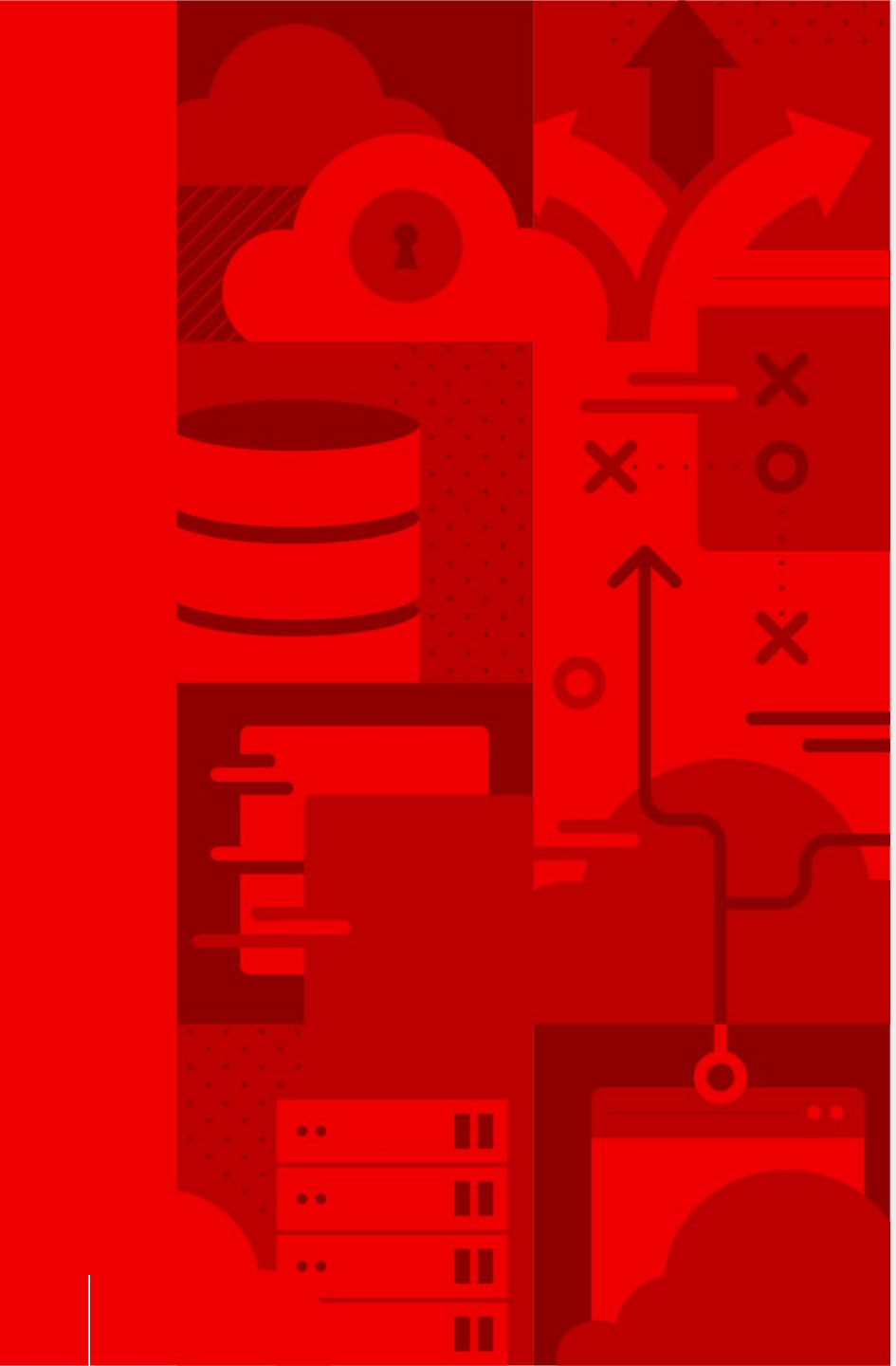
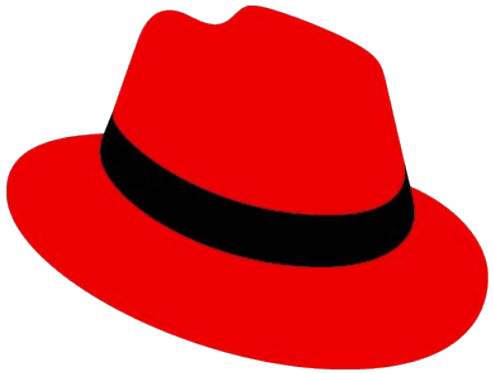


Kubernetes Patterns

Reusable Elements for Designing Cloud-Native Applications

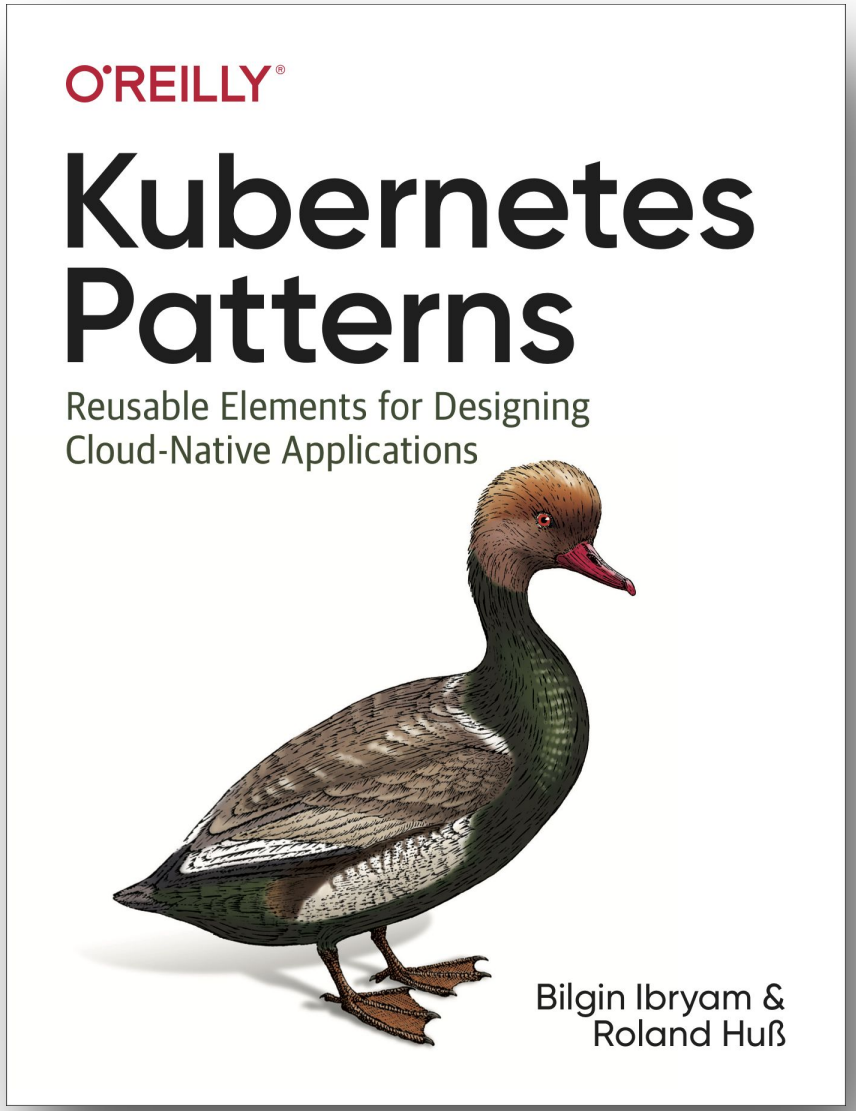
Dr. Roland Huß
Principal Software Engineer
@ro14nd
https://k8spatterns.io

Red Hat



Red Hat

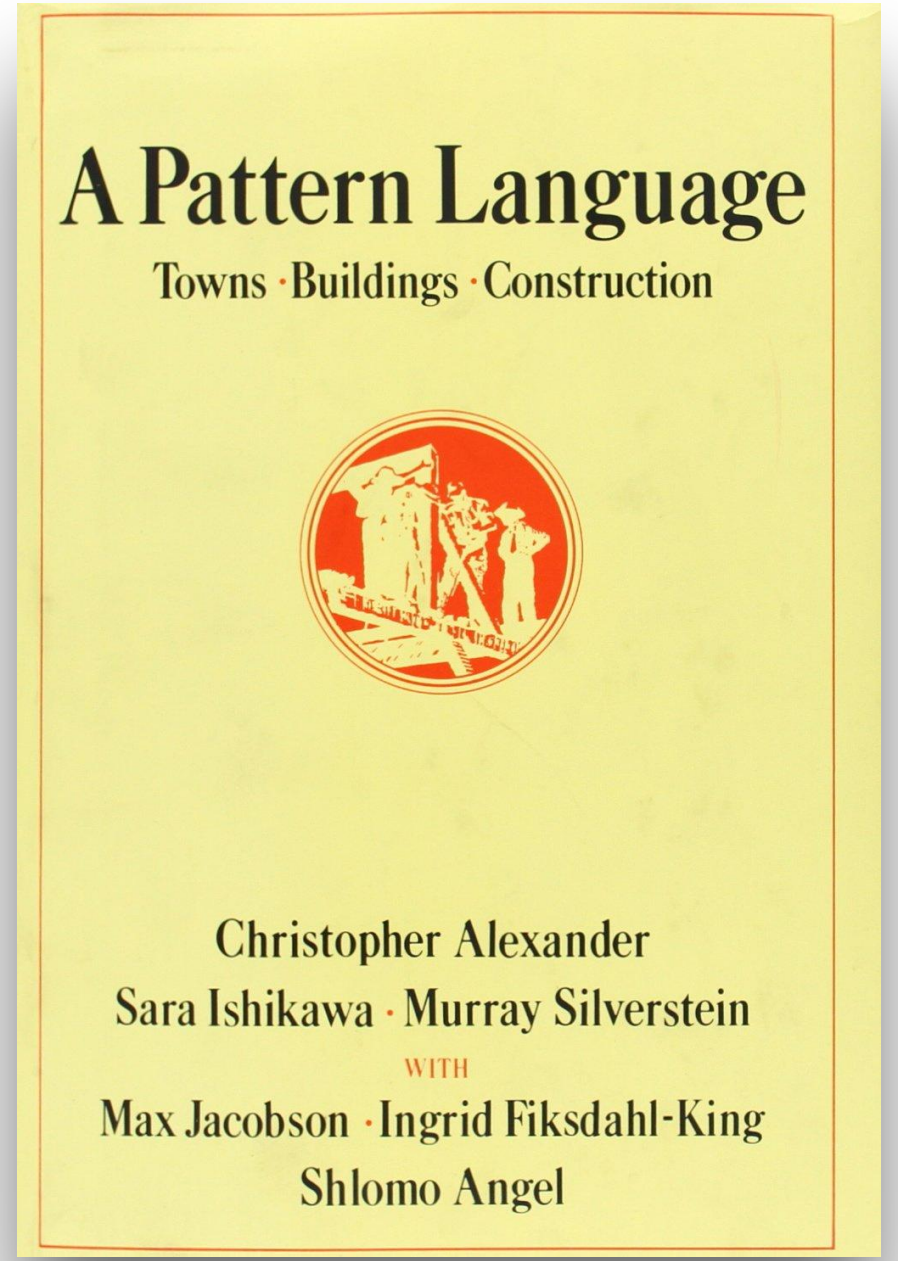
New Logo !



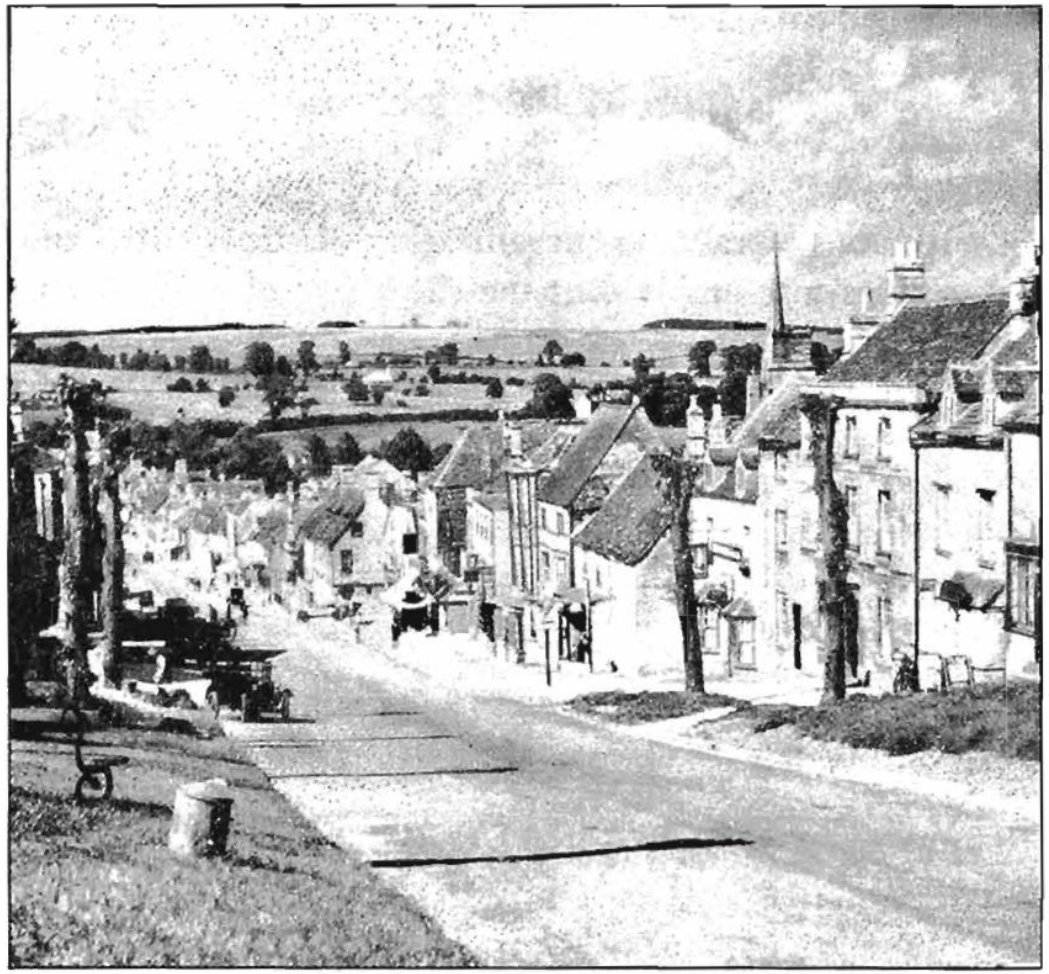
https://k8spatterns.io

Red Hat

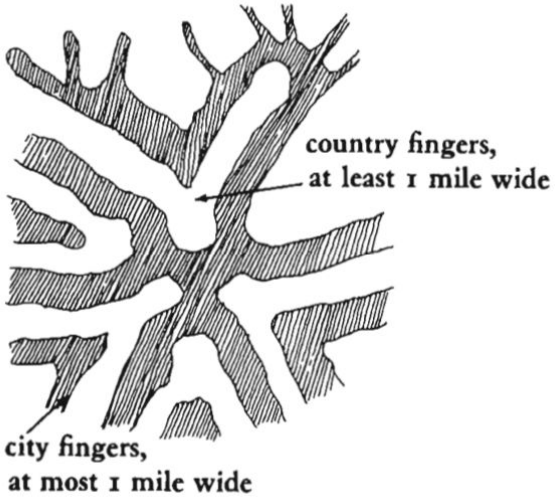

Patterns


A Pattern Language
Towns · Buildings · Construction
Christopher Alexander
Sara Ishikawa · Murray Silverstein
WITH
Max Jacobson · Ingrid Fiksdahl-King
Shlomo Angel

3 CITY COUNTRY FINGERS**

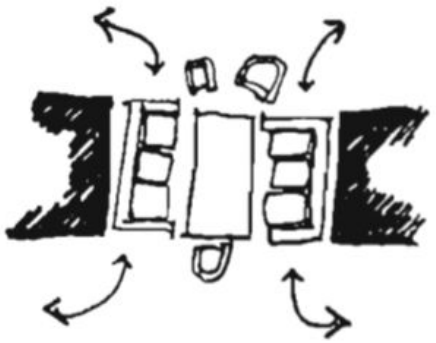


When the countryside is far away the city becomes a prison.



A Pattern Language, Christopher Alexander et. al, 1977, pp. 21

90 BEER HALL



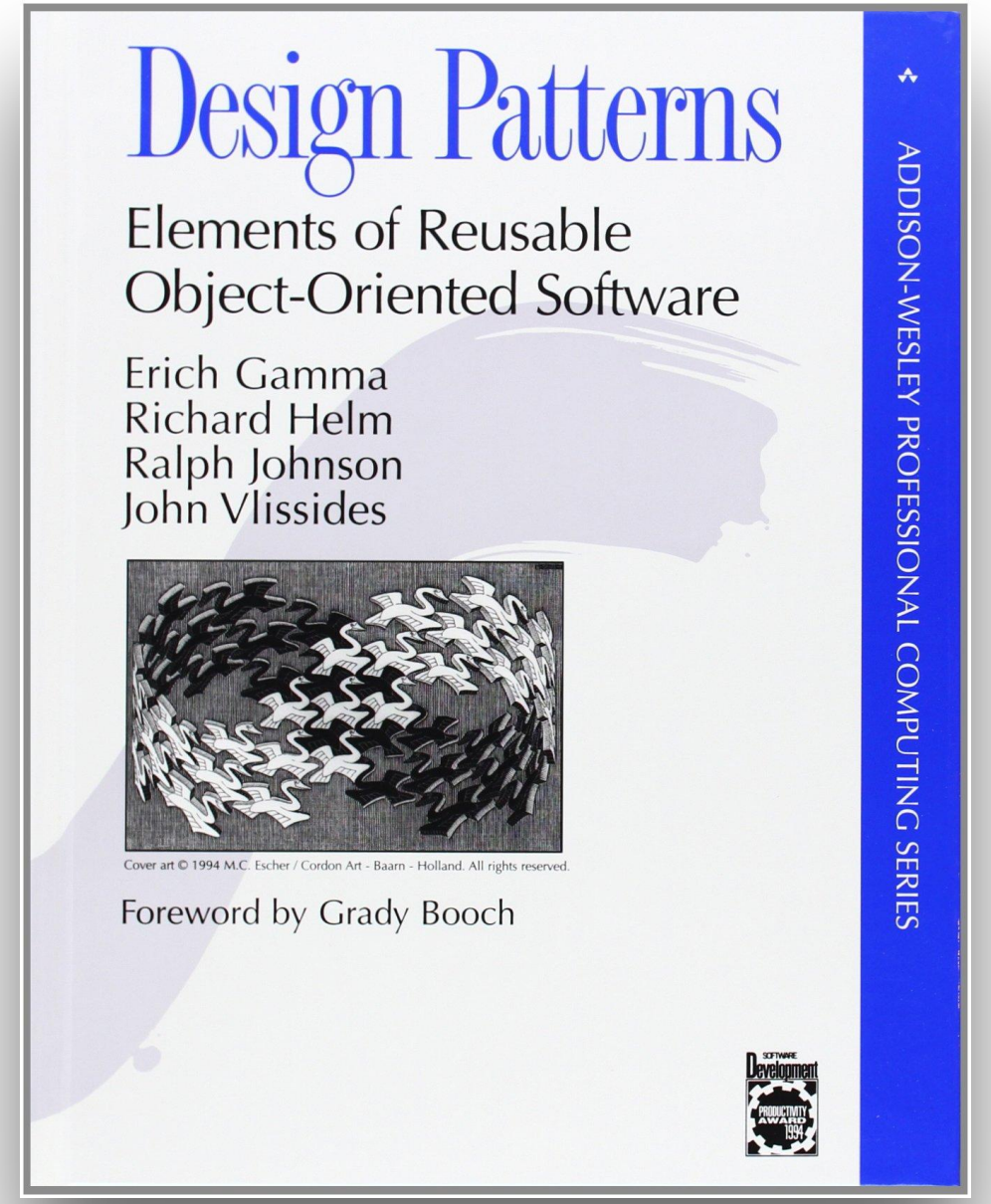
The open alcove—supports the fluidity of the scene.

criss-cross paths

activities

open alcoves

A Pattern Language, Christopher Alexander et. al, 1977, pp. 444


Design Patterns
Elements of Reusable
Object-Oriented Software
Erich Gamma
Richard Helm
Ralph Johnson
John Vlissides
Cover art © 1994 M.C. Escher / Cordon Art - Baarn - Holland. All rights reserved.
Foreword by Grady Booch
ADDISON-WESLEY PROFESSIONAL COMPUTING SERIES

Patterns

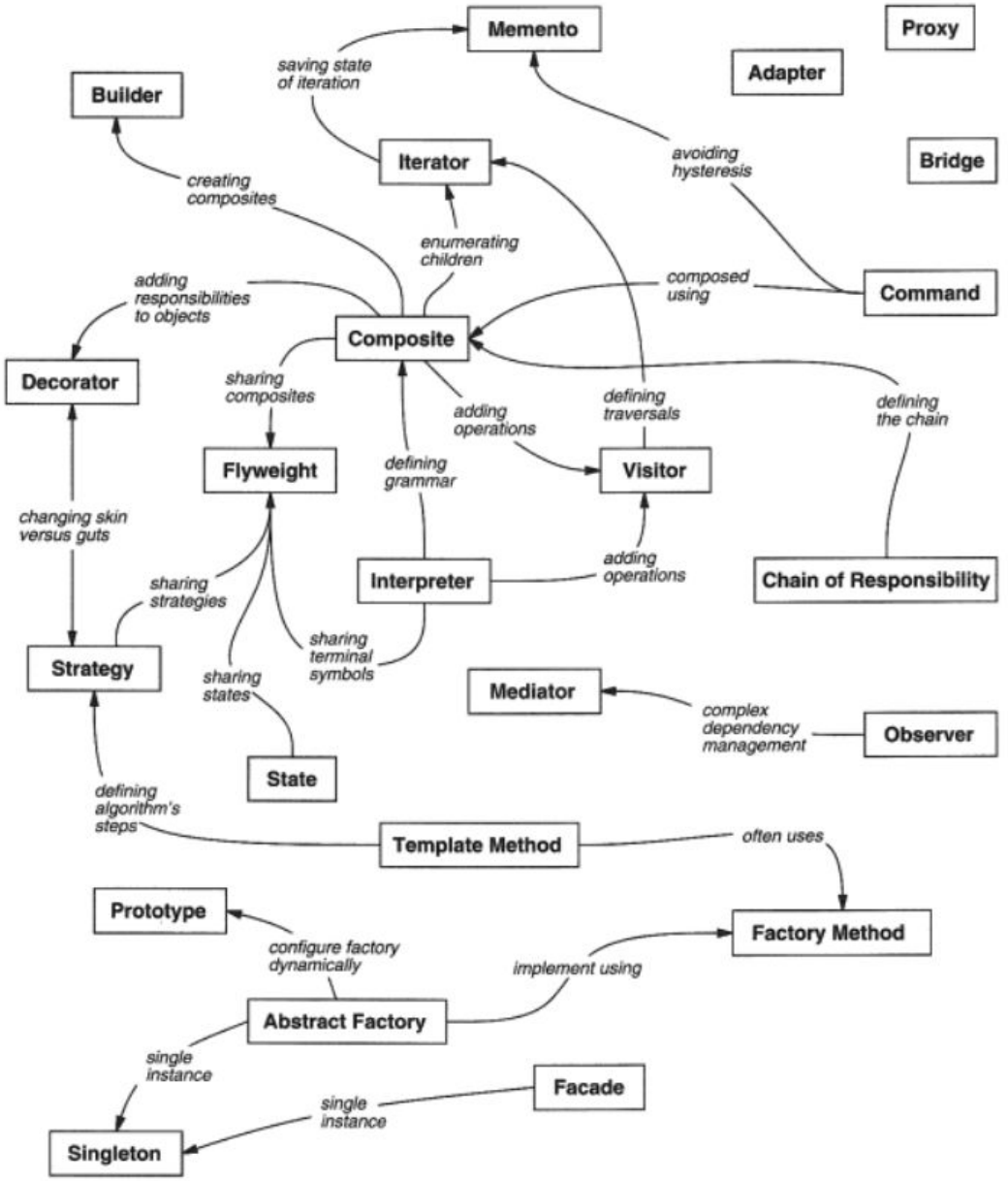
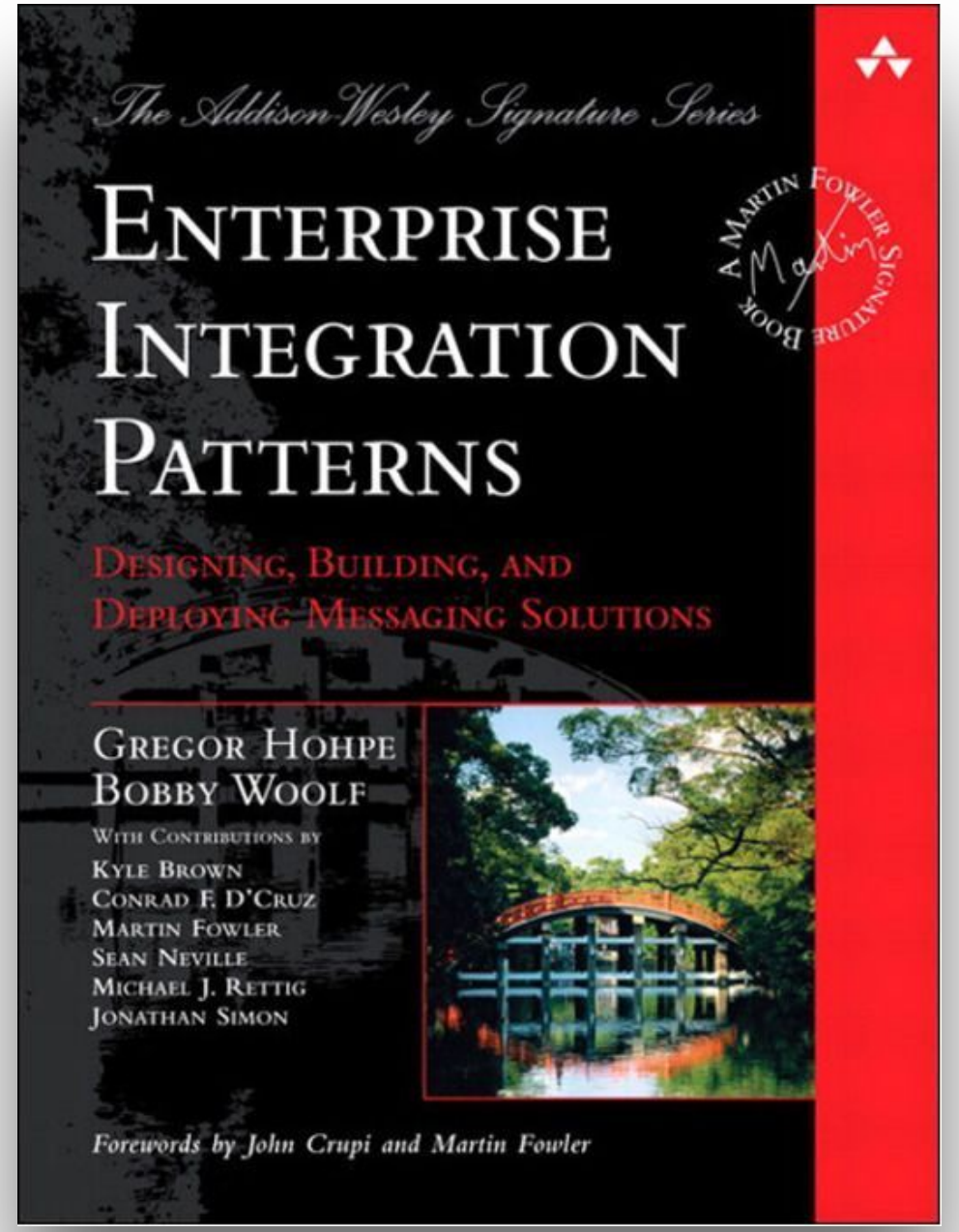


Figure 1.1: Design pattern relationships

Design Patterns, Elements of Reusable Object-Oriented Software, E. Gamma et. al., 1994, p. 12

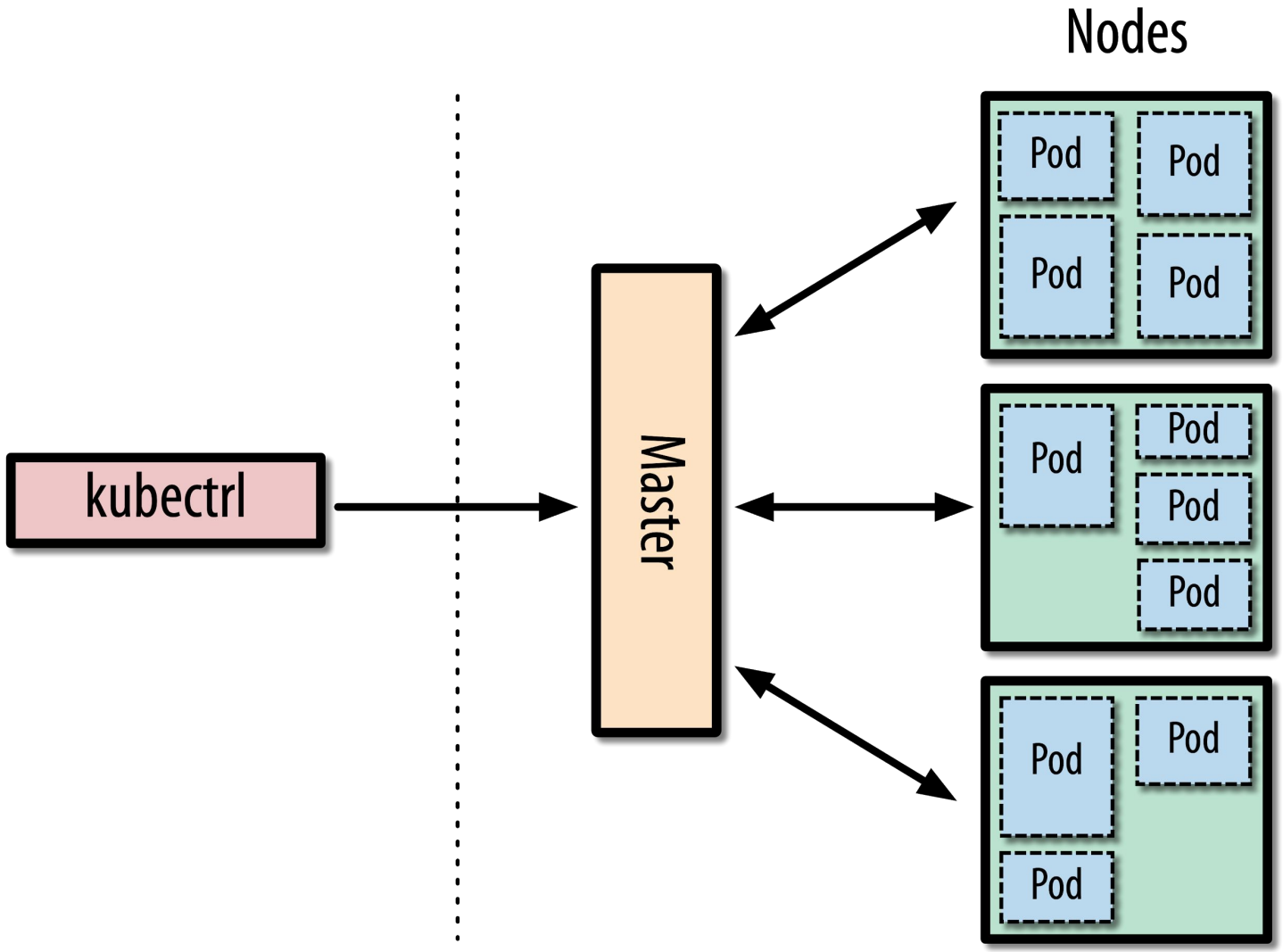

The Addison Wesley Signature Series
A Martin Fowler Signature Book
Enterprise Integration Patterns
Designing, Building, and Deploying Messaging Solutions
Gregor Hohpe
Bobby Woolf
With Contributions by
Kyle Brown
Conrad F. D'Cruz
Martin Fowler
Sean Neville
Michael J. Rettig
Jonathan Simon
Forewords by John Crupi and Martin Fowler


Kubernetes

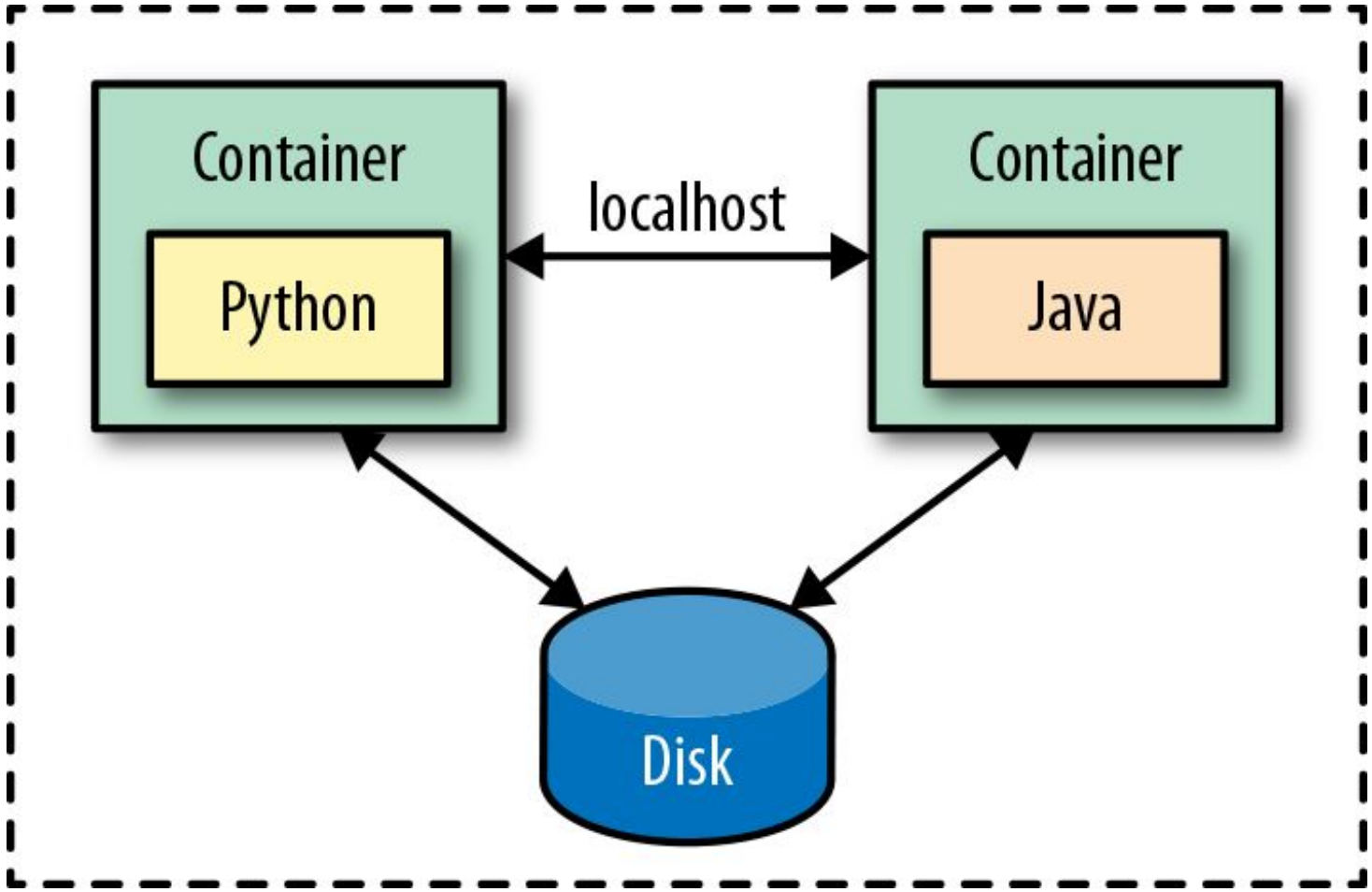
Kubernetes

- Open Source container orchestration system started by Google in 2014
  - Scheduling
  - Self-healing
  - Horizontal and vertical scaling
  - Service discovery
  - Rollout and Rollbacks
- Declarative resource-centric REST API

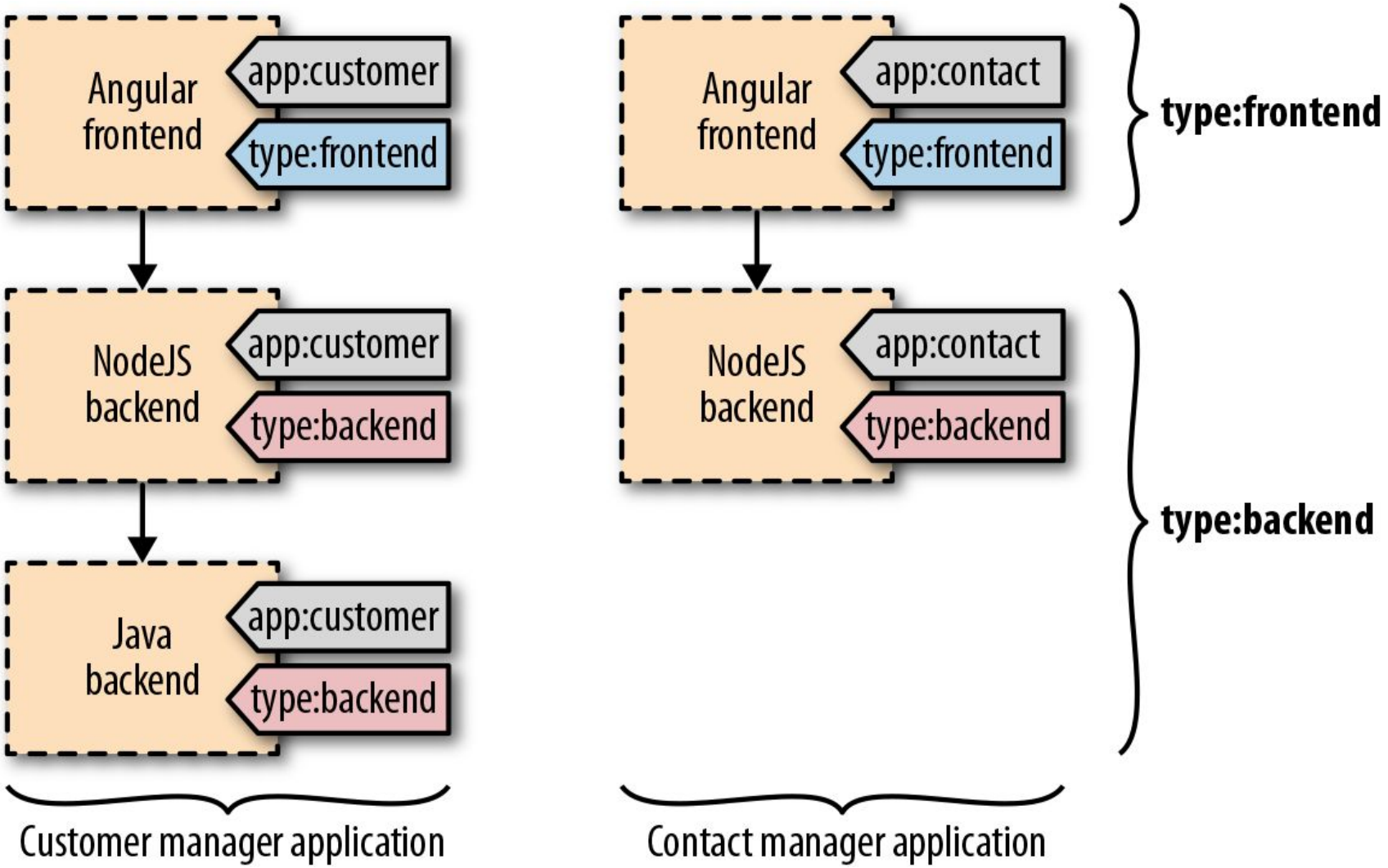
Architecture



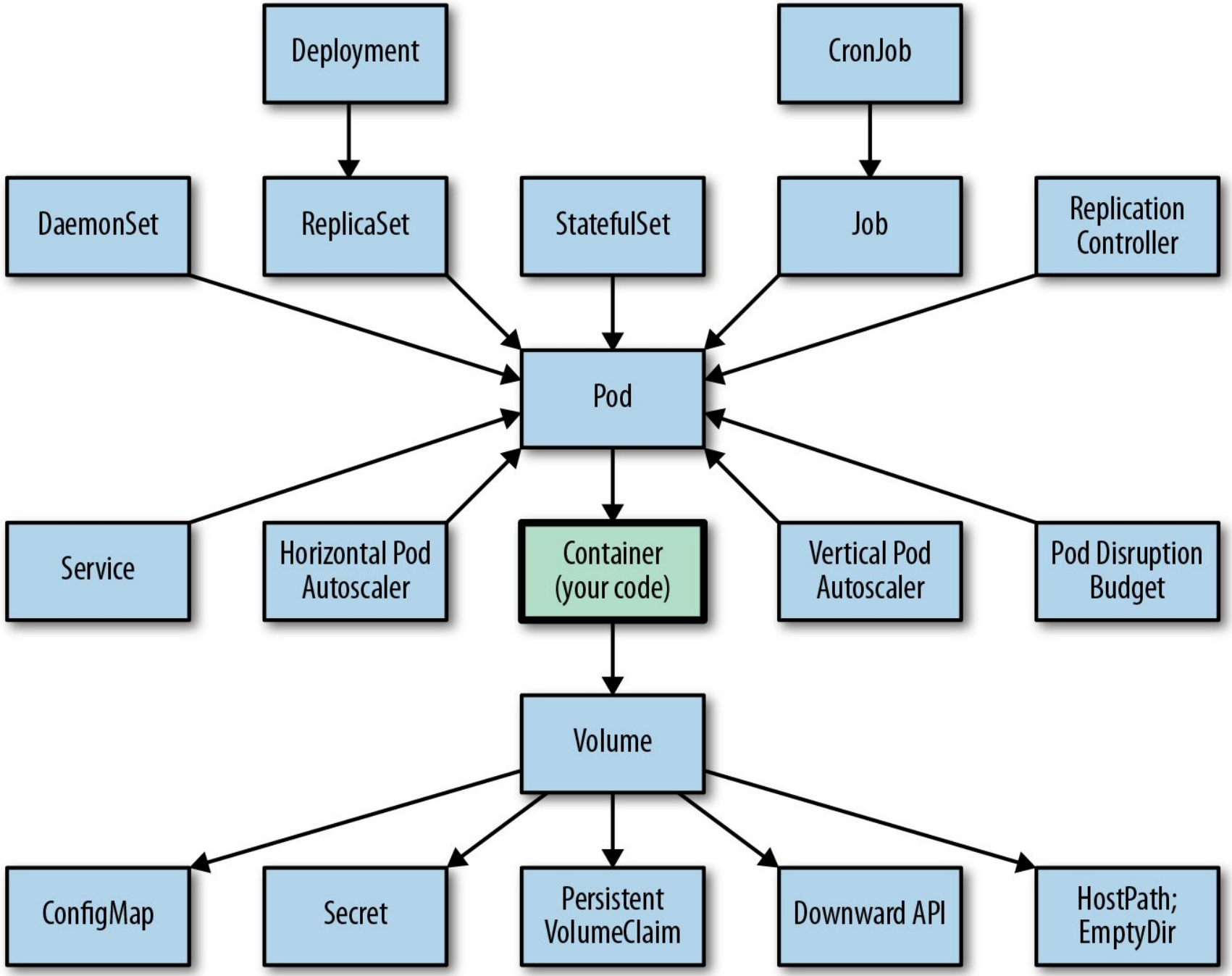
Pod



Labels



Red Hat


Deployment
CronJob
DaemonSet
ReplicaSet
StatefulSet
Job
Replication Controller
Pod
Service
Horizontal Pod Autoscaler
Container (your code)
Vertical Pod Autoscaler
Pod Disruption Budget
Volume
ConfigMap
Secret
Persistent VolumeClaim
Downward API
HostPath; EmptyDir


Predictable
Demands

How to declare application requirements.

Application Requirements

- Declared requirements help in
  - Scheduling decisions
  - Capacitiy planning
  - Matching infrastructure services
- Runtime dependencies
  - Persistent Volumes
  - Host ports
  - Dependencies on ConfigMaps and Secrets

Resource Profile

```
apiVersion: v1
kind: Pod
metadata:
  name: http-server
spec:
  containers:
  - image: nginx
    name: nginx
    resources:
      requests:
        cpu: 200m
        memory: 100Mi
      limits:
        cpu: 300m
        memory: 200Mi
```

Quality-of-Service Classes

- **Best Effort**
  - No requests or limits
- **Burstable**
  - requests < limits
- **Guaranteed**
  - requests == limits


Health
Probe

How to communicate an application's health state to Kubernetes.

Monitoring Health

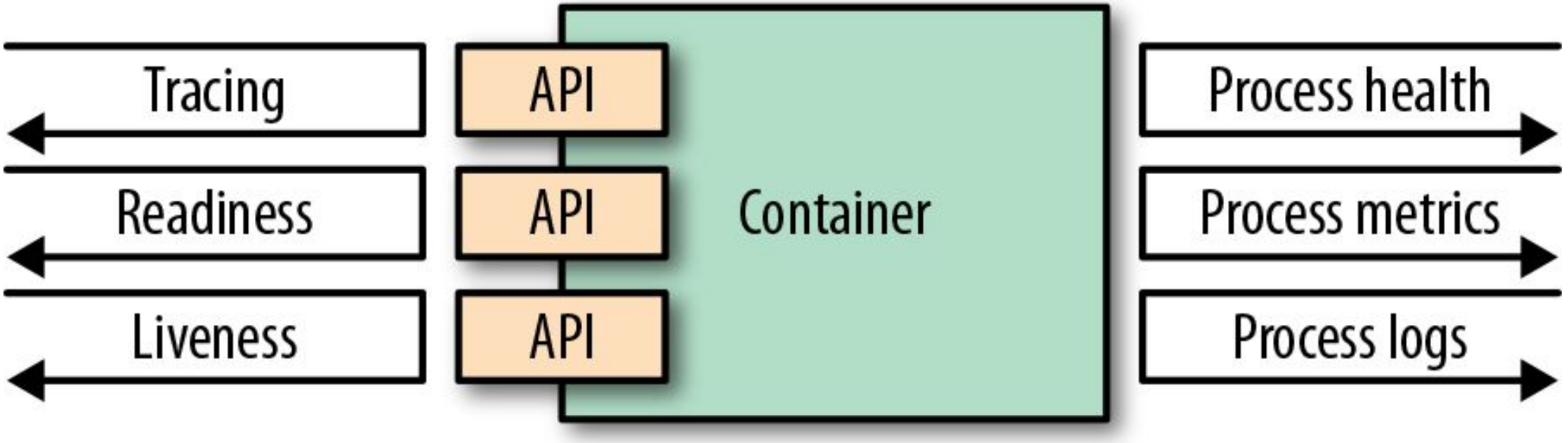
- Process health checks
  - Checks running process
  - Restarts container if container process died
- Application provided Health Probes
  - **Liveness Probe**: Check application health
  - **Readiness Probe**: Check readiness to process requests

Liveness & Readiness

- Liveness Probe
  - Restarting containers if liveness probes fail
- Readiness Probe
  - Removing from service endpoint if readiness probe fails
- Probe methods
  - HTTP endpoint
  - TCP socket endpoint
  - Unix command’s return value

```
apiVersion: v1
kind: Pod
metadata:
  name: pod-with-readiness-check
spec:
  containers:
  - image: k8spatterns/random-generator:1.0
    name: random-generator
    livenessProbe:
      httpGet:
        path: /actuator/health
        port: 8080
      initialDelaySeconds: 30
    readinessProbe:
      exec:
        command: [ "stat", "/var/run/random-generator-ready" ]
```

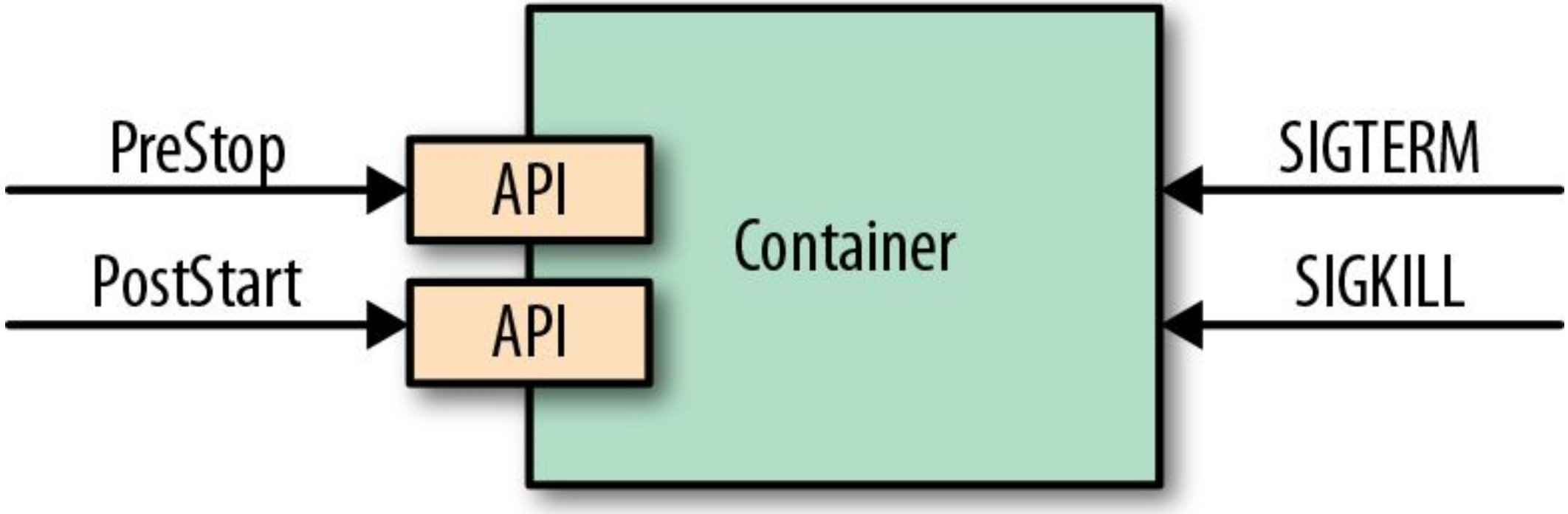
Container Observability Options




Managed
Lifecycle

How applications should react on lifecycle events.

Managed Container Lifecycle



Lifecycle Events

- SIGTERM
  - Initial event issued when a container is going to shutdown
  - Application should listen to this event to cleanup properly and then exit
- SIGKILL
  - Final signal sent after a grace period which can't be catched
  - `terminationGracePeriodSeconds`: Time to wait after SIGTERM (default: 30s)

Lifecycle Hooks

- `postStart`
  - Called after container is created
  - Runs in parallel to the main container
  - Keeps Pod in status *Pending* until exited successfully
  - **exec** or **httpGet** handler types (like *Health Probe*)
- preStop
  - Called before container is stopped
  - Same purpose & semantics as for SIGTERM

```
apiVersion: v1
kind: Pod
metadata:
  name: pre-stop-hook
spec:
  containers:
  - image: k8spatterns/random-generator:1.0
    name: random-generator
    lifecycle:
      postStart:
        exec:
          command:
          - sh
          - -c
          - sleep 30 && echo "Wake up!" > /tmp/postStart_done
      preStop:
        httpGet:
          port: 8080
          path: /shutdown
```

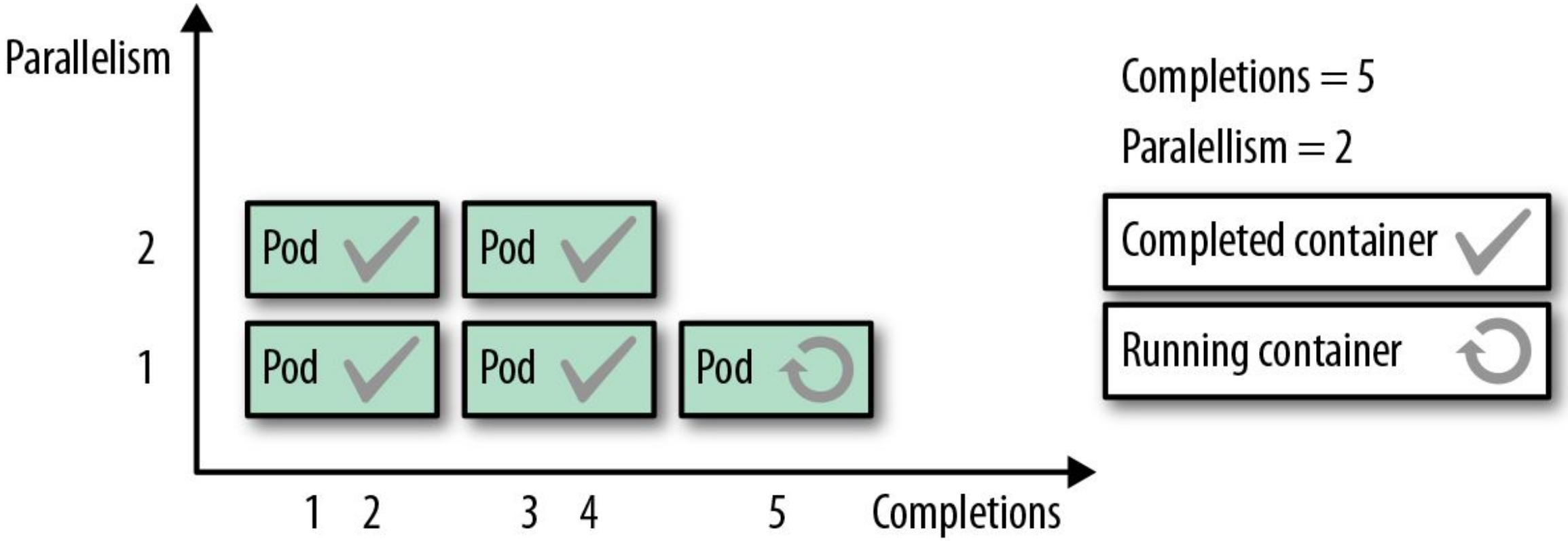

Batch
Job

How to run short-lived Pods reliably until completion.

Job

- Resource for a predefined *finite* unit-of-work
- Survives cluster restarts and node failures
- Support for multiple Pod runs
- `.spec.completions`
  - How many Pods to run to complete Job
- `.spec.parallelism`
  - How many Pods to run in parallel

Parallel Batch Job



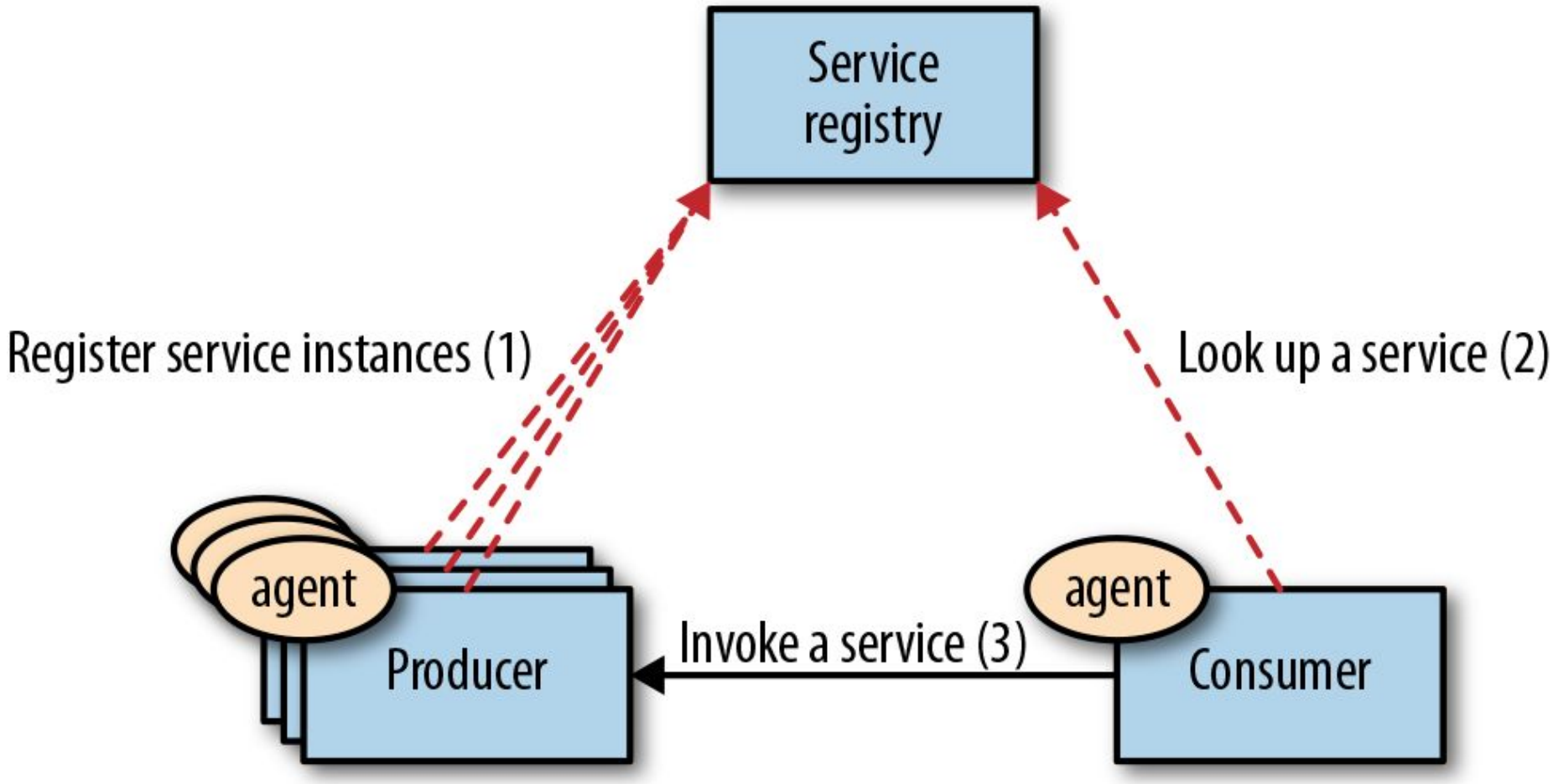
Job Types

- Single Pod Job
  - completions = 1 and parallelism = 1
- Fixed completion count Jobs
  - completions > 1
  - One Pod per work item
- Work queue Jobs
  - completions = 1 and parallelism > 1
  - All Pods need to finish, with at least one Pod exciting successfully
  - Pods needs to coordinate to shutdown in a coordinate fashion

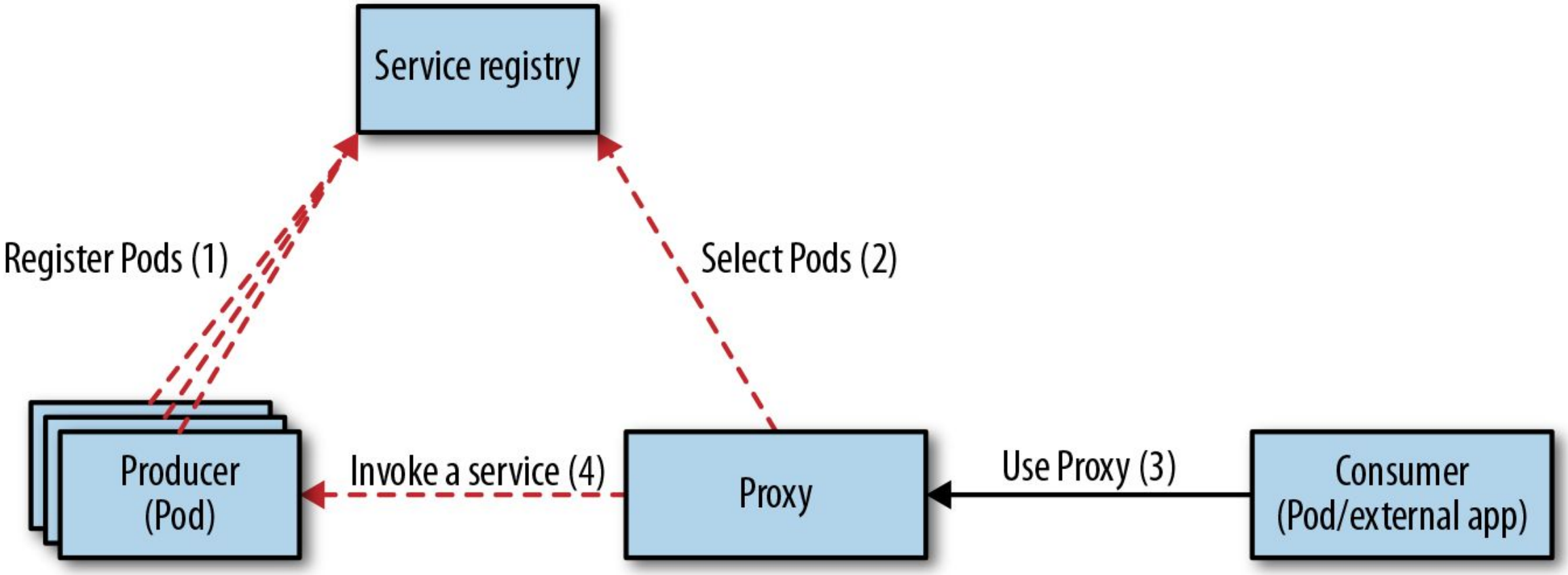

Service
Discovery

How to discover and use services.

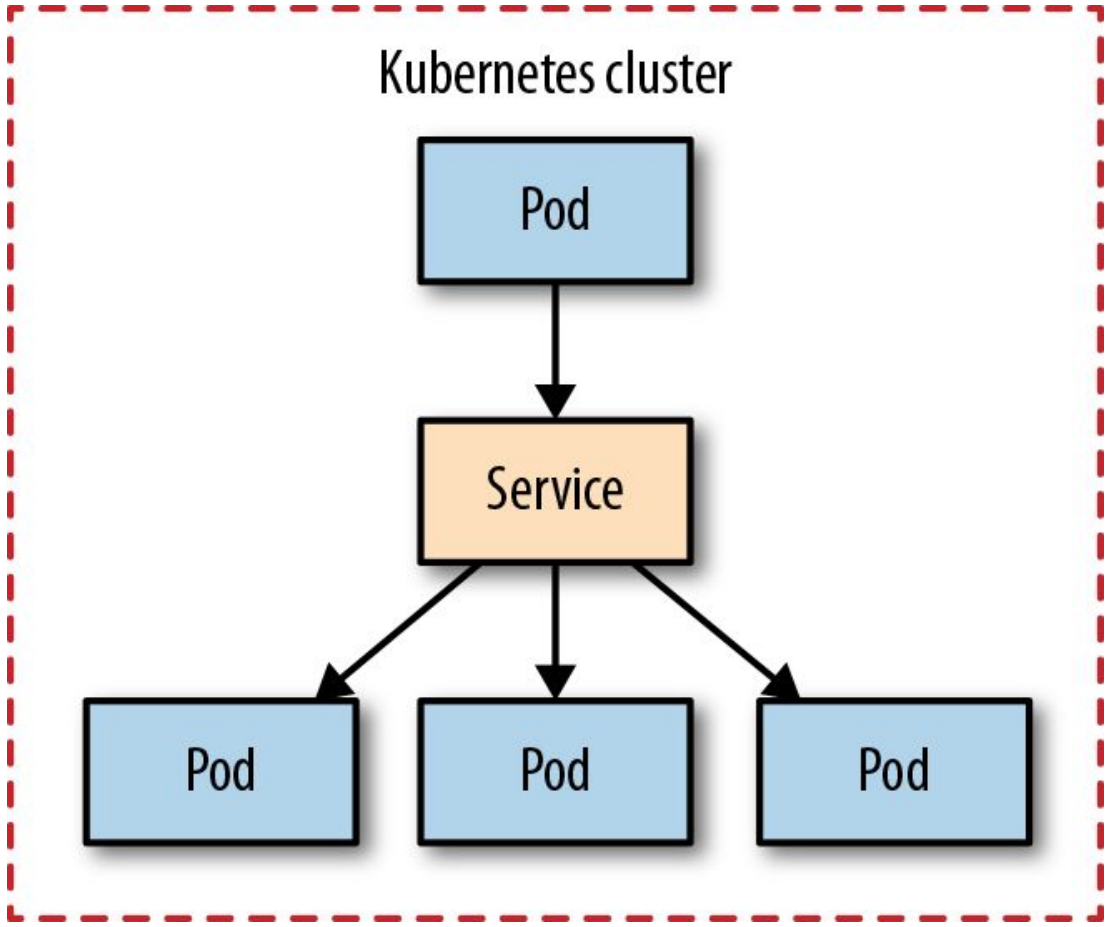
Client-side Service Discovery (non Kubernetes)



Server-side Service Discovery (Kubernetes)

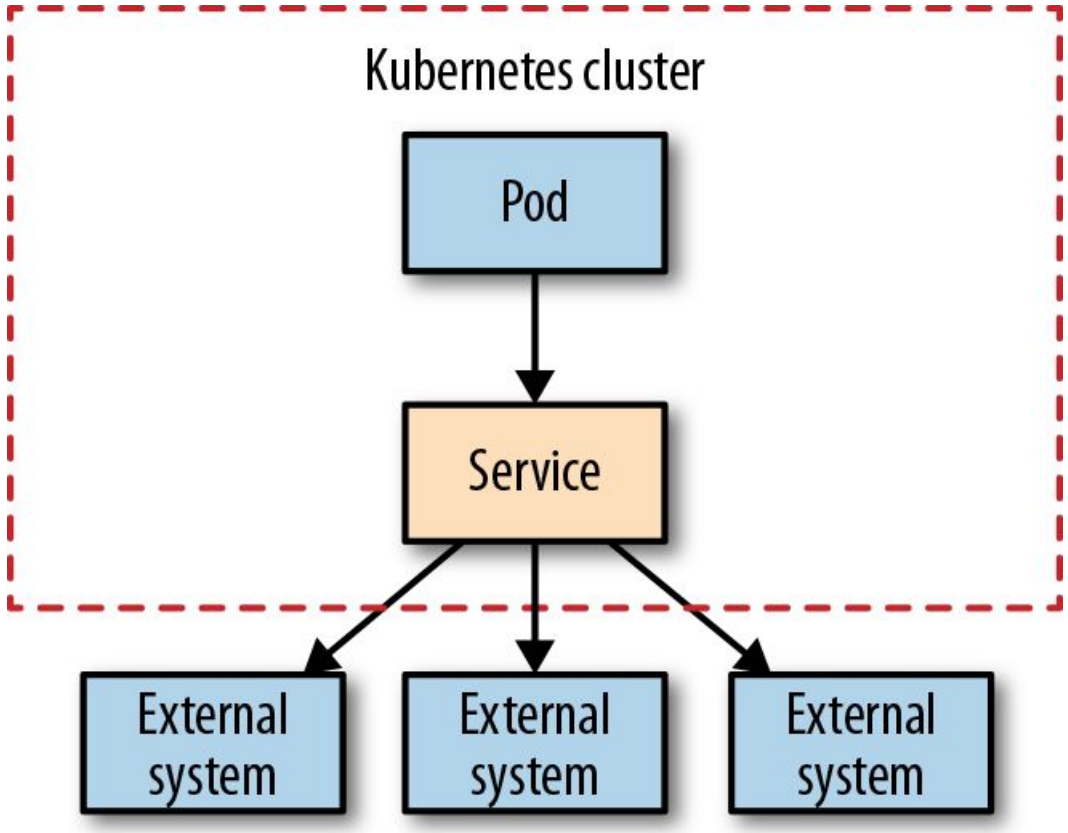


Internal Service Discovery



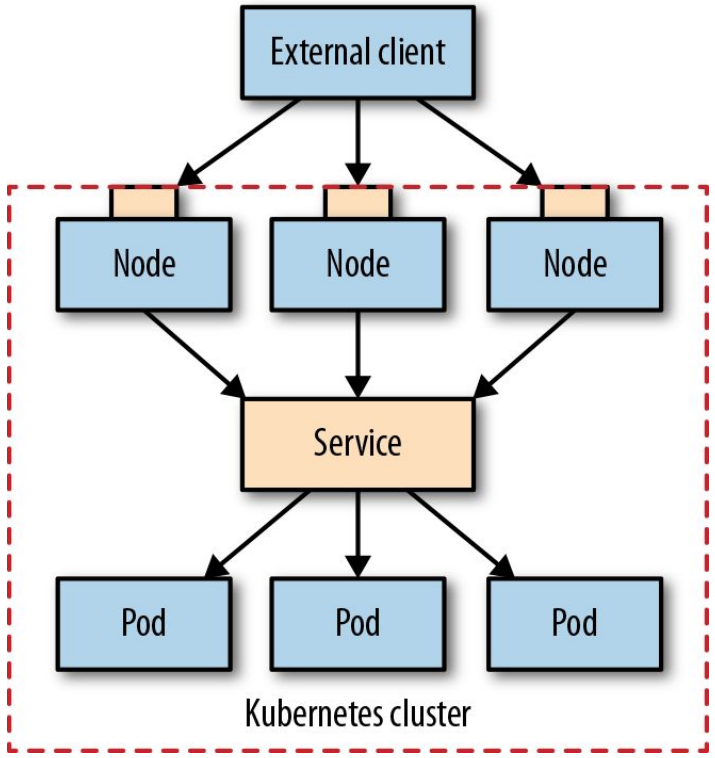
- Discovery through DNS lookups
- Pods picked by label selector
- Multiple ports per Service
- Session affinity on IP address
- Successful readiness probes required for routing
- Virtual IP address for each Service

Manual Service Discovery

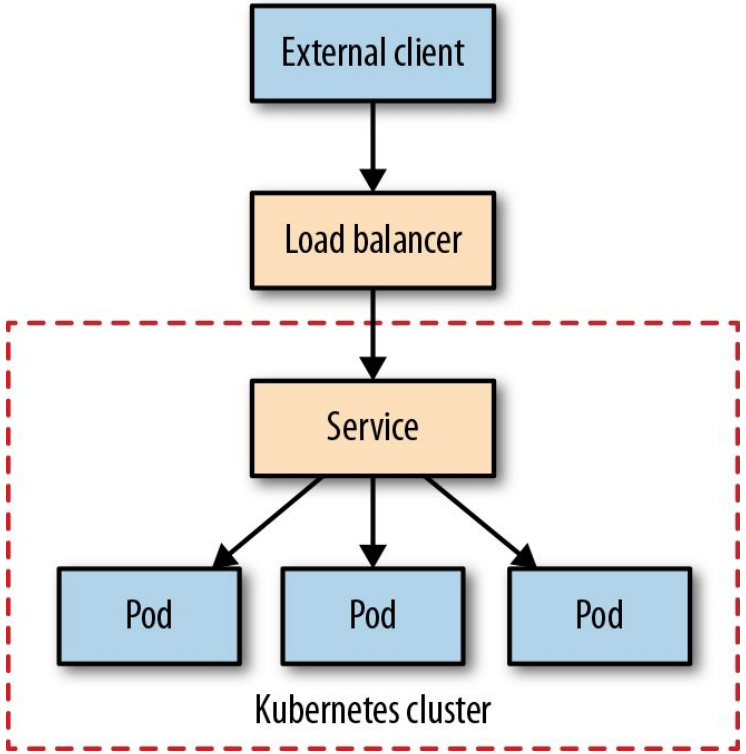


- Service without selector
- Manually creating Endpoint resource with the same name as the Service
- Service of type **`ExternalName`** map are registered as DNS CNAMEs

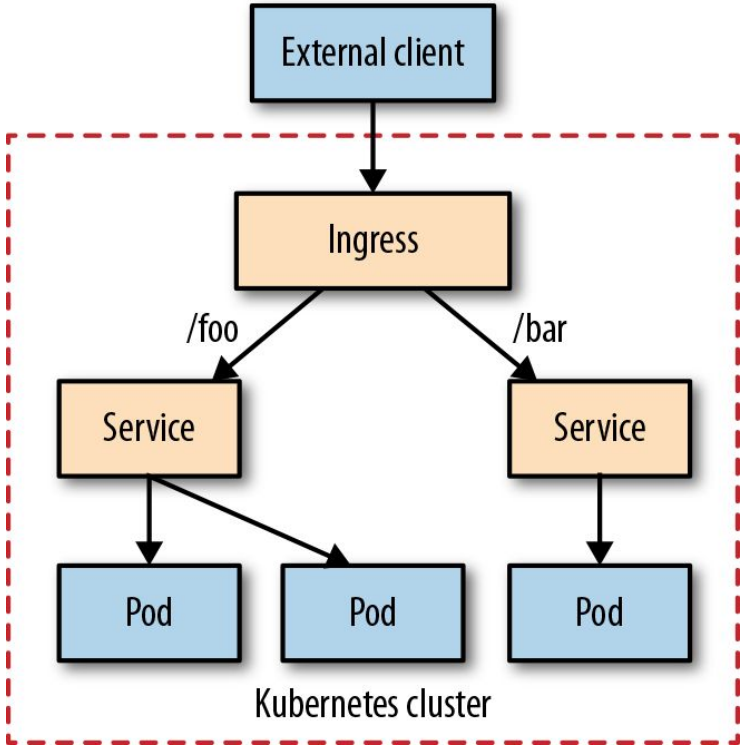
Node Port



Load Balancer



Ingress

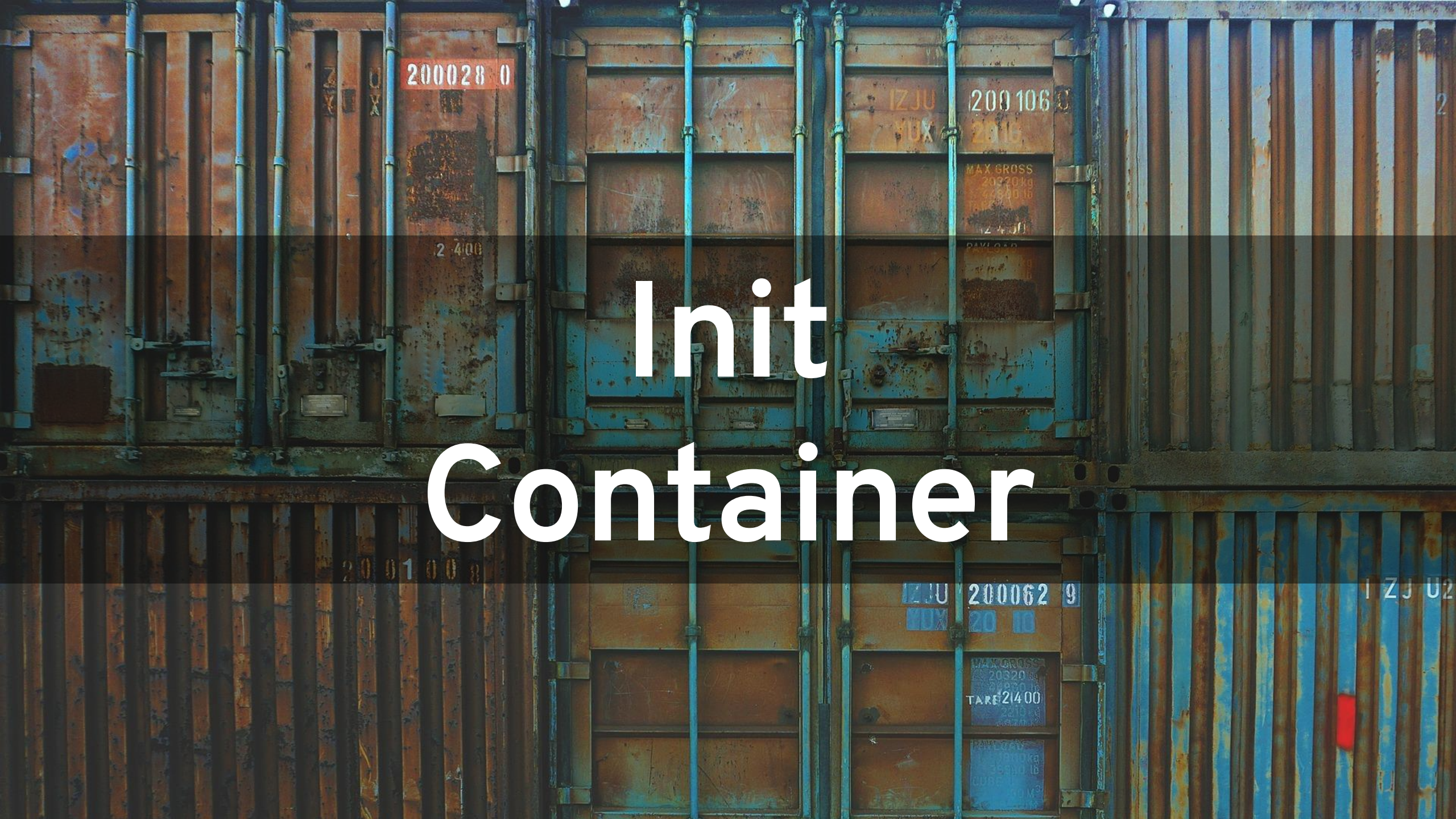


Ingress

```
apiVersion: extensions/v1beta1
kind: Ingress
metadata:
  name: random-generator
spec:
  rules:
  - http:
      paths:
      - path: /
        backend:
          serviceName: random-generator
          servicePort: 8080
      - path: /cluster-status
        backend:
          serviceName: cluster-status
          servicePort: 80
```

Service Discovery

Name	Configuration	Client type	Summary
ClusterIP	`type: ClusterIP` `.spec.selector`	Internal	The most common internal discovery mechanism
Manual IP	`type: ClusterIP` `kind: Endpoints`	Internal	External IP discovery
Manual FQDN	`type: ExternalName` `.spec.externalName`	Internal	External FQDN discovery
Headless Service	`type: ClusterIP` `.spec.clusterIP: None`	Internal	DNS-based discovery without a virtual IP
NodePort	`type: NodePort`	External	Preferred for non-HTTP traffic
LoadBalancer	`type: LoadBalancer`	External	Requires supporting cloud infrastructure
Ingress	`kind: Ingress`	External	L7/HTTP-based smart routing mechanism



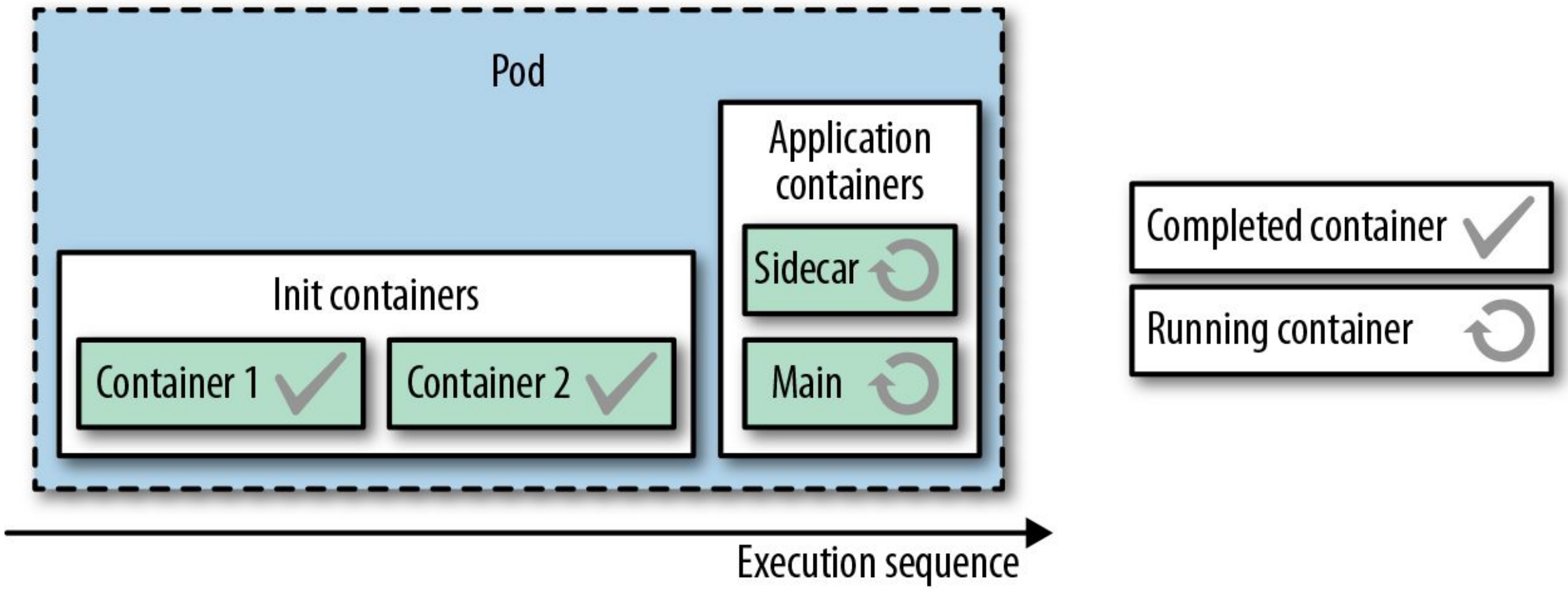
Init Container

How to separate initialization steps from the main application.

Init Container

- Part of a Pod
- One shot actions before application starts
- Needs to be idempotent
- Has own resource requirements

Init Container



Red Hat

Init Container

```
apiVersion: v1
kind: Pod
....
spec:
  initContainers:
  - name: download
    image: axeclbr/git
    command: [ "git","clone","https://github.com/myrepo","/data"]
    volumeMounts:
    - mountPath: /var/lib/data
      name: source
  containers:
  - name: run
    image: docker.io/centos/httpd
    volumeMounts:
    - mountPath: /var/www/html
      name: source
  volumes:
  - emptyDir: {}
    name: source
```

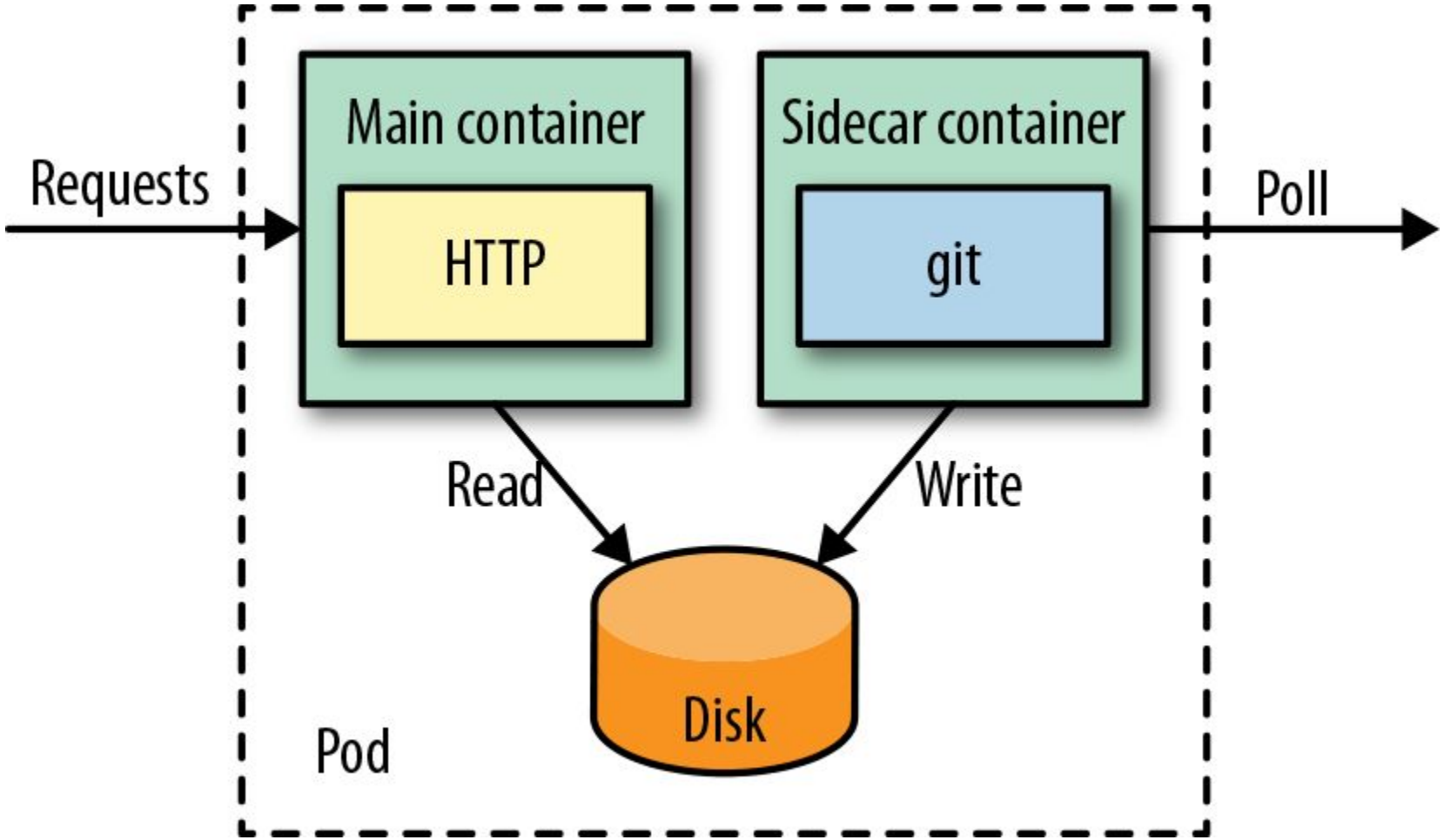
Sidecar

How to enhance the functionality of an application without changing it.

Sidecar

- Runtime collaboration of containers
- Connected via shared resources:
  - Network
  - Volumes
- Similar what AOP is for programming
- Separation of concerns

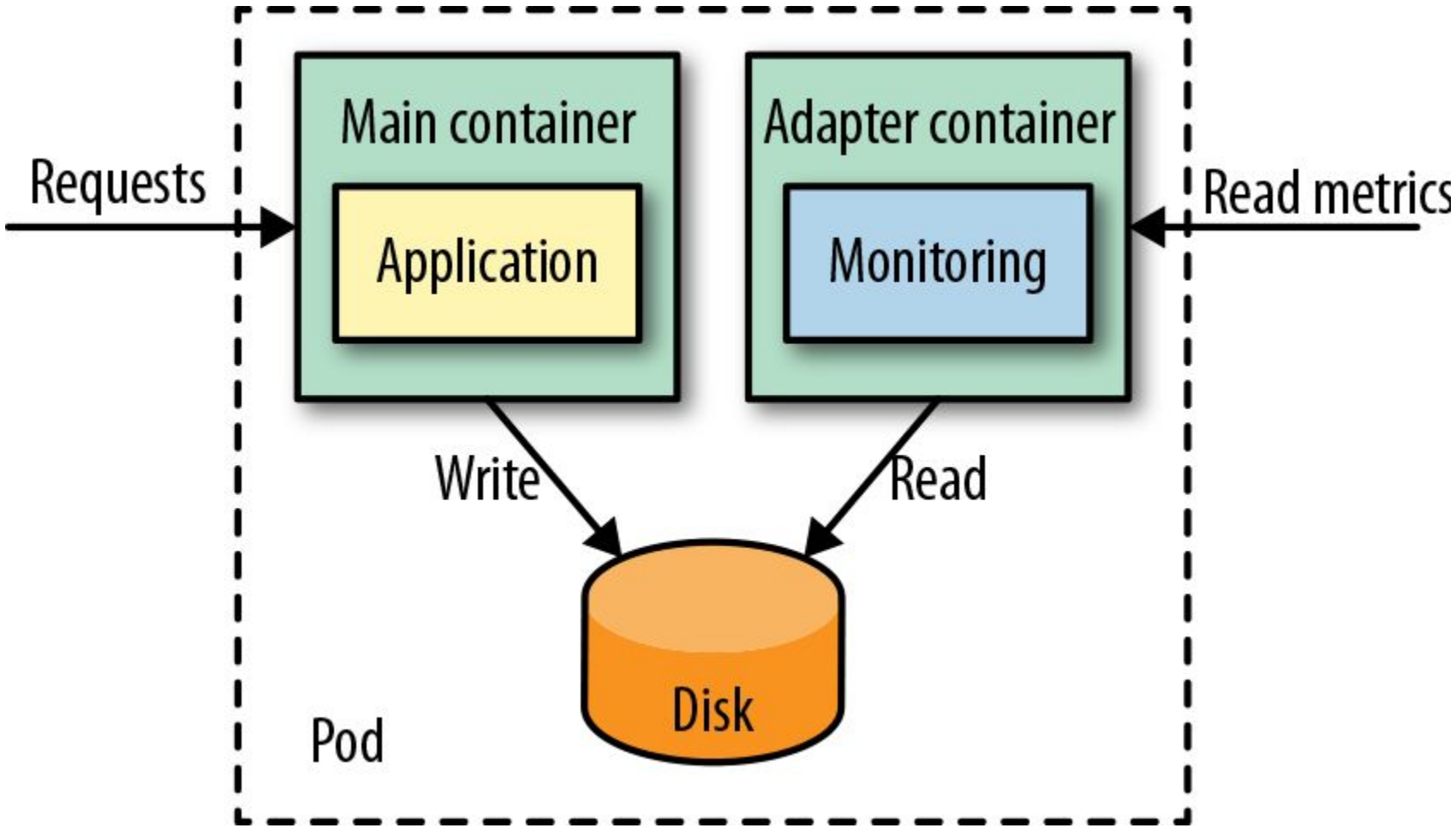
Sidecar



Adapter

How to decouple access to a container **from** the outside world.

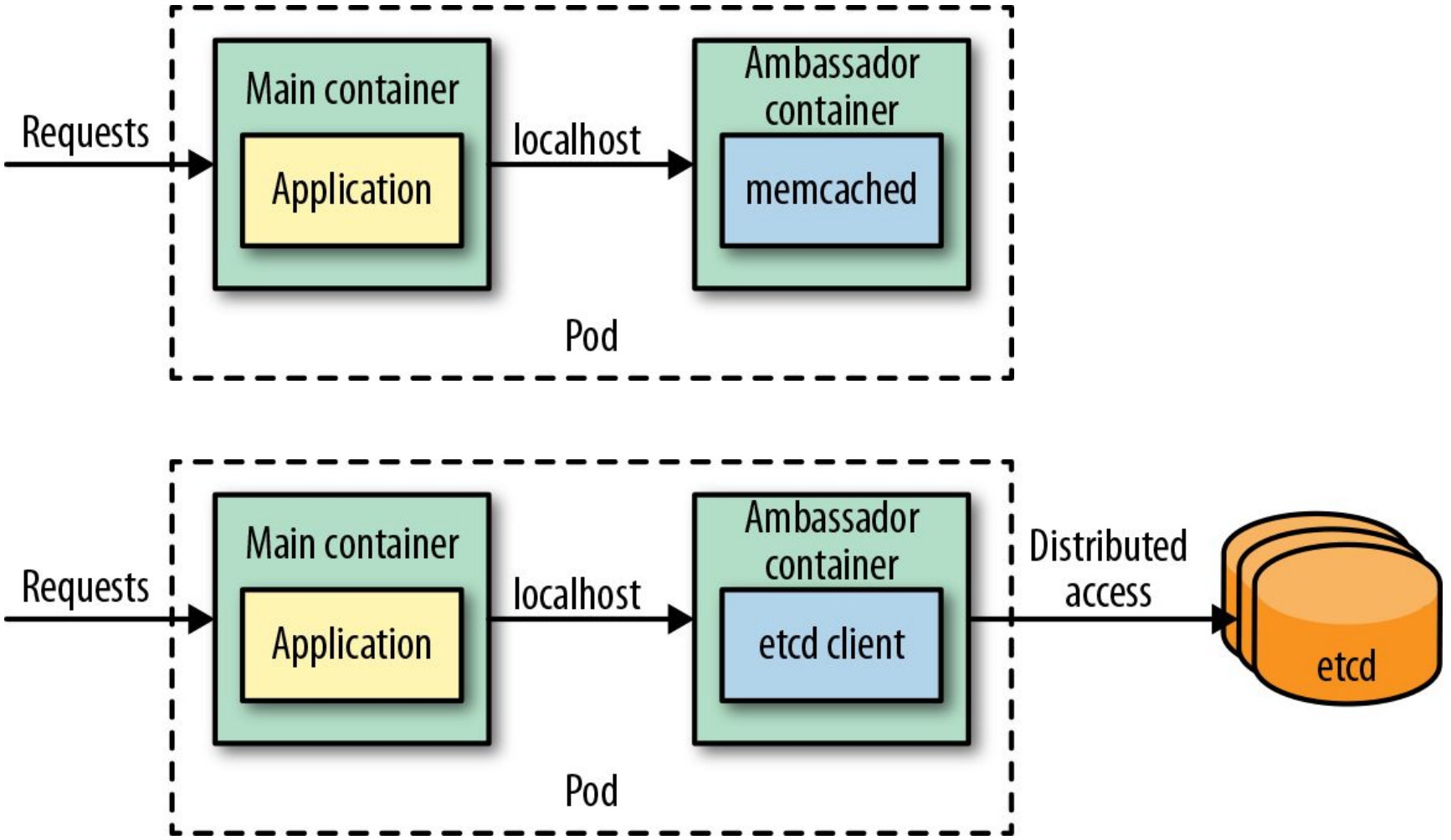
Adapter




Ambassador

How to decouple a container's access **to** the outside world

Ambassador



Controller

How to get from the current state to a declared target state.

State Reconciliation

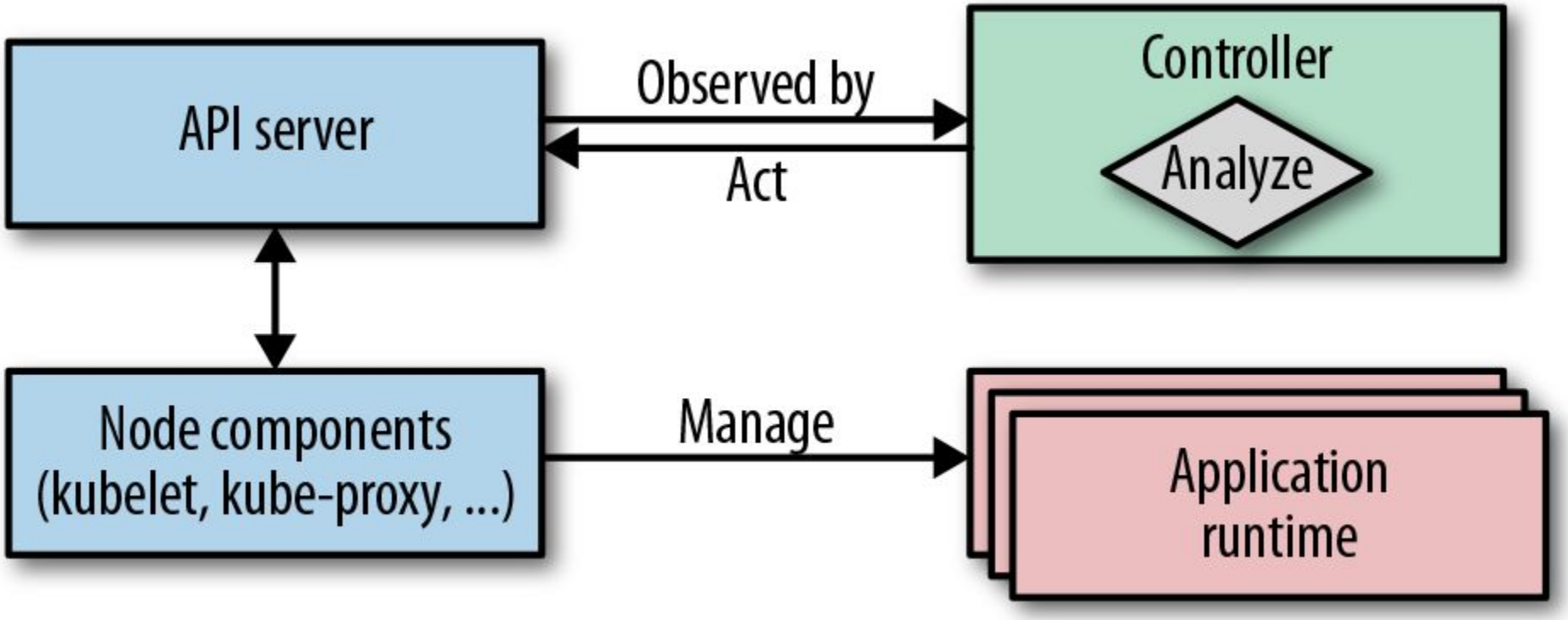
- Kubernetes as distributed state manager
- Make the **actual** state more like the declared **target** state.

🔎 ***Observe*** - Discover the actual state

🤔 ***Analyze*** - Determine difference to target state

🔨 ***Act-*** Perform actions to drive the actual to the desired state

Observe - Analyze - Act



Common Triggers

- Labels
  - Indexed by backend
  - Suitable for selector-like functionality
  - Limitation on characterset for names and values
- Annotations
  - No syntax restrictions
  - Not indexed
- ConfigMaps
  - Good for complex structured state declarations
  - Simple alternative to CustomResourceDefinitions

ConfigMap Watch Controller

```
namespace=${WATCH_NAMESPACE:-default}
base=http://localhost:8001
ns=namespaces/$namespace

curl -N -s $base/api/v1/${ns}/configmaps?watch=true | \
while read -r event
do
  type=$(echo "$event" | jq -r '.type')
  config_map=$(echo "$event" | jq -r '.object.metadata.name')
  annotations=$(echo "$event" | jq -r '.object.metadata.annotations')

  if [ $type = "MODIFIED" ]; then
    # Restart Pods using this ConfigMap
    # ...
  fi
done
```


Operator

How to encapsulate operational knowledge into executable software.

Definition

> An **operator** is a Kubernetes **controller** that understands two domains: Kubernetes and *something else*. By combining knowledge of both areas, it can **automate** tasks that usually require a human operator that understands both domains.
>
> **Jimmy Zelinskie**
> http://bit.ly/2Fjlx1h

Technical:

Operator = Controller + CustomResourceDefinition

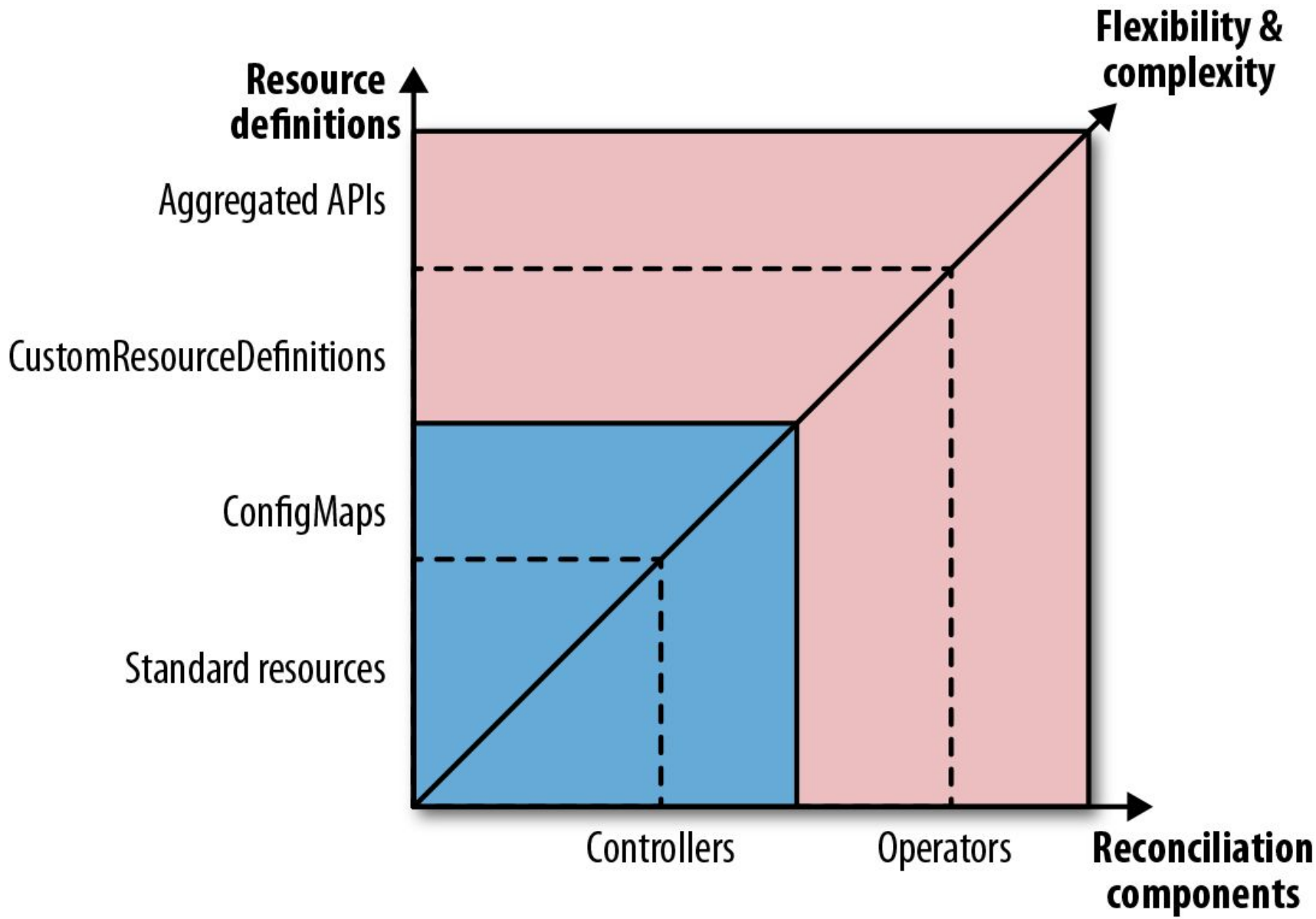
CustomResourceDefinition

Custom resource is modelling a custom domain and managed through the Kubernetes API

```
apiVersion: apiextensions.k8s.io/v1beta1
kind: CustomResourceDefinition
metadata:
  name: configwatchers.k8spatterns.io
spec:
  scope: Namespaced
  group: k8spatterns.io
  version: v1
  names:
    kind: ConfigWatcher
    plural: configwatchers
  validation:
    openAPIV3Schema:
    ...
```

Custom Resource

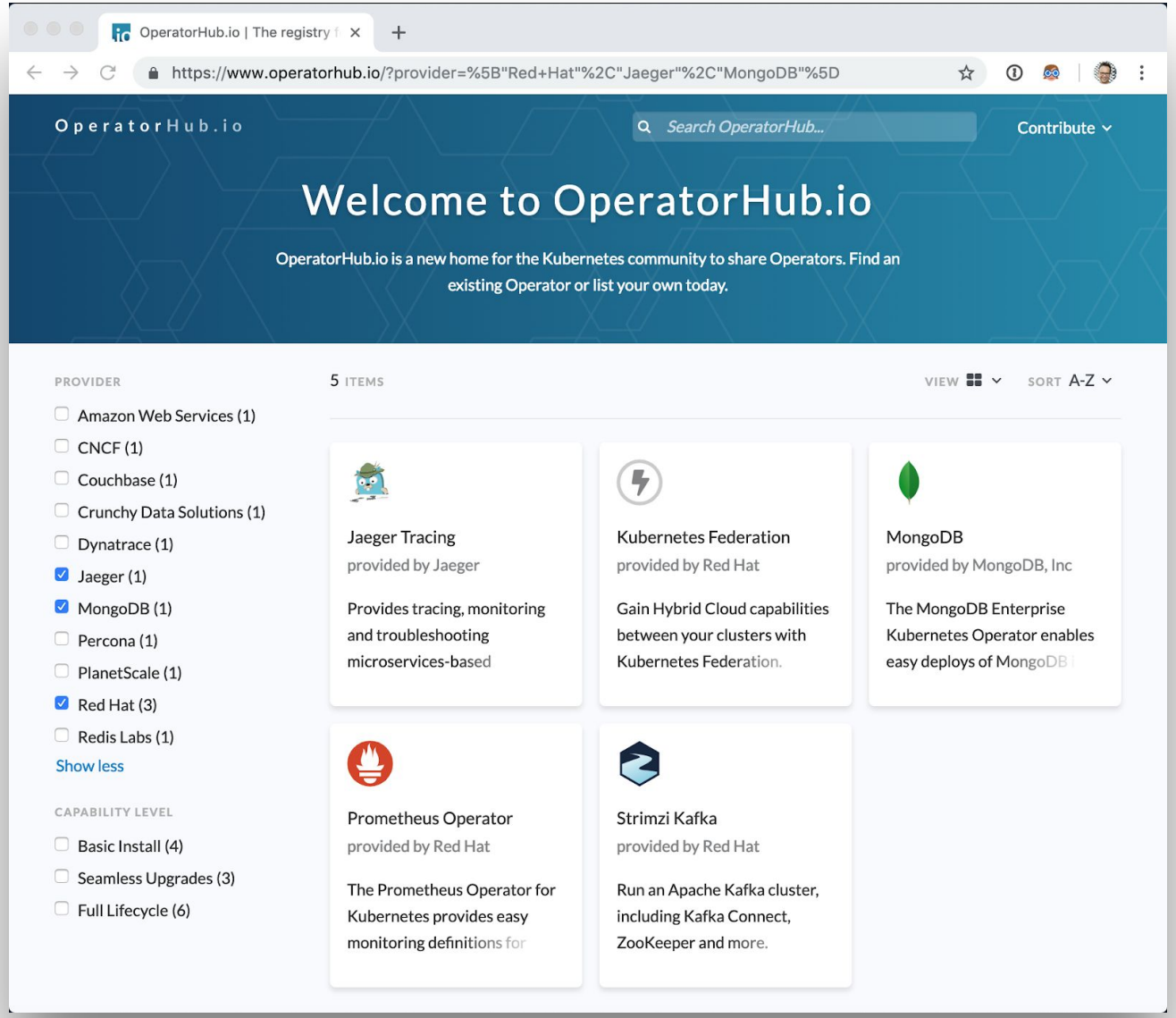
```
kind: ConfigWatcher
apiVersion: k8spatterns.io/v1
metadata:
  name: webapp-config-watcher
spec:
  configMap: webapp-config
  podSelector:
    app: webapp
```


Flexibility & complexity
Resource definitions
Aggregated APIs
CustomResourceDefinitions
ConfigMaps
Standard resources
Controllers
Operators
Reconciliation components

CRD Classification

- Installation CRDs
  - Installing and operating applications
  - Backup and Restore
  - Monitoring and self-healing
  - Example: Prometheus for installing Prometheus & components
- Application CRDs
  - Application specific domain concepts
  - Example: ServiceMonitor for registering Kubernetes service to be scraped by Prometheus

Operator Hub



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Operator Development

- Operator can be implemented in any language
- Frameworks:
  - Operator Framework (Golang, Helm, Ansible) https://github.com/operator-framework
  - Kubebuilder (Golang) https://github.com/kubernetes-sigs/kubebuilder
  - Metacontroller (Language agnostic) https://metacontroller.app/
  - jvm-operators (Java, Groovy, Kotlin, ...) https://github.com/jvm-operators


Elastic
Scale

How to automatically react to dynamically changing resource requirements.

Scaling

- **Horizontal**: Changing replicas of a Pod
- **Vertical:** Changing resource constraints of containers in a single Pod
- **Cluster**: Adding new nodes to a cluster
- **Manual**: Changing scale parameters manually,. imperatively or declaratively
- **Automatic**: Change scaling parameters based on observed metrics

Scaling

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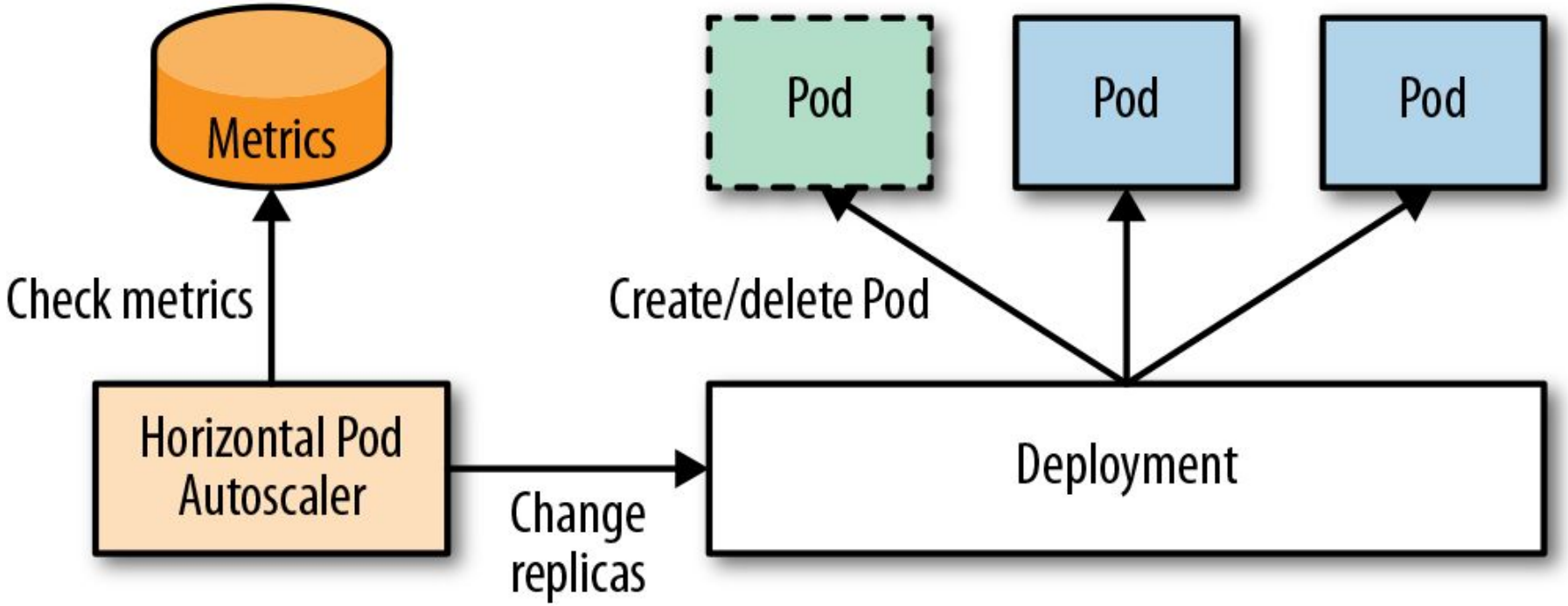
Horizontal Pod Autoscaler (HPA)




```
kubectl autoscale deployment random-generator --cpu-percent=50 --min=1 --max=5
```

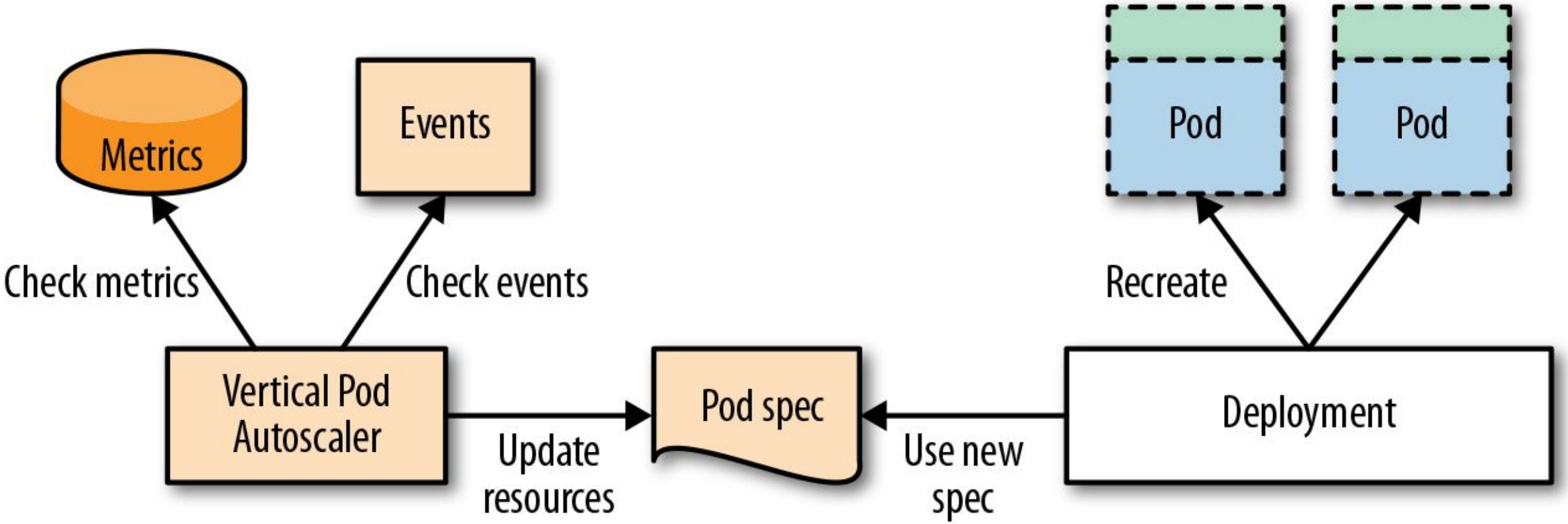
HorizontalPodAutoscaler

```
apiVersion: autoscaling/v2beta2
kind: HorizontalPodAutoscaler
metadata:
  name: random-generator
spec:
  minReplicas: 1
  maxReplicas: 5
  scaleTargetRef:
    apiVersion: extensions/v1beta1
    kind: Deployment
    name: random-generator
  metrics:
  - resource:
      name: cpu
      target:
        averageUtilization: 50
        type: Utilization
    type: Resource
```

HPA: Metrics & Challenges

- Metrics
  - **Standard Metrics** - CPU & Memory Pod data obtained from Kubernetes metrics server
  - **Custom Metrics** - Metrics delivered via an aggregated API server at the `custom.metrics.k8s.io` API path
  - **External Metrics** - Metrics obtained from outside the cluster
- Challenges
  - **Metric Selection** - Correlation between metric value and replica counts
  - **Preventing Thrashing** - Windowing to avoid scaling on temporary spikes
  - **Delayed Reaction** - Delay between cause and scaling reaction

Vertical Pod Autoscaler (VPA)



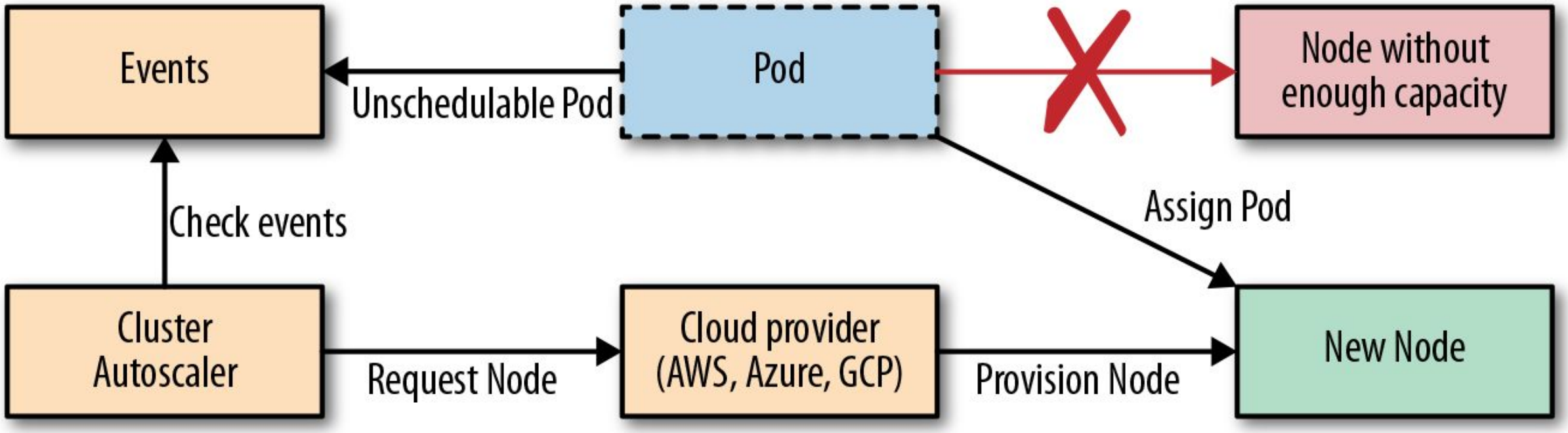
VerticalPodAutoscaler

```
apiVersion: poc.autoscaling.k8s.io/v1alpha1
kind: VerticalPodAutoscaler
metadata:
  name: random-generator-vpa
spec:
  selector:
    matchLabels:
      app: random-generator
  updatePolicy:
    updateMode: "Off"
```

VPA: Update Mode

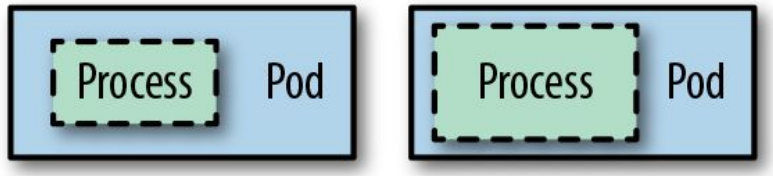
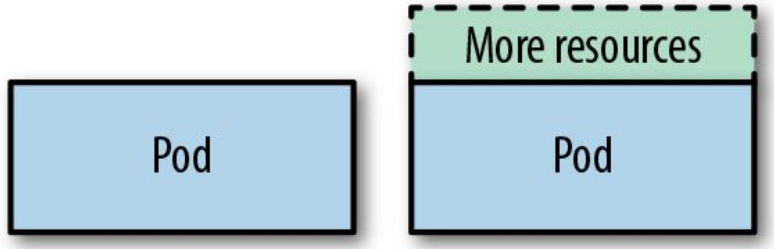
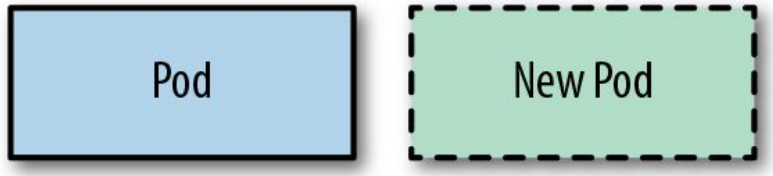
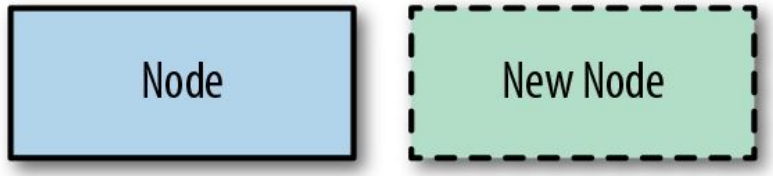
- `updateMode: Off`
  - Recommendations are stored in the `status:` section of the VPA resource
  - No changes to the selected resources are performed
- `updateMode: Initial`
  - Recommendations are applied during creation of a Pod
  - Influences scheduling decission
- `updateMode: Auto`
  - Automatically restarts Pods with updated resources based on recommendation

Cluster Autoscaler



Cluster Autoscaler

- Scale-Up
  - Adding a new node if a Pod is marked as *unschedulable* because of scarce resources.
  - Cluster API: Kubernetes API for dynamically managing node groups.
- Scale-Down
  - … more than half of a nodes capacity is unused
  - … all movable Pods can be placed on other nodes
  - … no other reasons to prevent node deletion
  - … no Pods that can not be moved

Technique	Action	Scaling Example
Application Tuning	Tune process (threads, heap, etc.)	
Vertical Pod Autoscaler	Increase/reduce container resources	
Horizontal Pod Autoscaler	Add/remove Pods	
Cluster Autoscaler	Add/remove Nodes	

Thank you

https://k8spatterns.io

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