Kubernetes APIs Under the Hood

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Who Am I?

Phillip Wittrock (@pwittrock)

Software Engineer at Google working on GKE and OSS Kubernetes

My mission is to make using Kubernetes simple and enjoyable

You might have come across me through…

- Kubectl
- Kubebuilder
- Kubernetes Steering Committee

Kubernetes Refresher

- ***Nodes*** are machines in a cluster that run Containers in ***Pods***
- ***Pods*** are created and managed by higher level abstractions such as ***ReplicaSets***
- ***ReplicaSets*** managed by higher level abstractions such as ***Deployments***
- **Deployments** (and all other user owned objects) defined in files and created / updated with `kubectl apply`
- **APIs** (deployments, replicasets, pods, nodes) == *Resource Types* and **Objects** == *Resources*

Kubernetes APIs Are...

Declarative, **Asynchronous, Level-Triggered**, **Observable,** Discoverable, **Versioned**, Access Controlled, **Extensible, ...**

Kubernetes APIs are… Declarative

Configuration for a ***Deployment*** that manages 3 ***Pods*** each running an nginx container

Deployment resource is declared in a *file*

```
apiVersion: apps/v1
kind: Deployment
metadata:
    name: nginx-deployment
    labels: {app: nginx}
spec:
    replicas: 3
    selector:
        matchLabels: {app: nginx}
    template:
        metadata:
            labels: {app: nginx}
        spec:
            containers: [
             {name: nginx,
              image: 'nginx:1.7.9'}]
```

Create or update the resource in the cluster by run *kubectl apply* on a file or directory

```
kubectl apply -f deploy.yaml
```

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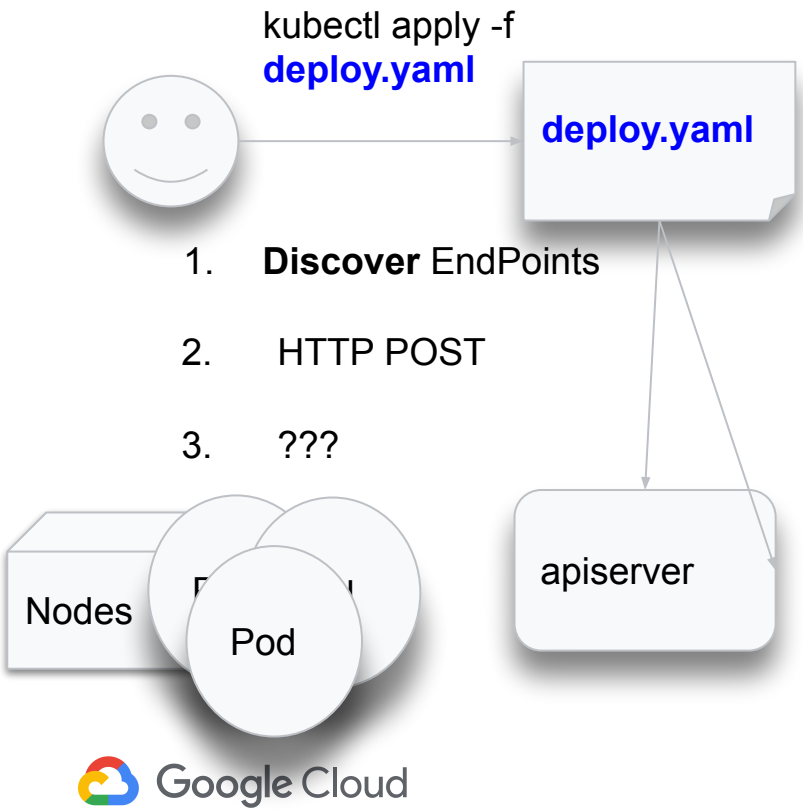
Create Deployment Example




```yaml
apiVersion: apps/v1
kind: Deployment
metadata:
    name: nginx-deployment
    labels: {app: nginx}
spec:
    replicas: 3
    selector:
        matchLabels: {app: nginx}
    template:
        metadata:
            labels: {app: nginx}
        spec:
            containers: [
             {name: nginx,
              image: 'nginx:1.7.9'}]
```

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Lifecycle - Resources, Controllers and Webhooks

- APIs declared as ***Resources*** - provide storage and endpoints
- APIs actuated by ***Controllers*** - execute the business logic
- APIs admitted by ***Webhooks*** - defaulting, validation, conversion

Kubernetes APIs are... Asynchronous & Observable

Resource:
Stores Stuff

Foo **Resources** stored in etcd by the apiserver

Asynchronous *watch* notification on object create / update / delete

Controller:
Does Stuff

Foo **Controller**

Loose coupling between Controller and API endpoints: Storage doesn't know about Controllers

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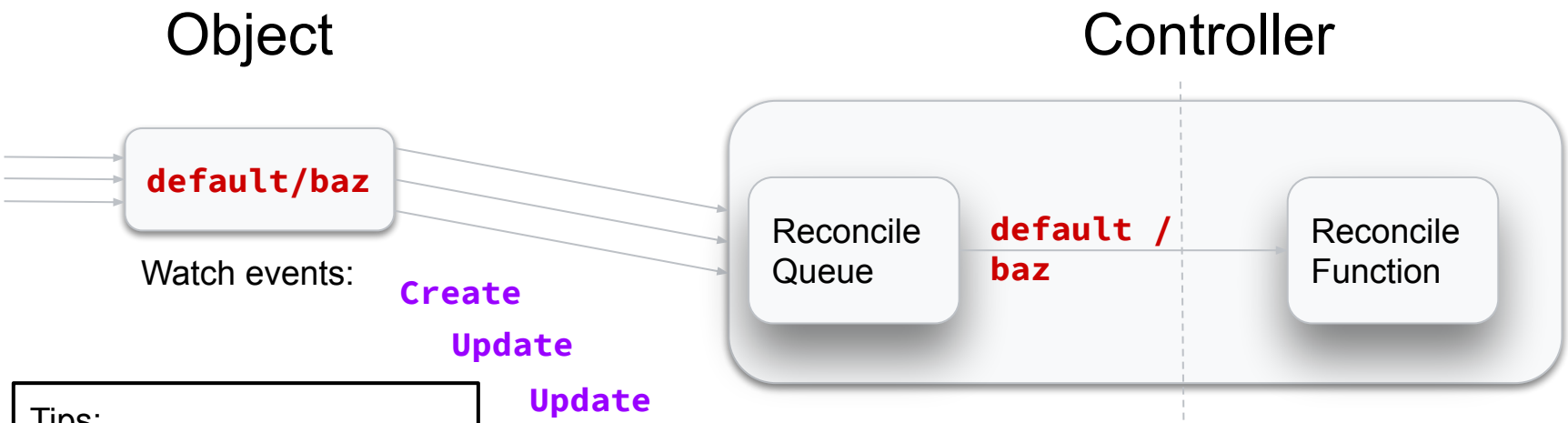
Kubernetes APIs are... Level Triggered



Tips:

- Internal cleanup with `ownerReferences`
- External cleanup with `finalizers`

Batch events together into single Reconcile call

Reconcile on namespace/name only, not the event

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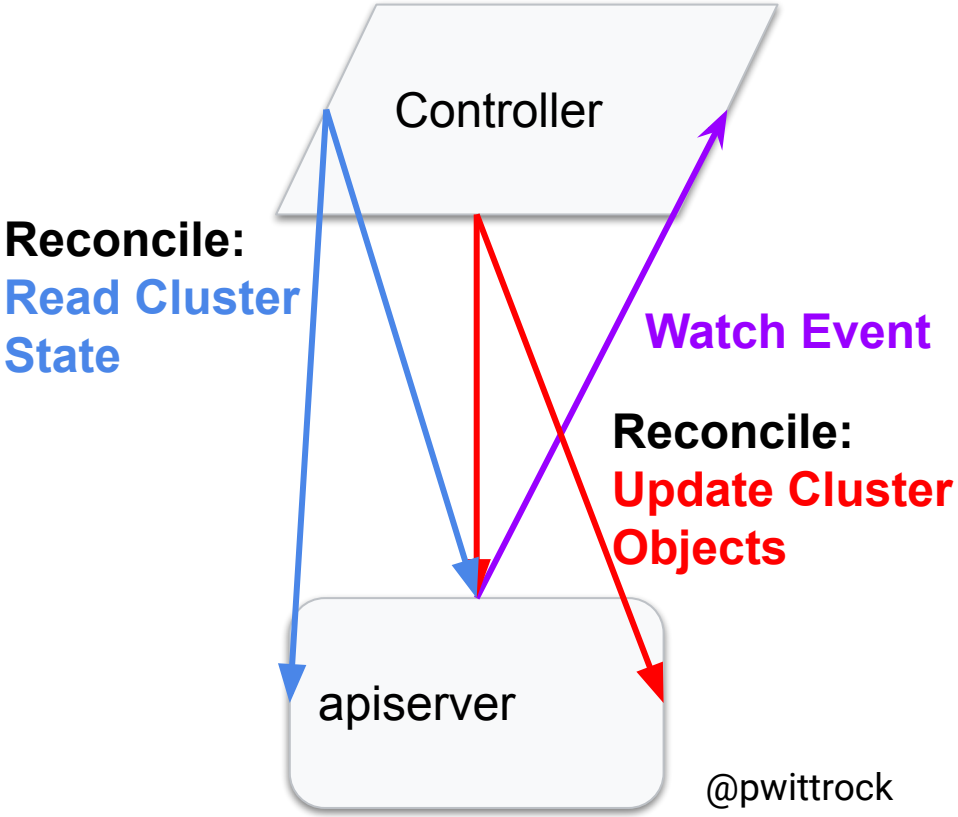
Controller Workflow

- apiserver streams **Watch Event** to Controller
- Controller **Reads Object + Related Objects** (e.g. Deployment + ReplicaSets)
- Controller **Creates new owned objects, updates owned objects, updates object status**



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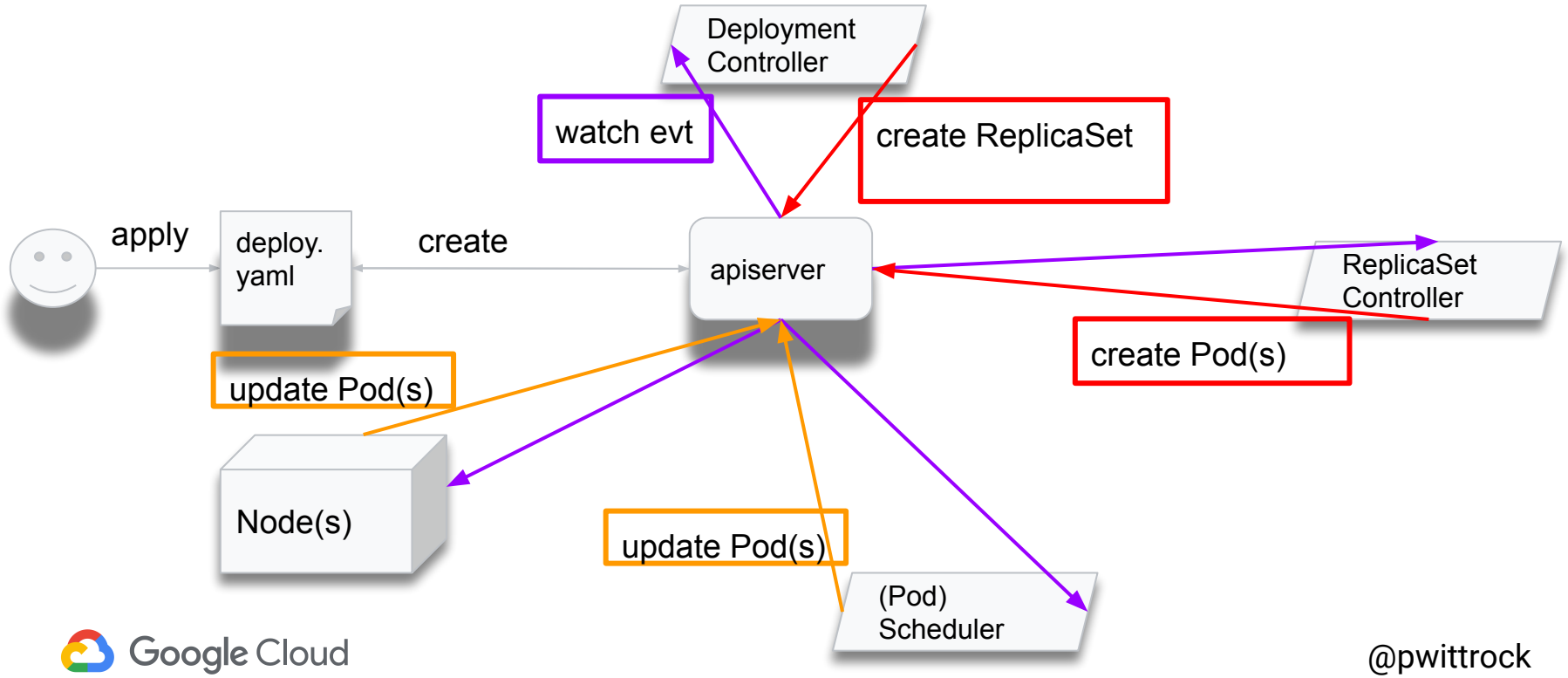
Kubectl Apply: Create Deployment



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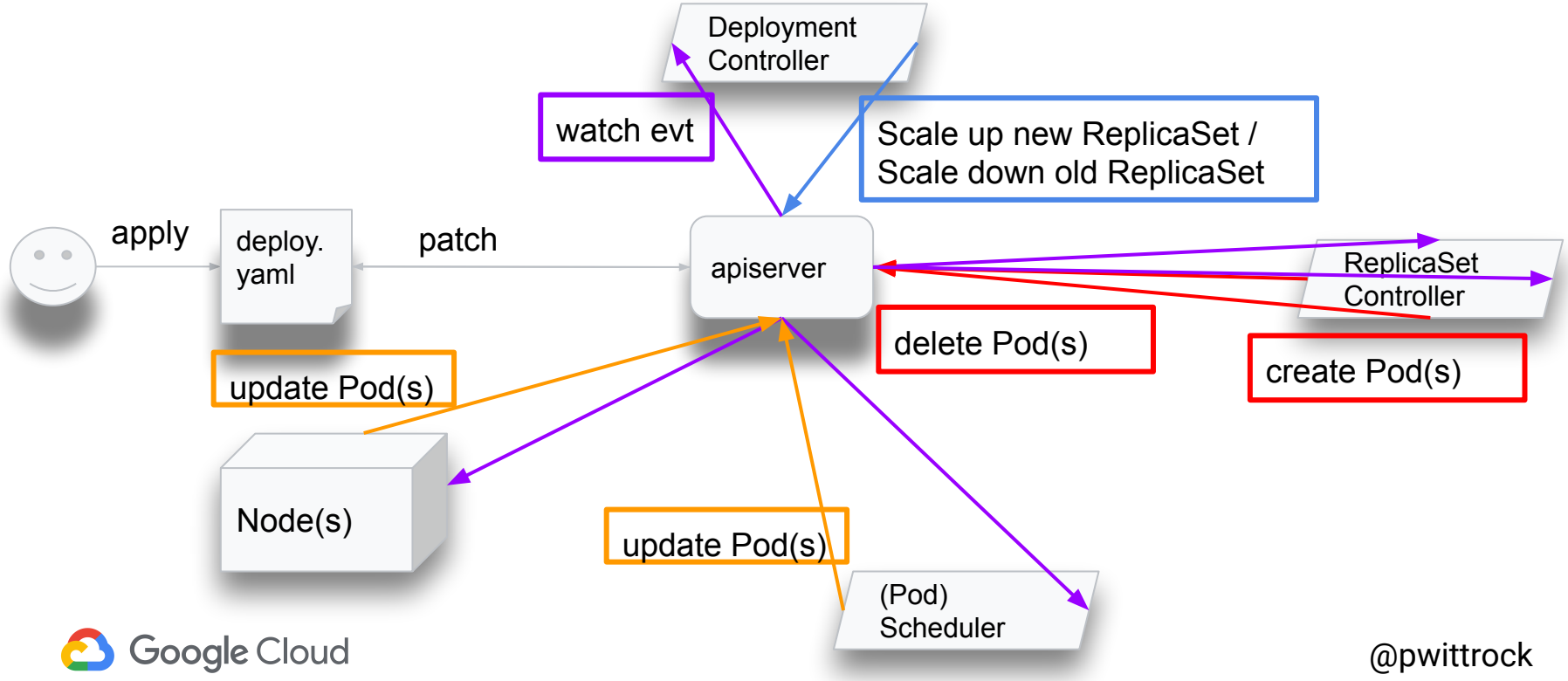
Kubectl Apply: Update Deployment



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Resources

- Resource Types *declare* APIs
- Resources provide storage for objects
- Standardized schema structure
- Discoverable API endpoints and schema
- “Just work” with declarative tooling - e.g. `kubectl apply`

metadata

spec

status

```
apiVersion: v1
kind: Pod
metadata:
  name: my-app
  namespace: default
  ...
spec:
  containers:
  - args: [sh]
    image: gcr.io/some-project/udptest
    imagePullPolicy: Always
    name: client
    ...
  dnsPolicy: ClusterFirst
...
status:
  podIP: 10.8.3.11
  ...
```

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TypeMeta

- *Kind (Deployment)*
  - Name of the API (e.g. Deployment)
- **Group (apps)**
  - Like a package in go, java, etc (e.g. *apps*)
- *Version (v1)*
  - Ensures backwards compatibility of: Defaulted Fields & Schema

```
apiVersion: apps/v1
kind: Deployment
metadata:
    name: nginx-deployment
    labels: {app: nginx}
spec:
    replicas: 3
    selector:
    ...
    template:
    ...
```

ObjectMeta

- *Name* ***and*** **Namespace* uniquely identify an object for a given Resource
- ***Annotations*** are arbitrary key-value pairs that cannot be queried
- ***Labels*** are key-value pairs that may be queried (selected)

```
apiVersion: apps/v1
kind: Deployment
metadata:
    name: nginx-deployment
    namespace: default
    labels: {app: nginx}
spec:
    replicas: 3
    selector:
    ...
    template:
    ...
```

Spec and Status

- Spec
  - *Object Desired State* (e.g. how many replicas to run, template for Pods, etc)
- Status (not shown)
  - Defines the observed state for an object (e.g. how many replicas are running)

```yaml
apiVersion: apps/v1
kind: Deployment
metadata:
    name: nginx-deployment
    labels: {app: nginx}
spec:
    replicas: 3
    selector:
        matchLabels: {...}
    template:
        metadata:
            labels: {...}
        spec:
        ...
```

Resource Wiring

- Labels/Selectors locate objects
- **Label** - generated objects
- **Selector** - find labeled objects
- **OwnerReference** on generated objects

Tip: Objects with owner references are automatically garbage collected when all of their owners have been deleted

Deployment
name:`nginx`
labels:`run=nginx`
selector:`run=nginx`

ReplicaSet
name:`nginx-65899c769f`
labels:`run=nginx`
selector:`run=nginx`
owner: `Deployment nginx`

Pod
name:`nginx-65899c769f-6slpx`

Pod
name:`nginx-65899c769f-fbgcv`
labels: `run=nginx`
owner: `ReplicaSet nginx-65899c769f`

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Synchronous Defaulting and Validation

- Unspecified optional fields may be defaulted by the apiserver before the object is stored
- Simple Schema validation performed through OpenAPI
- Complex validation performed by the apiserver before the object is stored

```yaml
apiVersion: apps/v1
kind: Deployment
metadata:
    name: nginx-deployment
    labels: {app: nginx}

spec:
    # server defaults this value
    # to 1 if unset
    replicas: 1

    # make sure these match the
    # template labels
    selector:
        matchLabels: {...}
    template:
        metadata:
            labels: {...}
```

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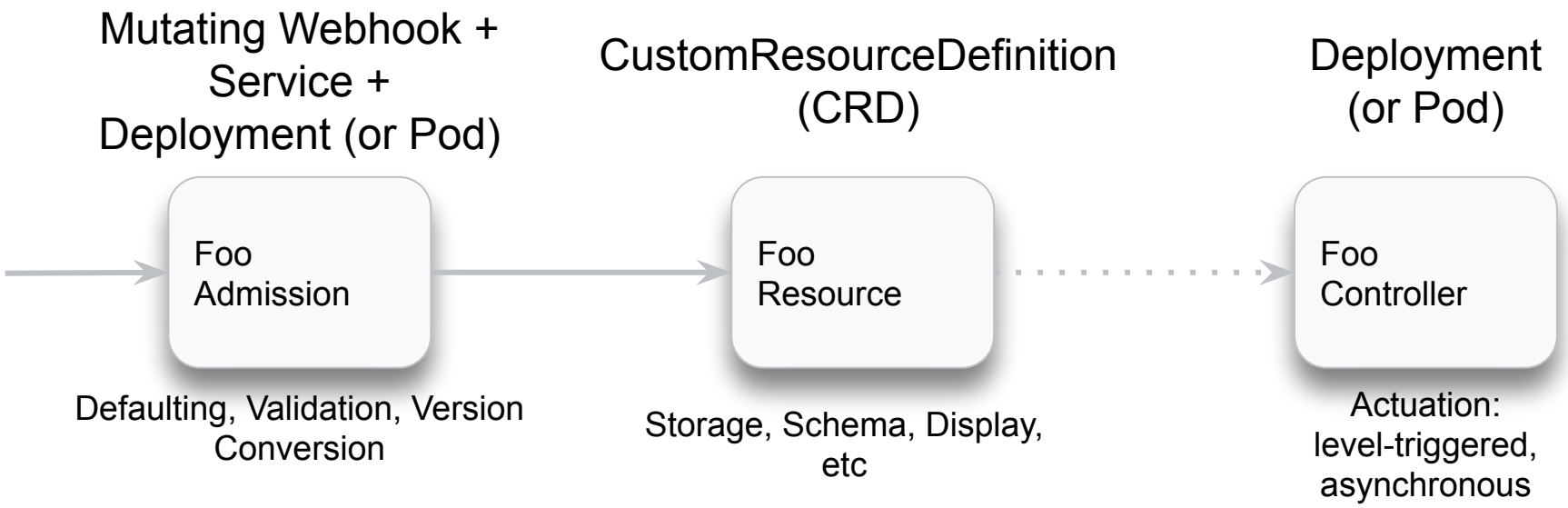
Kubernetes APIs are… Extensible



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Tip: build your own APIs in go using kubebuilder

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Updating Resources Gotchas

- Spec has shared ownership across multiple parts of the system
- Controllers or other actors may update the Spec with *new fields* which must be retained across updates to the object
- Both an issue for Controllers and for users managing Resources using config
- Need to either read-update-write or *apply*

```yaml
apiVersion: v1
kind: Service
metadata:
  name: nginx
  labels: {app: nginx}
spec:
  selector:
    app: nginx
  ports:
  - protocol: TCP
    port: 80
  # not set by owner!
  # don't overwrite!
  clusterIp: 10.0.171.239
  # not set by owner!
  # don't overwrite!
  loadBalancerIp: 78.1124.19
  type: LoadBalancer
```

Observing Objects - Status and Events

- Actuation performed asynchronously
- Status published to users, tools and other controllers through Status field
- Conditions: key/value pairs that communicate status (current) to other tools (part of Status field)
- Events: separate objects that communicate past events to users

```
Kind: Pod
...
spec:
  readinessGates:
    - conditionType:
"www.example.com/feature-1"
status:
  conditions:
    - type: Ready
      status: "False"
      lastProbeTime: null
      lastTransitionTime: ...
    - type: "www.example.com/feature-1"
      status: "False"
      lastProbeTime: null
      lastTransitionTime: ...
  containerStatuses:
    - containerID: docker://abcd…
      ready: true
```

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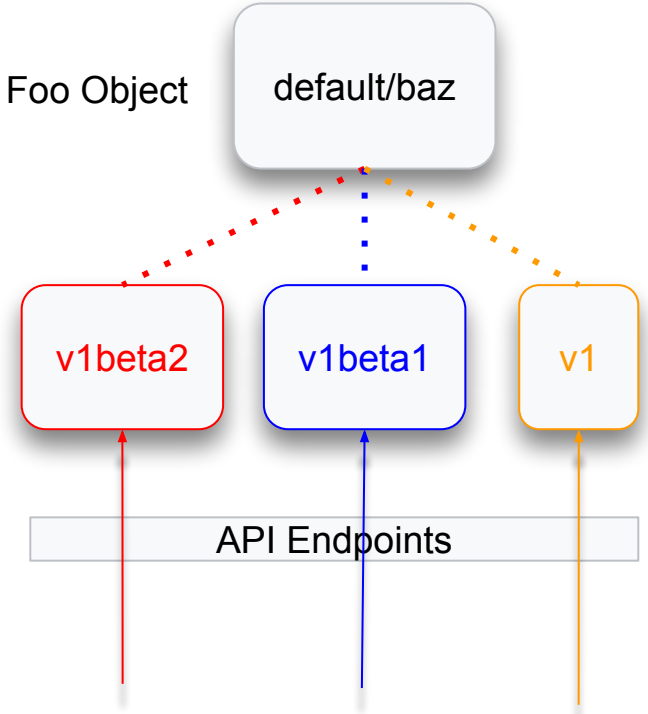
Converting API versions

- Different versions of an API may have different representations
  - Changing default values and field names / field types requires a new version
- All versions of the same API are logically equivalent
- The same object may be read or written in any version -- the underlying object remains the same -- but the endpoints are different.



Classes of APIs

Composites

Operators
Spark, Airflow

Cloud Native Abstractions
Tekton, Knative

Decorators

Autoscalers, Resource Tuners

Kubernetes APIs Are...

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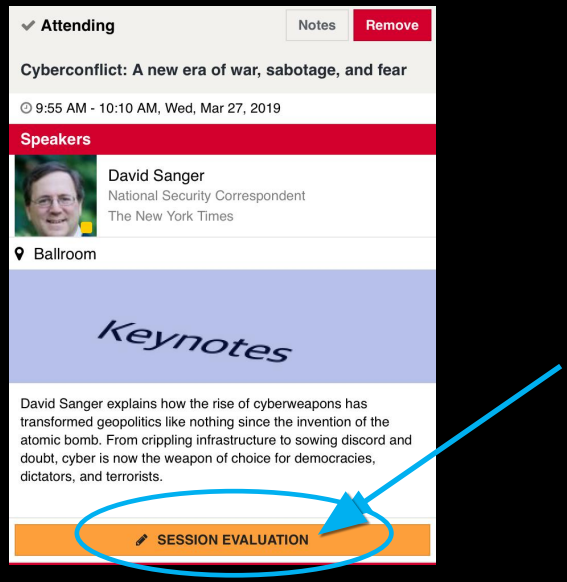
Level-Triggered, **Observable,**
Discoverable, Versioned, Access
Controlled, **Extensible, ...**

Kubebuilder Workshop

https://github.com/DirectXMan12/kubebuilder-workshops/tree/software-architecture-2019

Rate today’s session

Session page on conference website



O’Reilly Events App

Questions?