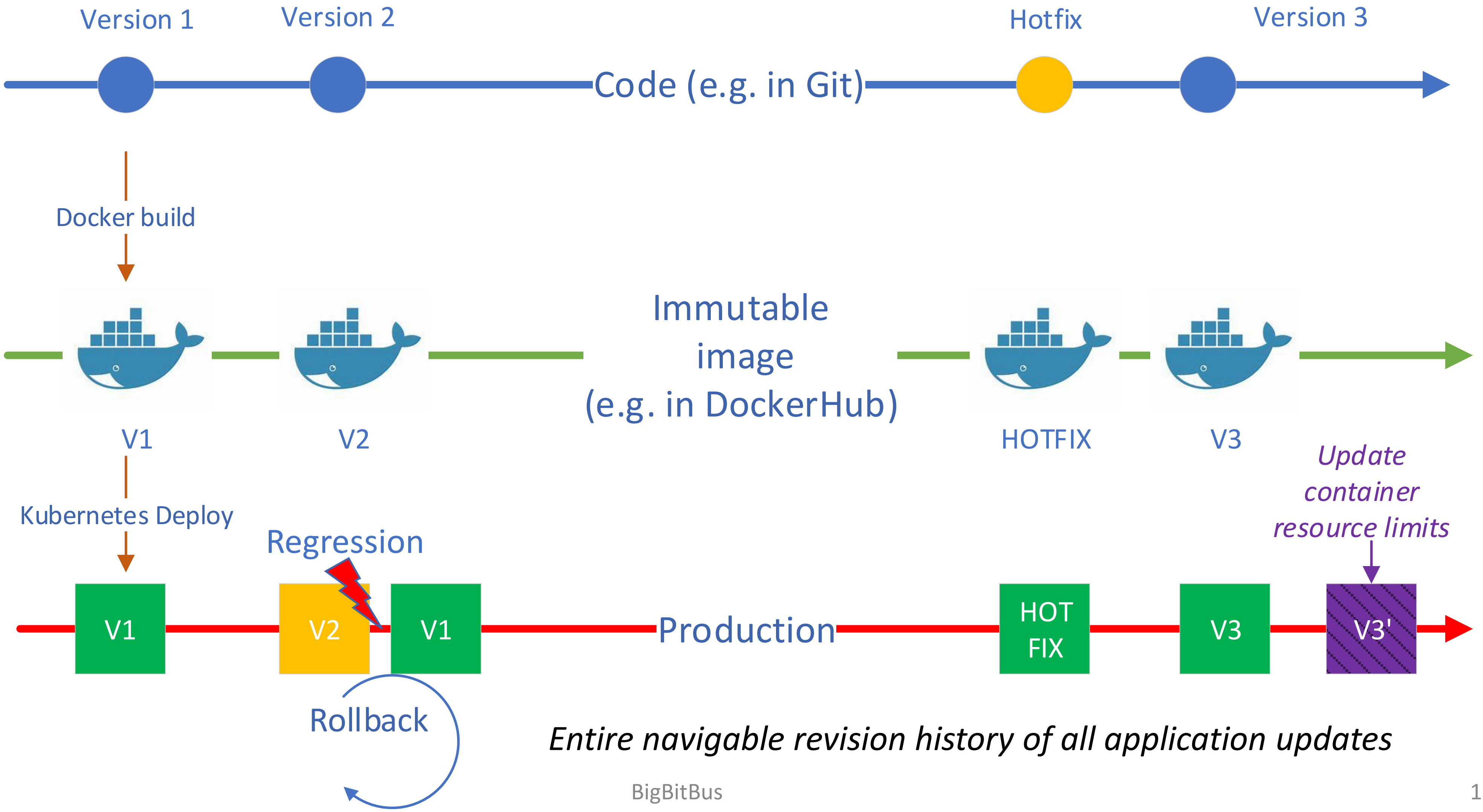
Scaling up/down and Failures

(a node hosting 2 pods dies)

https://kubernetes.io/docs/concepts/workloads/controllers/replicaset/

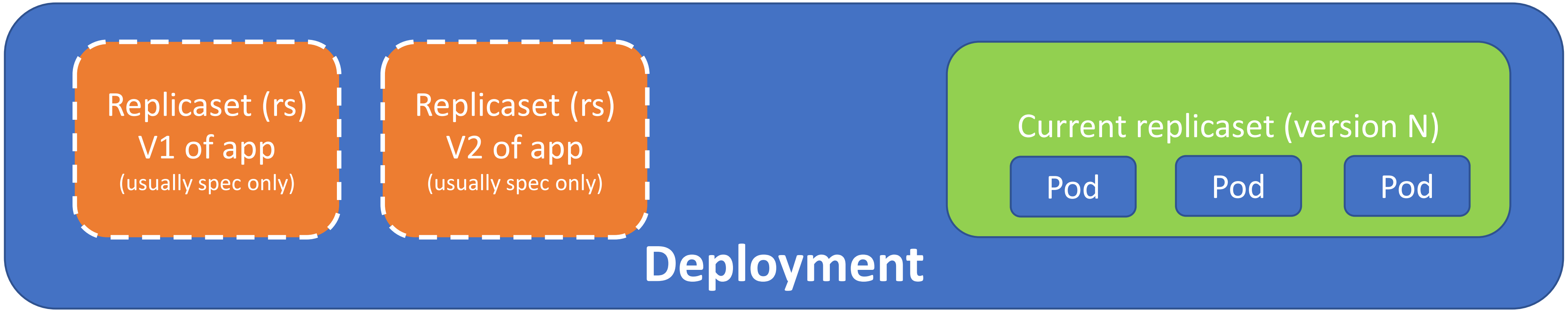
Application updates, rollbacks, jumps to any revision

Deployments



Entire navigable revision history of all application updates

Deployment defined in YAML



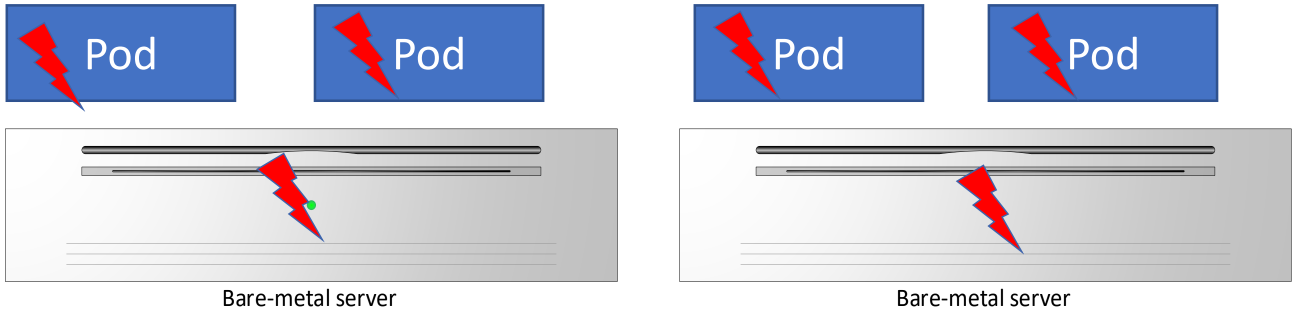
- Deployments help manage application versions
  - Click here to see the Django deployment yaml file
  - Click here to see the Postgres deployment yaml file
- A new replicaset is created every time the deployment changes
- Deleting deployments will delete the underlying replica-sets and pods

Service Discovery

1. Assign a “cluster-IP” to a service to which other services within the cluster can connect. Example
2. Expose service externally (Load-balancer). Example
3. Connect to an external service. Example

Pods are “cattle” - expendable, replaceable - not pets

Underlying pods and hardware are ephemeral and very dynamic



Environment Variables & Secrets

- Inject meta-data into pods, e.g. based on namespace
- Configmaps for environment variables
  - Example (development vs. production namespace)
- Configmaps are very powerful e.g. for injecting custom scripts etc.
- Secrets
  - Create a secret

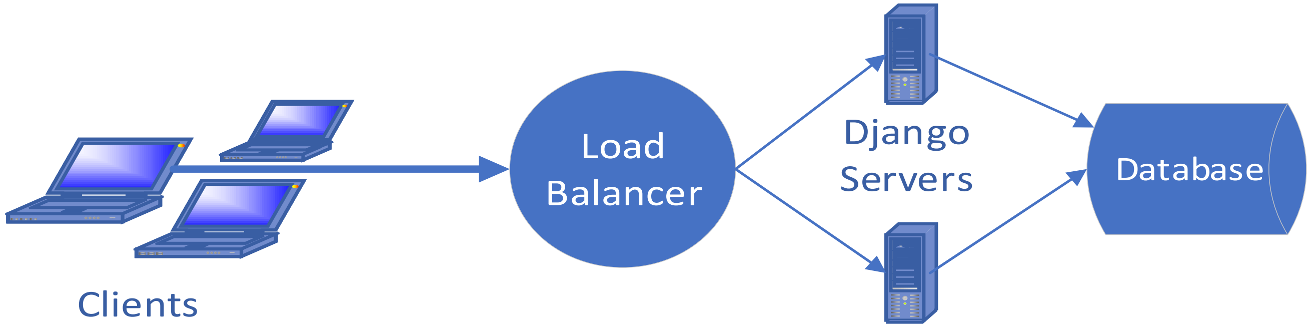
```
kubectl create secret generic db-password --from-literal=db-password=superSecret
```

  - Expose secret inside pod as an environment variable

Rollout, Rollbacks

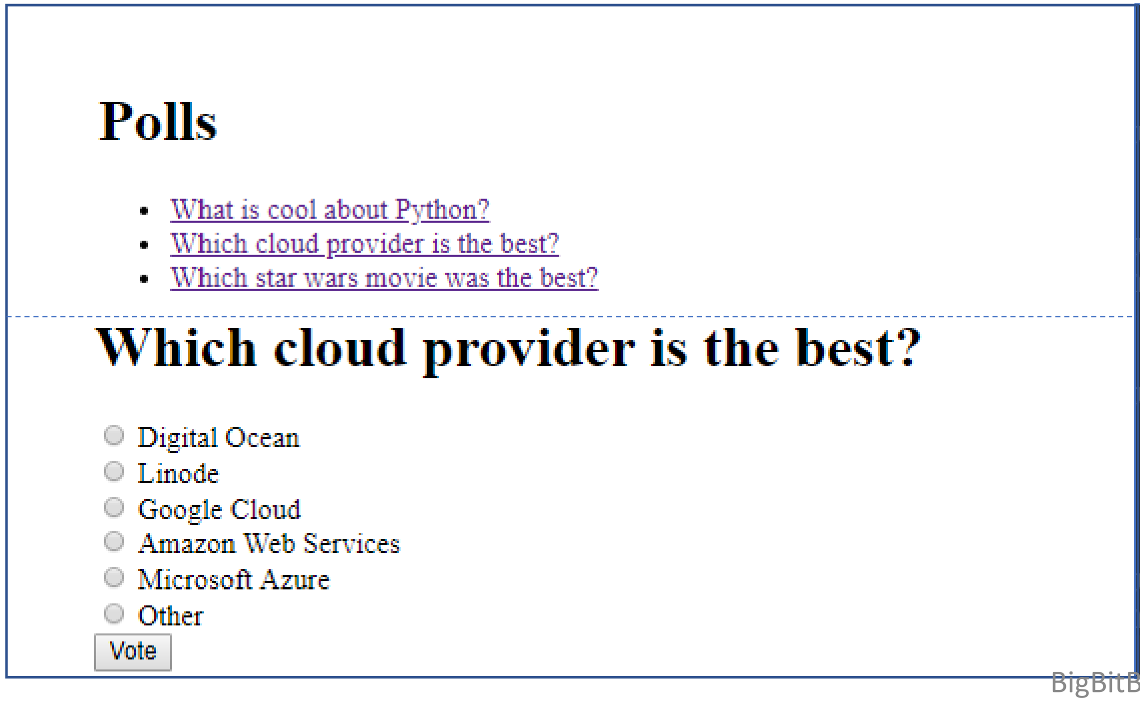
- TBD

Polls Application Example



- Stateless Django servers (cattle)
- All state data stored in database (pet)

Polling Application in Browser



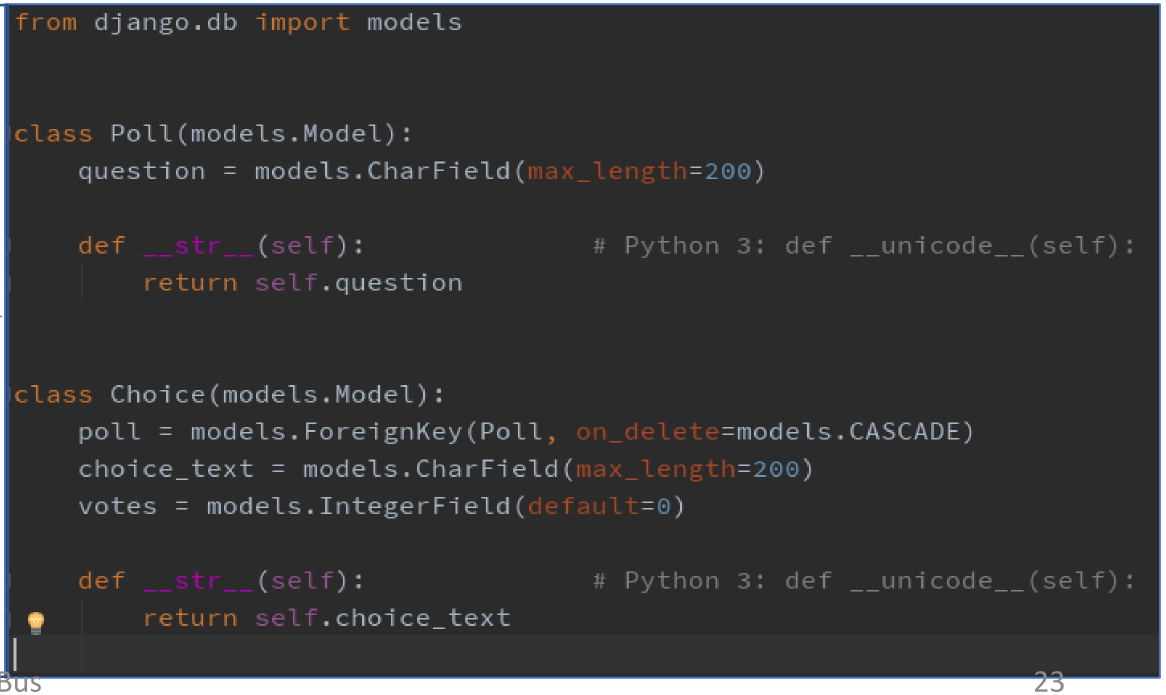
Polls

- What is cool about Python?
- Which cloud provider is the best?
- Which star wars movie was the best?

Which cloud provider is the best?

○ Digital Ocean
○ Linode
○ Google Cloud
○ Amazon Web Services
○ Microsoft Azure
○ Other

State definition - models.py



```
from django.db import models


class Poll(models.Model):
    question = models.CharField(max_length=200)

    def __str__(self):              # Python 3: def __unicode__(self):
        return self.question


class Choice(models.Model):
    poll = models.ForeignKey(Poll, on_delete=models.CASCADE)
    choice_text = models.CharField(max_length=200)
    votes = models.IntegerField(default=0)

    def __str__(self):              # Python 3: def __unicode__(self):
        return self.choice_text
```

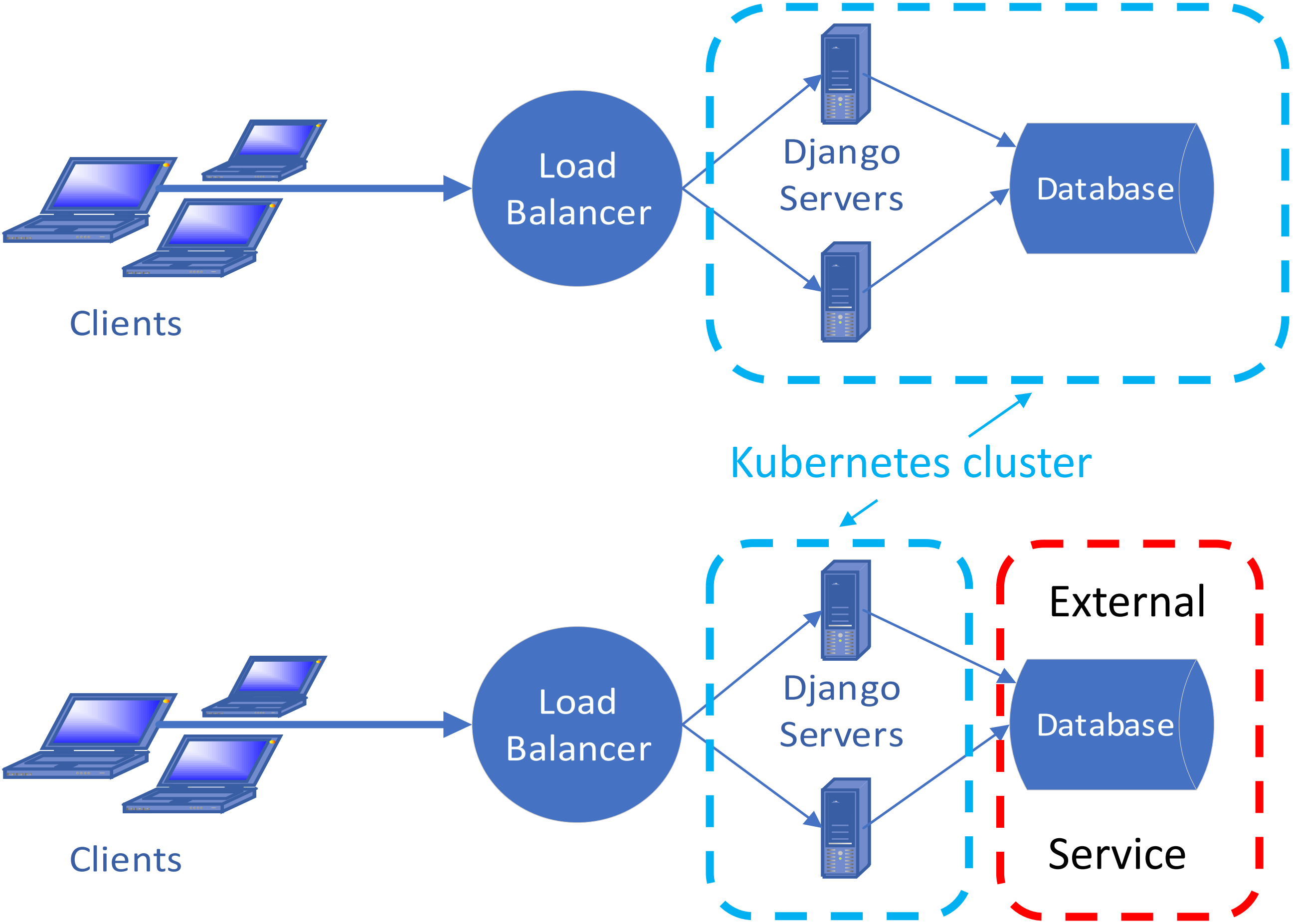
Stateful Databases in Kubernetes (?)

Option 1

- Kubernetes provides constructs for this (stateful sets, volumes, etc.)
- Possible cost saving (bin packing containers)
- Is self-managed state worth your developer/SRE time?

Option 2

- Use cloud-provider stateful solutions
  - AWS RDS, Google cloudsql, etc.
- Expensive, but much less operations tasks



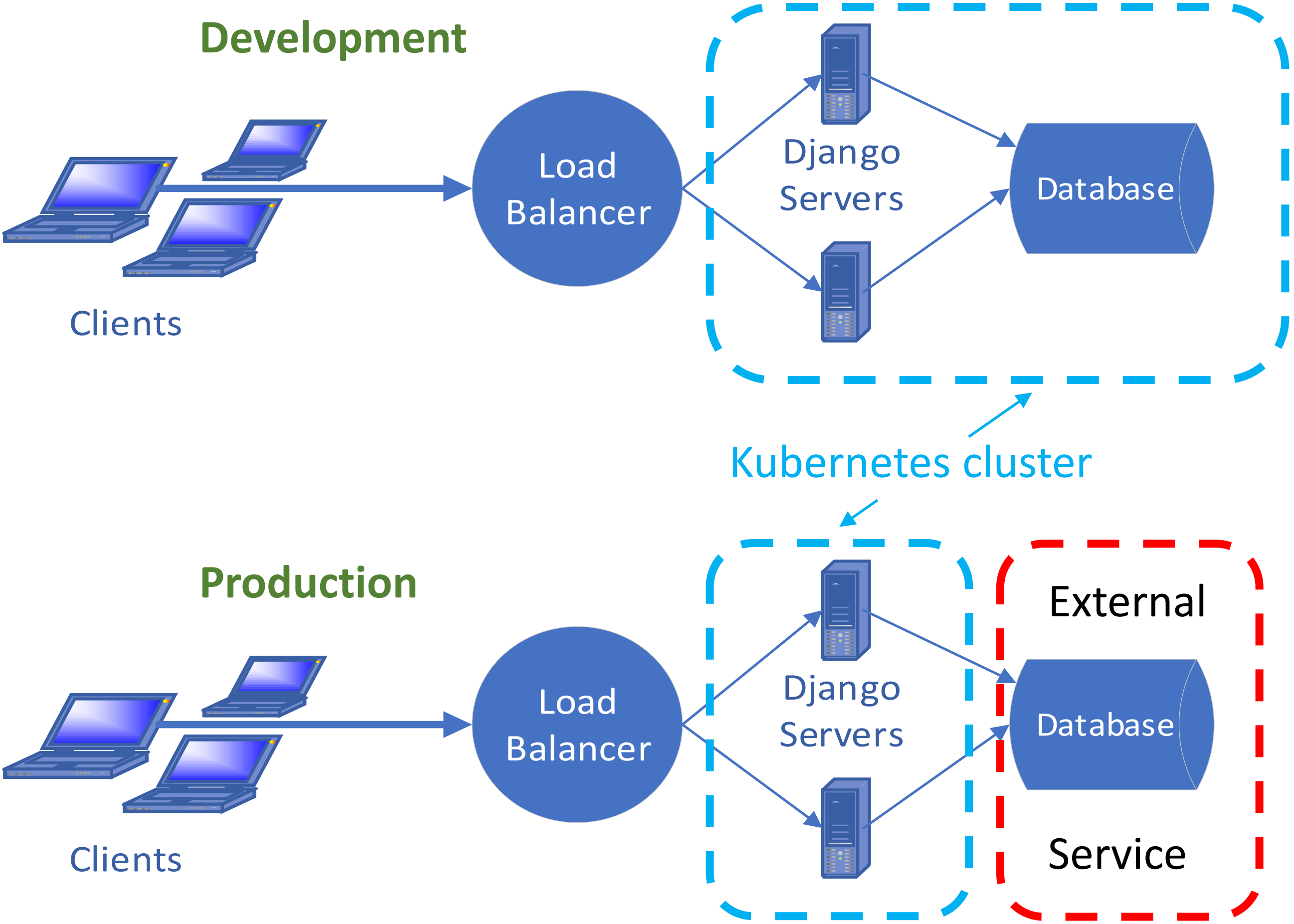
Development and Production Setup

Development

- Helps improve development and production code parity.

Production

- Leave the stateful heavy-lifting to the experts.



Django settings.py example

Developer workflow example

Kubernetes Anti-patterns

- Large pods – avoid making pets!
- Imperative kubectl commands instead of declarative yaml
- Single namespace for multiple environments
- Lack of consistent names (images/deployments/services etc.)
- Single cluster for development and production
- Missing application-level health-checks
- Missing cluster-level (node) auto-scaling

Cost Math

Cloud provider

- Master API server Currently (11/2018) $0.20/hour per Amazon EKS cluster **($1,752** annually)
- Add worker node VMs cost
- You still need to buy all the storage/load balancers/IP addresses etc.

Minikube

- Free, but needs a good PC capable of running a fairly big VM.
- No high availability - this is only for development work

Other important concepts

- Labels and Annotations: Very powerful construct to filter and track K8s resources: Required reading!
- Horizontal pod autoscaling: Triggers for pod quantity adjustment
- Statefulsets (instead of replicasets): Customizing individual pods in a deployment e.g. to take on different roles.
- Persistent volumes: Attach block devices to pods
- Jobs and Cronjobs: Running one-off tasks or periodic pods.

BigBitBus

Transparency in public cloud and big data/analytics