Writing a Kubernetes Operator to deploy a complex system

—

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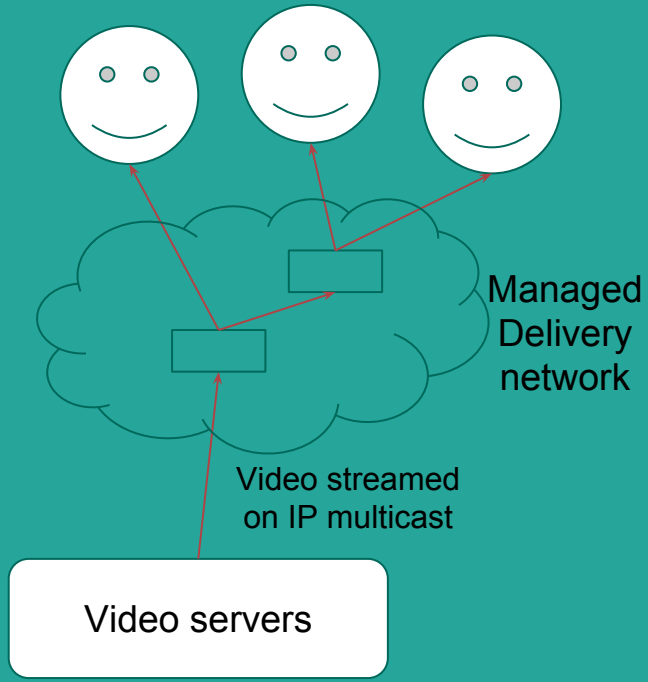
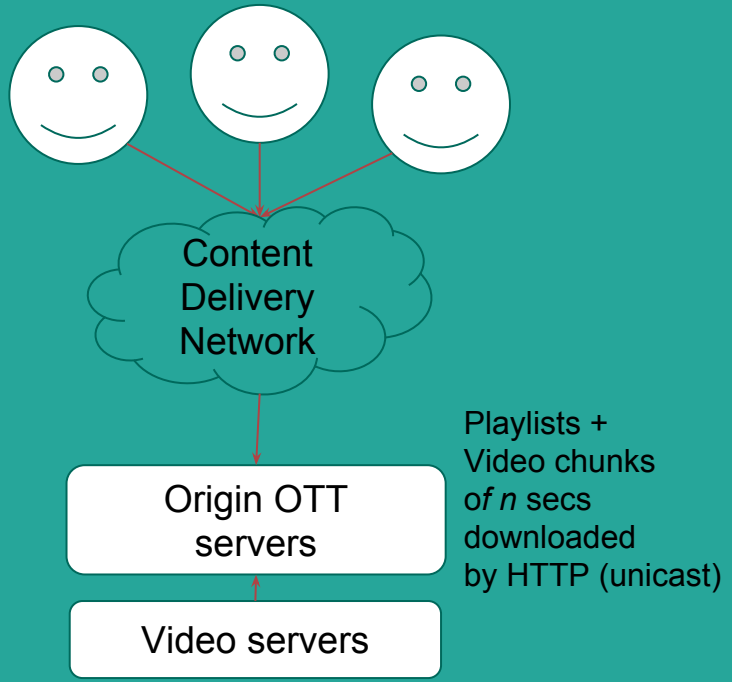
Anevia

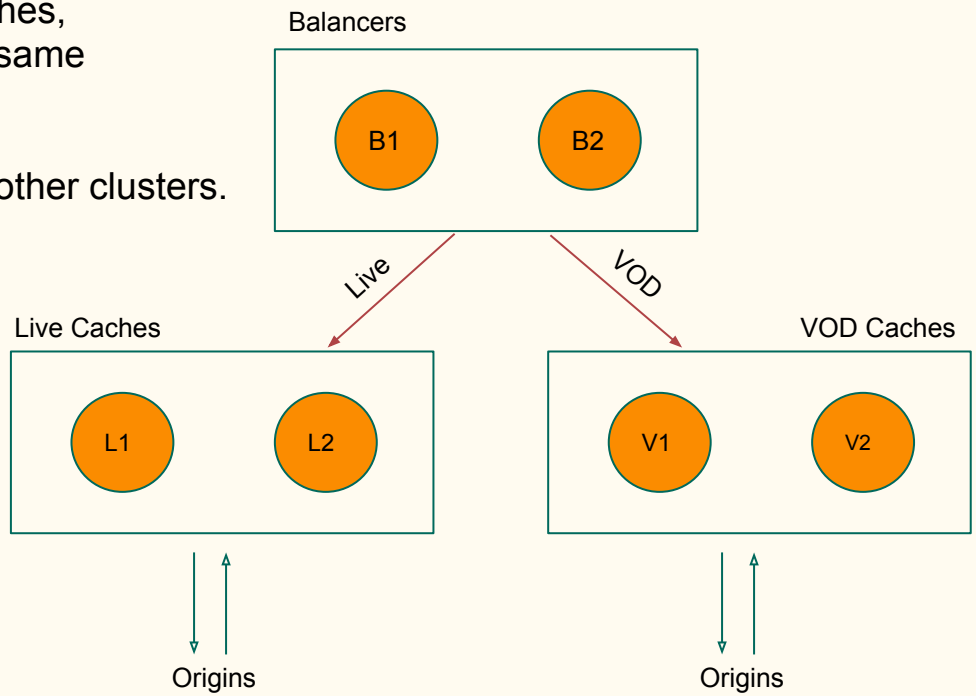
IPTV vs OTT


Managed
Delivery
network
Video streamed
on IP multicast
Video servers


Content
Delivery
Network
Playlists +
Video chunks
of *n* secs
downloaded
by HTTP (unicast)
Origin OTT
servers
Video servers

A use-case at Anevia

- Deploy clusters of Balancers or Caches, all instances of a cluster having the same configuration,
- Define some clusters as sources of other clusters.



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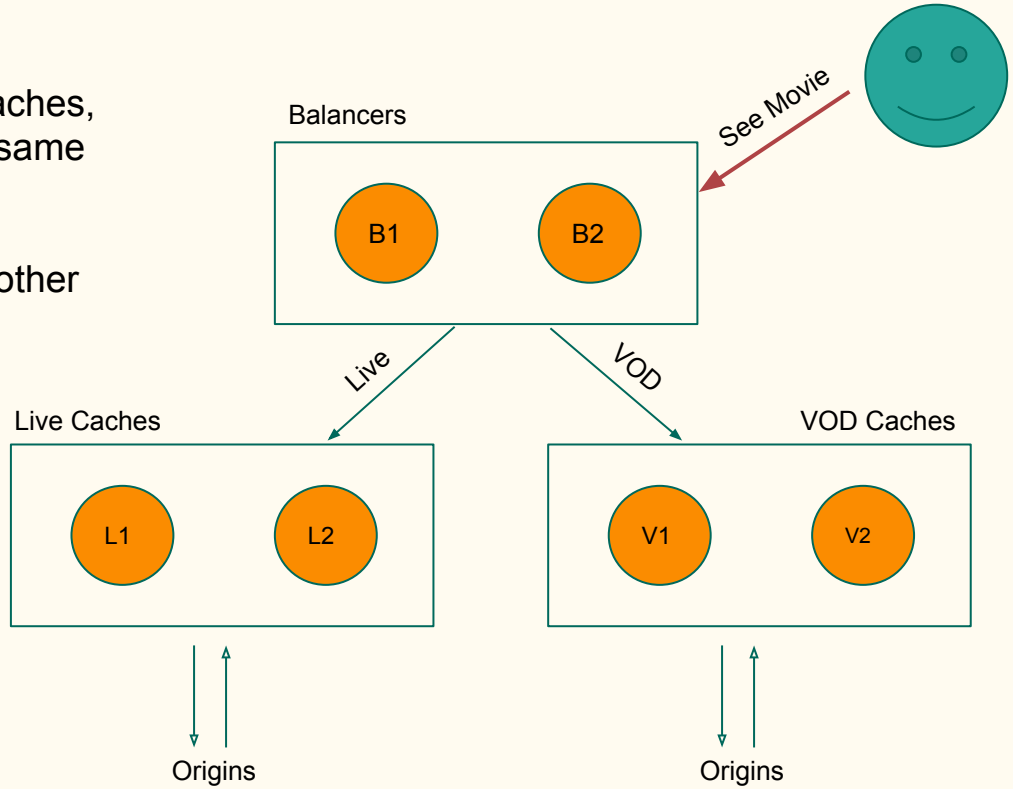

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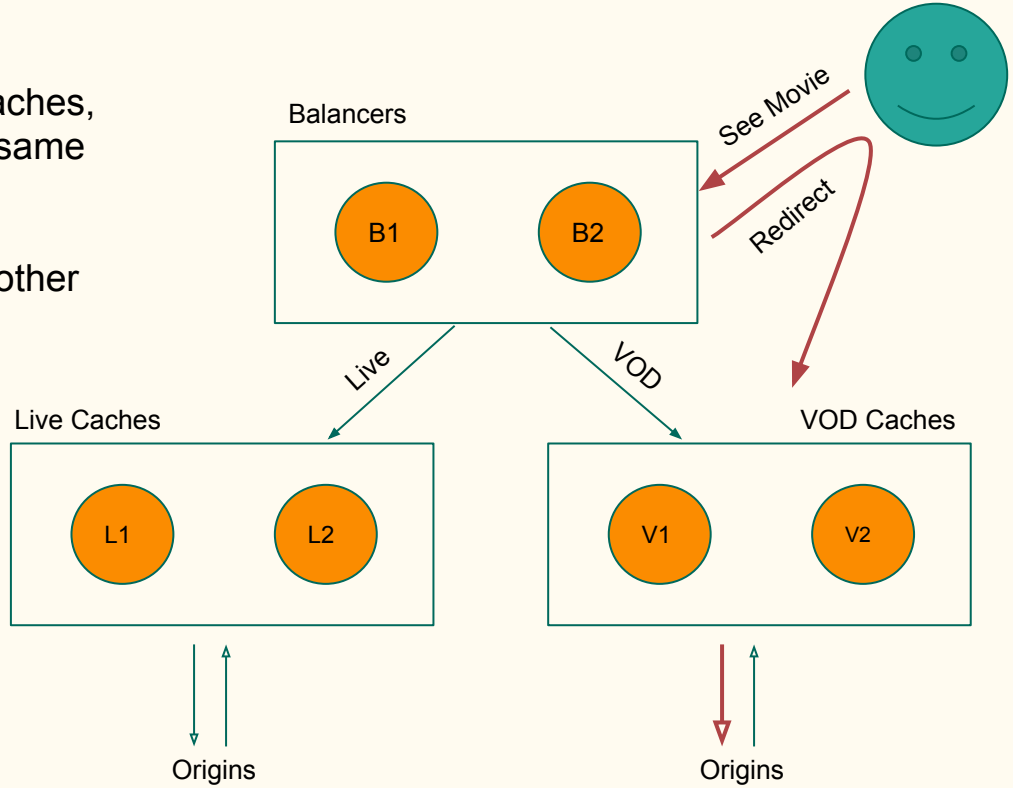

A use-case at Anevia

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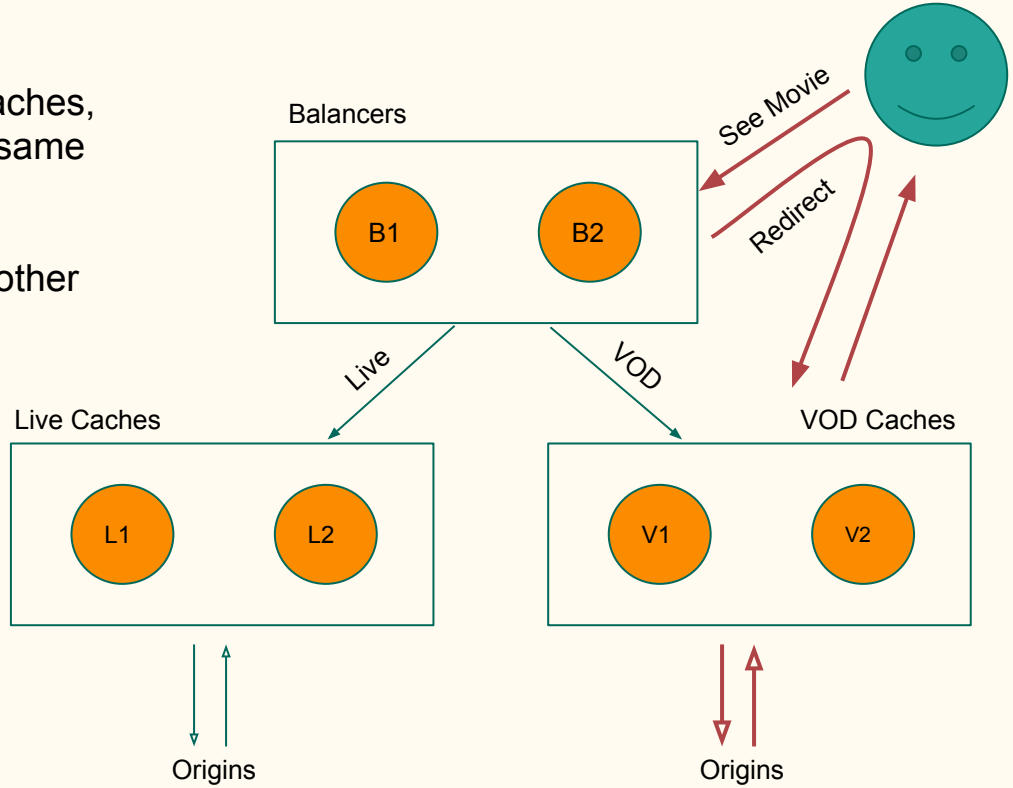


A solution based on a Kubernetes Operator

- **a Custom Resource**
  - Representing a Cluster of Balancers or Caches
  - Defining the list of Sources of this cluster
- **an Operator**
  - Reading resources
  - Deploying containers into a Kubernetes cluster
  - Configuring the containers depending on the sources

“Presenting complexity in familiar ways
- *Kubernetes CRDs”*

Kris Nova, this morning

using sample-controller

https://github.com/kubernetes/sample-controller

Using sample-controller

- **Benefits**
  - Easy way to begin with a functional and simple CRD and an operator

- **Limits**
  - How to extend?
  - How to write tests?
  - How to deploy, especially which RBAC auth to apply?

using kubebuilder

kubebuilder init --domain anevia.com

The resource

Creating a new `CdnCluster` Resource

Customizing the `CdnCluster` Resource

Creating `CdnCluster`s instances from client

Creating a new `CdnCluster` Resource

The Resource

Creating a new resource

Group	Version	Kind
core	v1	Pod
apps	v1	Deployment
cluster	v1	CdnCluster

```
$ kubebuilder create api \
  --group cluster \
  --version v1 \
  --kind CdnCluster
```

The Resource

Examining the created files

Generated sources in config/

```
$ make manifests
```

CustomResourceDefinition

- crds/cluster_v1_cdncluster.yaml

Custom Resource Definition

```yaml
apiVersion: apiextensions.k8s.io/v1beta1
kind: CustomResourceDefinition
metadata:
 creationTimestamp: null
 labels:
   controller-tools.k8s.io: "1.0"
 name: cdnclusters.cluster.anevia.com
spec:
 group: cluster.anevia.com
 names:
   kind: CdnCluster
   plural: cdnclusters
 scope: Namespaced
```

```yaml
spec:
 validation:
   openAPIV3Schema:
     properties:
       apiVersion:
         type: string
       kind:
         type: string
       metadata:
         type: object
       spec:
         type: object
       status:
         type: object
 version: v1
```

```yaml
status:
 acceptedNames:
   kind: ""
   plural: ""
 conditions: []
 storedVersions: []
```

The Resource

Examining the created files

Generated sources in config/

```
$ make manifests
```

CustomResourceDefinition

- crds/cluster_v1_cdncluster.yaml

ClusterRole & ClusterRoleBinding

- rbac/rbac_role.yaml
- rbac/rbac_role_binding.yaml

Cluster Role

```yaml
apiVersion: rbac.authorization.k8s.io/v1
kind: ClusterRole
metadata:
 creationTimestamp: null
 name: manager-role
rules:
```

The sample operator can work on Deployments and CdnClusters

```yaml
rules:
- apiGroups:
 - apps
 resources:
 - deployments
 verbs:
 - get
 - list
 - watch
 - create
 - update
 - patch
 - delete
```

```yaml
rules:
- apiGroups:
 - cluster.anevia.com
 resources:
 - cdnclusters
 verbs:
 - get
 - list
 - watch
 - create
 - update
 - patch
 - delete
```

The Resource

Examining the created files

Generated sources in config/

```
$ make manifests
```

CustomResourceDefinition

- crds/cluster_v1_cdncluster.yaml

ClusterRole & ClusterRoleBinding

- rbac/rbac_role.yaml
- rbac/rbac_role_binding.yaml

CdnCluster

- samples/cluster_v1_cdncluster.yaml

Sample CdnCluster

```yaml
apiVersion: cluster.anevia.com/v1
kind: CdnCluster
metadata:
 labels:
   controller-tools.k8s.io: "1.0"
 name: cdncluster-sample
spec:
 # Add fields here
 foo: bar
```

The Resource

Examining the created files

Go sources in pkg/apis/
of the Custom Resource Definition

```
├ addtoscheme_cluster_v1.go
├ apis.go
└ cluster
 ├ group.go
 └ v1
   ├ cdncluster_types.go # definition
   ├ cdncluster_types_test.go # tests
   ├ doc.go
   ├ register.go
   ├ v1_suite_test.go
   └ zz_generated.deepcopy.go
```

The Resource

The sample
Custom Resource Definition
sources

```
// CdnClusterSpec defines the desired state
type CdnClusterSpec struct {
}

// CdnClusterStatus defines the observed state
type CdnClusterStatus struct {
}

// CdnCluster is the Schema for the cdnclusters
type CdnCluster struct {
  metav1.TypeMeta   `json:",inline"`
  metav1.ObjectMeta `json:"metadata,omitempty"`

  Spec   CdnClusterSpec   `json:"spec,omitempty"`
  Status CdnClusterStatus `json:"status,omitempty"`
}
```

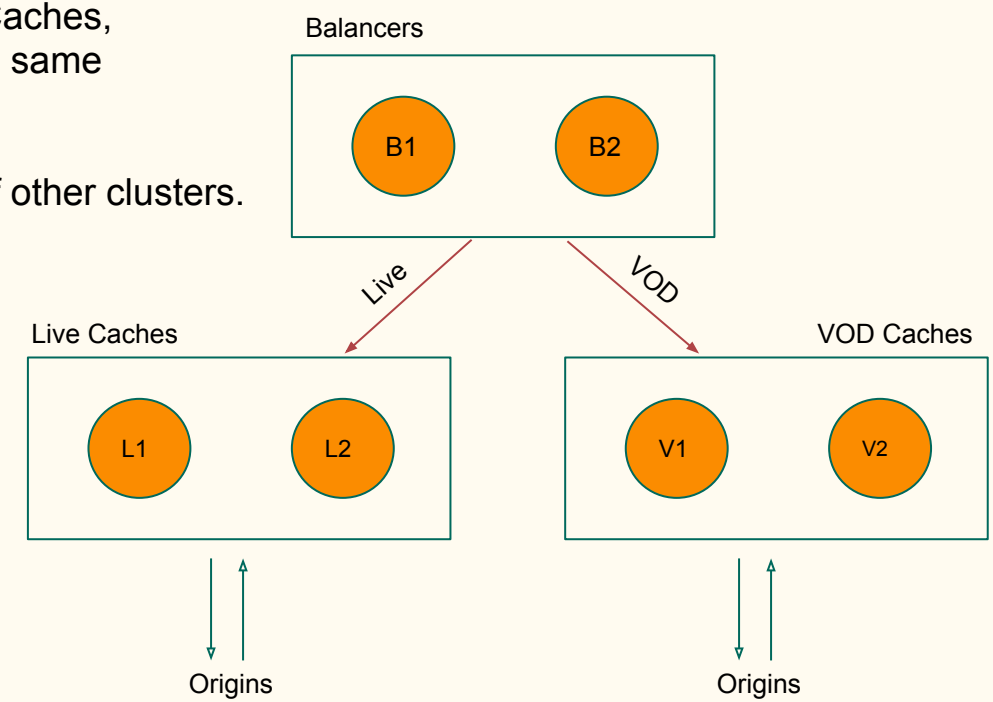
How are RBAC authorizations generated?

```
// In pkg/controller/cdncluster/cdncluster_controller.go

// Automatically generate RBAC rules to allow the Controller
// to read and write Deployments
// +kubebuilder:rbac:groups=apps,resources=deployments,verbs=get;list;...

// Automatically generate RBAC rules to allow the Controller
// to read and write CdnClusters
// +kubebuilder:rbac:groups=cluster.anevia.com,resources=cdnclusters,verbs=get;list;..
```

Customizing the `CdnCluster` Resource

A use-case at Anevia

- Deploy clusters of Balancers and Caches, all instances of a cluster having the same configuration,
- Define some clusters as sources of other clusters.



The Resource

Customizing the
Custom Resource Definition
from sources

```go
// CdnClusterSpec defines the desired state
type CdnClusterSpec struct {
  // Role must be 'balancer' or 'cache'
  Role string `json:"role"`
  // Sources is the list of source clusters
  Sources []CdnClusterSource `json:"sources"`
}

// CdnClusterSource defines a source cluster
type CdnClusterSource struct {
  // The name of the source cluster
  Name string `json:"name"`
  // The path condition to enter this cluster,
  // can be omitted for the default source
  PathCondition string `json:"pathCondition,omitempty"`
}

// CdnClusterStatus defines the observed state
type CdnClusterStatus struct {
  // State of the CDN cluster
  State string `json:"state"`
}
```

```
$ make manifests
```

Creating CdnCluster instances

```yaml
apiVersion: cluster.anevia.com/v1
kind: CdnCluster
metadata:
 name: balancer
spec:
 role: balancer
 sources:
 - name: cache-live
   pathCondition: ^/live/
 - name: cache-vod
   pathCondition: ^/vod/

---
```

```yaml
apiVersion: cluster.anevia.com/v1
kind: CdnCluster
metadata:
 name: cache-live
spec:
 role: cache
 sources: [] # add origins here
---
apiVersion: cluster.anevia.com/v1
kind: CdnCluster
metadata:
 name: cache-vod
spec:
 role: cache
 sources: [] # add origins here
```

Deploying the `CdnCluster` Resource

The Resource

Deploying the sample
Custom Resource Definition
to augment the k8s API

```
$ kubectl get crds
No resources found.

$ make install(*)
[...]

$ kubectl get crds
NAME                                  AGE
cdnclusters.cluster.anevia.com        3s

(*) or
$ make manifests
$ kubectl apply -f config/crds
```

Creating `CdnCluster`s instances from clients

The Resource

Creating the sample CdnCluster instance with kubectl

```
$ kubectl get cdncluster
No resources found.

$ kubectl apply -f \
config/samples/cluster_v1_cdncluster.yaml
[...]

$ kubectl get cdncluster
NAME                AGE
cdncluster-sample   3s

$ kubectl delete \
cdncluster cdncluster-sample
```

The Resource

Generating CdnClusters with the controller-runtime client

```go
package main
import (
    "context"
    "fmt"
    "github.com/feloy/operator/pkg/apis"
    cdnclusterv1
      "github.com/feloy/operator/pkg/apis/cluster/v1"
    corev1 "k8s.io/api/core/v1"
    metav1 "k8s.io/apimachinery/pkg/apis/meta/v1"
    "k8s.io/client-go/kubernetes/scheme"
    "sigs.k8s.io/controller-runtime/pkg/client"
    "sigs.k8s.io/controller-runtime/pkg/client/config"
)
```

Using the controller-runtime client

```go
func main() {
  // Create the client
  config, _ := config.GetConfig()
  cl, err := client.New(config, client.Options{})
  if err != nil {
    fmt.Printf("%s\n", err.Error())
  }
  // Create a native ConfigMap
  cmap := &corev1.ConfigMap{
    ObjectMeta: metav1.ObjectMeta{
      Name: "cmap", Namespace: "default"
    },
  }
  err = cl.Create(context.Background(), cmap)
  if err != nil {
    fmt.Printf("%s\n", err.Error())
  }
  // Add Cluster scheme to global scheme
  apis.AddToScheme(scheme.Scheme)

  // Create a Custom Resource CdnCluster
  cdn := &cdnclusterv1.CdnCluster{
    ObjectMeta: metav1.ObjectMeta{
      Name: "cdn", Namespace: "default"},
    Spec: cdnclusterv1.CdnClusterSpec{
      Role:    "balancer",
      Sources: []cdnclusterv1.CdnClusterSource{},
    },
  }
  err = cl.Create(context.Background(), cdn)
  if err != nil {
    fmt.Printf("%s\n", err.Error())
  }
}
```

A solution based on a Kubernetes Operator

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The Operator

The Reconcile function

When to call Reconcile

Customizing Reconcile

Setting Status, sending Events

The Reconcile function

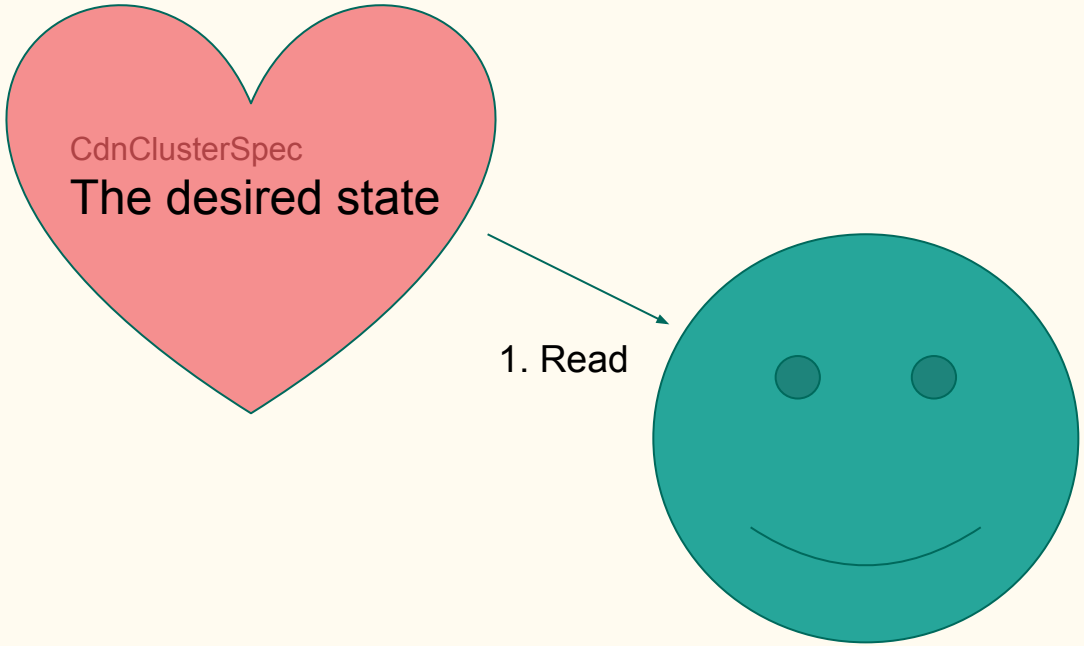
The Operator

The Reconcile function

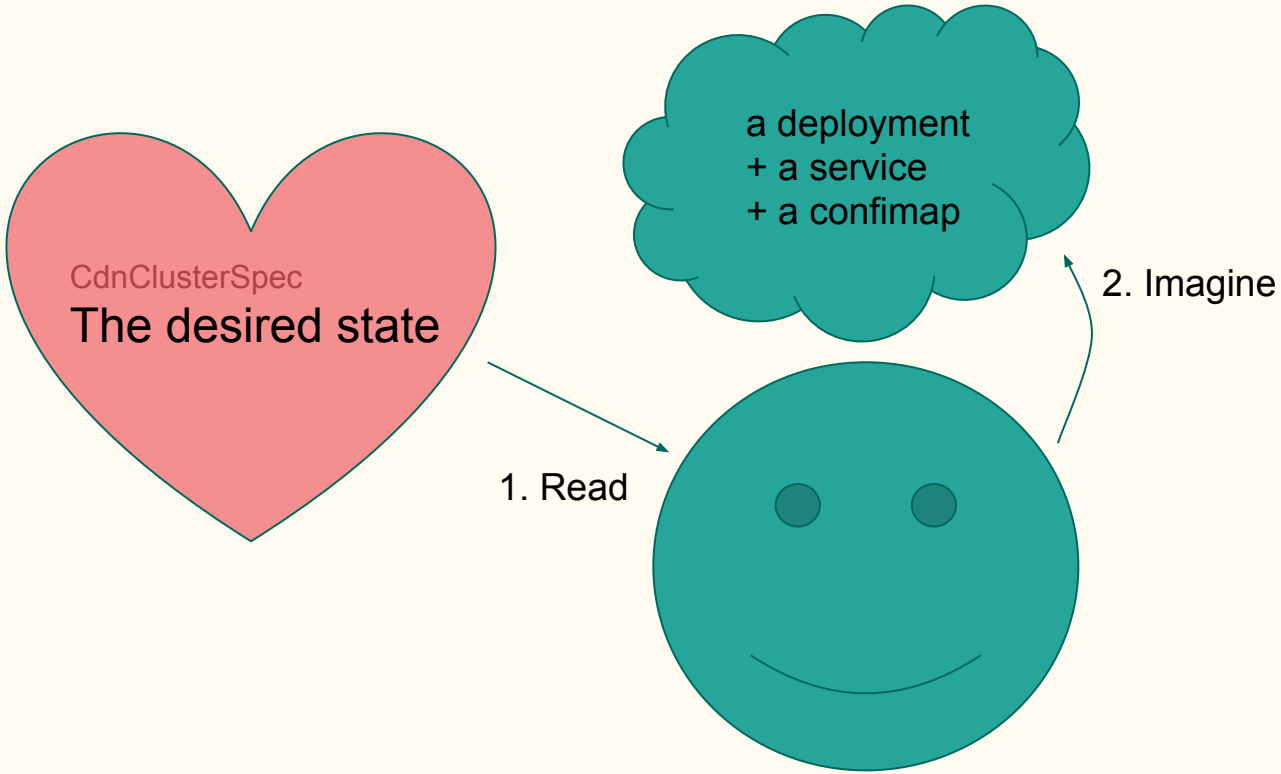
```
// cdncluster_controller.go

type ReconcileCdnCluster struct {
    client.Client
    scheme   *runtime.Scheme
}

func (r *ReconcileCdnCluster)
Reconcile(request reconcile.Request)
(reconcile.Result, error) {

}
```

The Reconcile function

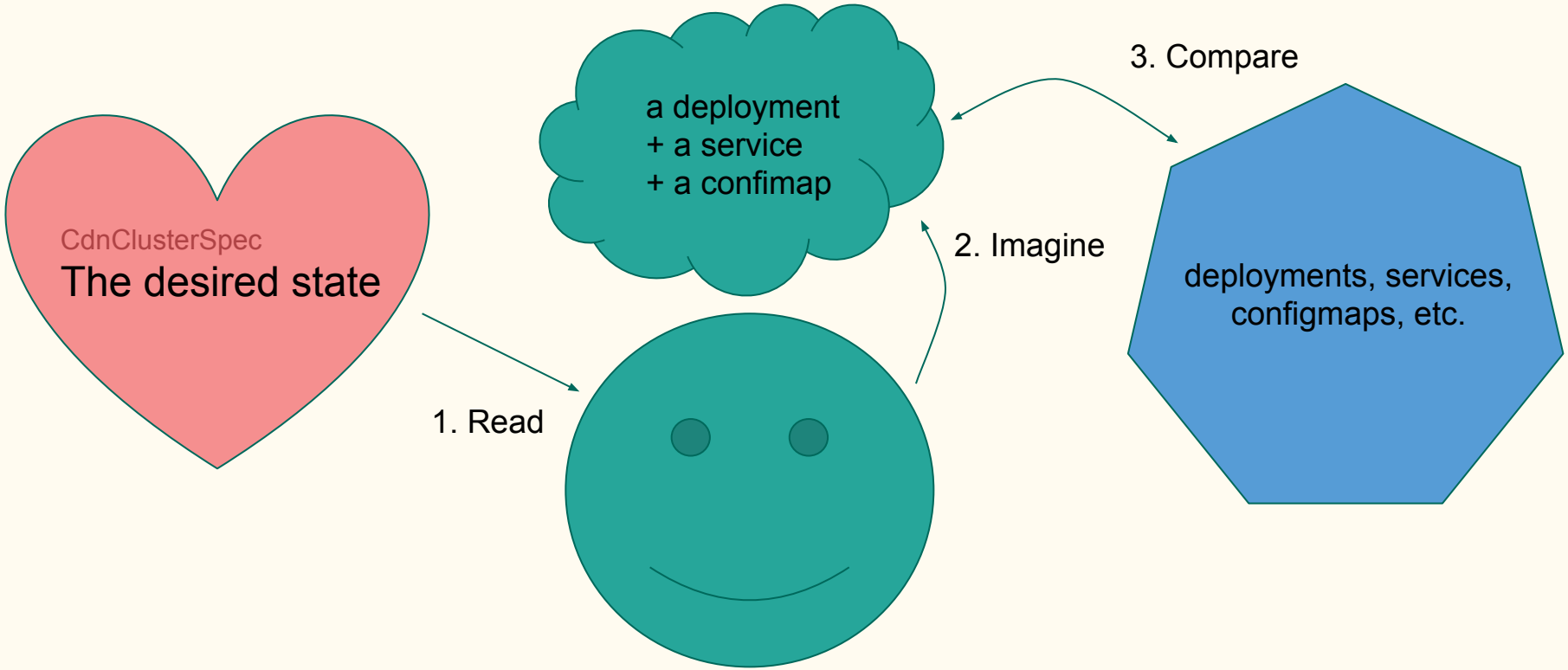
The Reconcile function



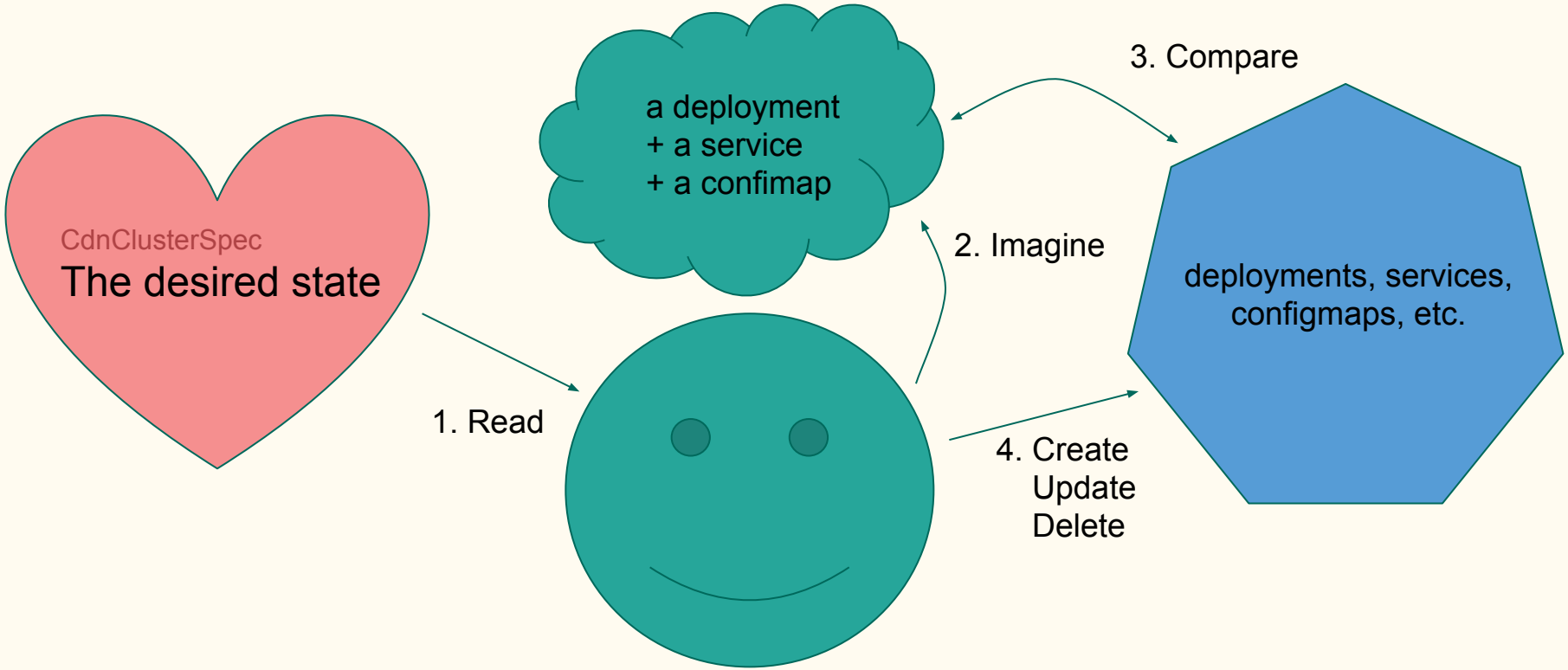
The Reconcile function



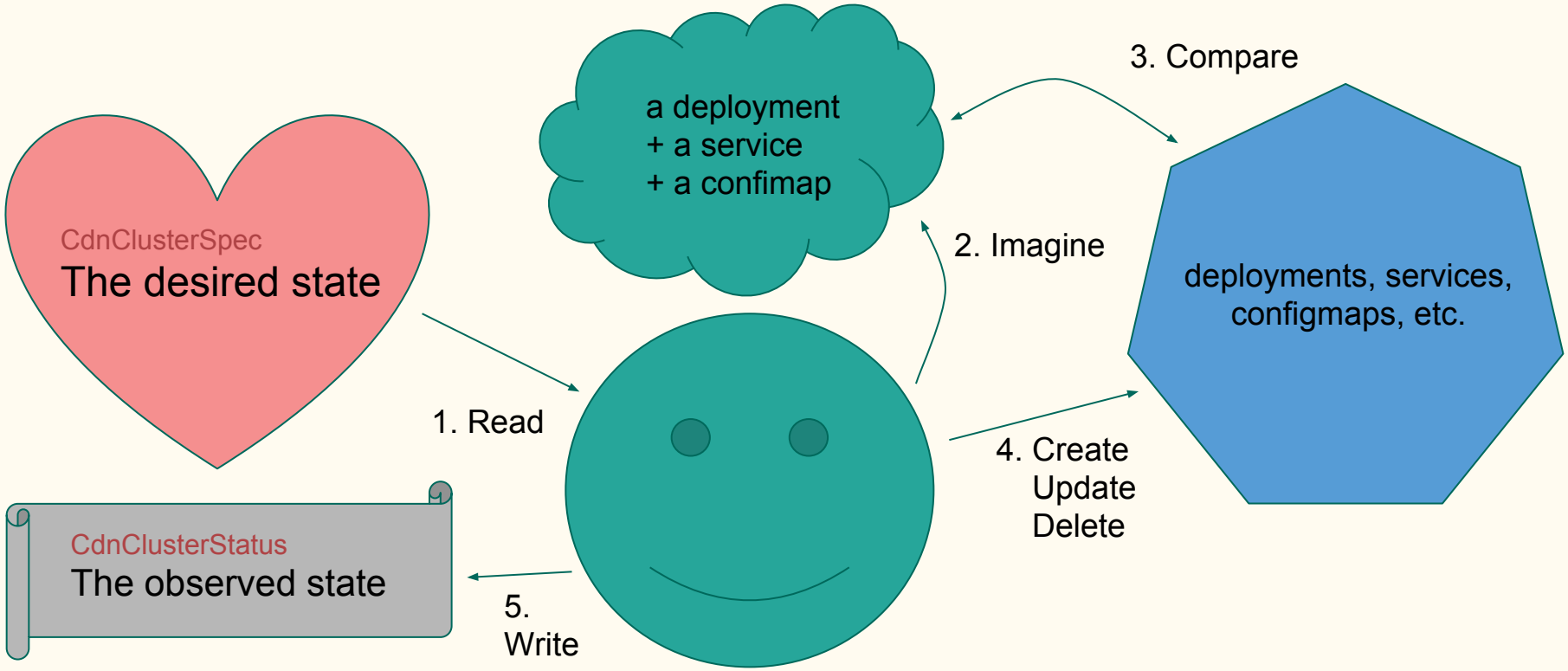
The Reconcile function



The Reconcile function



The Reconcile function



```
// 1. Get the CdnCluster instance in the `cdncluster` structure

cdncluster := &clusterv1.CdnCluster{}
err := r.Get(context.TODO(), request.NamespacedName, cdncluster)

if err != nil {
  if errors.IsNotFound(err) {
    // Object not found, return.  Created objects are automatically garbage collected.
    // For additional cleanup logic use finalizers.
    return reconcile.Result{}, nil
  }
  // Error reading the object - requeue the request.
  return reconcile.Result{}, err
}
```

```
// 2. Define the desired Deployment object in memory

deploy := &appsv1.Deployment{

  ObjectMeta: metav1.ObjectMeta{
    Name:      cdncluster.Name + "-deployment",
    Namespace: cdncluster.Namespace,
  },

  Spec: appsv1.DeploymentSpec{
    Selector: &metav1.LabelSelector{
      MatchLabels: map[string]string{"deployment": cdncluster.Name + "-deployment"},
    },
    Template: corev1.PodTemplateSpec{

      ObjectMeta: metav1.ObjectMeta{Labels: map[string]string{"deployment": cdncluster.Name +
"-deployment"}},

      Spec: corev1.PodSpec{Containers: []corev1.Container{{Name:  "nginx", Image: "nginx"}}}
    }
  },
}
```

```
// 2. Define the CdnCluster resource as the owner of
// the created deployment,
// so the garbage collector can handle the deletion of this object
// when the CdnCluster is deleted

err := controllerutil.SetControllerReference(cdncluster, deploy, r.scheme)

if err != nil {
  return reconcile.Result{}, err
}
```

```
// 3. Check if the Deployment already exists in the real world

found := &appsv1.Deployment{}
err = r.Get(context.TODO(), types.NamespacedName{
    Name: deploy.Name,
    Namespace: deploy.Namespace
  }, found)

if err != nil && errors.IsNotFound(err) {
  log.Printf("Creating Deployment %s/%s\n", deploy.Namespace, deploy.Name)
  err = r.Create(context.TODO(), deploy)
  if err != nil {
    return reconcile.Result{}, err
  }
} else if err != nil {
  return reconcile.Result{}, err
}
```

```
// 4. If there are any changes,
// update the found object and write the result back

if !reflect.DeepEqual(deploy.Spec, found.Spec) {
  found.Spec = deploy.Spec
  log.Printf("Updating Deployment %s/%s\n", deploy.Namespace, deploy.Name)
  err = r.Update(context.TODO(), found)
  if err != nil {
    return reconcile.Result{}, err
  }
}
```

When to call Reconcile

The Operator

On which events to call the Reconcile function

```
// Watch for changes to any
// CdnCluster resource

err = c.Watch(

  &source.Kind{
   Type: &clusterv1.CdnCluster{},
  },

  &handler.EnqueueRequestForObject{}

)
```

The Operator

On which events to call the Reconcile function

```
// Watch for changes to any
// Deployment created by CdnCluster

err = c.Watch(

  &source.Kind{
    Type: &appsv1.Deployment{},
  },

  &handler.EnqueueRequestForOwner{
    IsController: true,
    OwnerType:    &clusterv1.CdnCluster{},
  }

)
```

Customizing the Reconcile function

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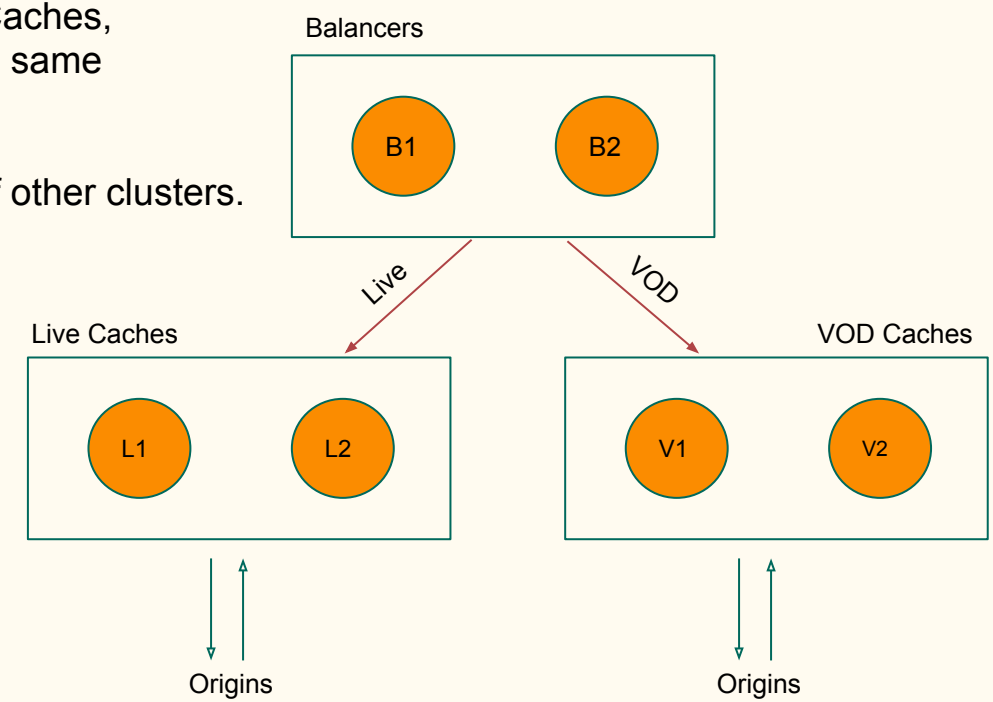


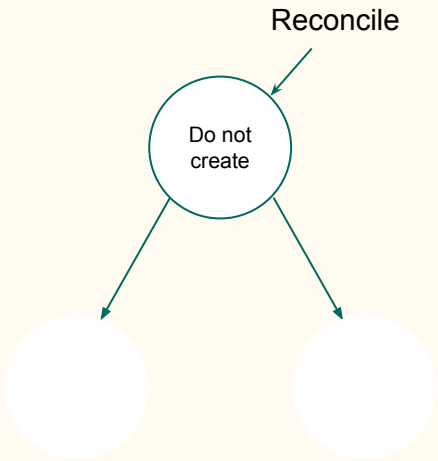
Customizing the Reconcile function

During initial deployment, sources must be created before the parent Cdn cluster can be deployed

- Store the dependencies between CdnClusters

- If some source does not exist, return from the Reconcile function

- When a Cdn Cluster is modified, call the Reconcile function for the parent CdnClusters



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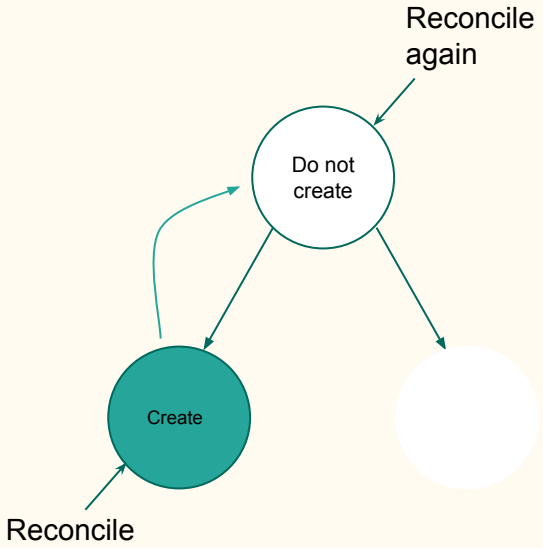

Customizing the Reconcile function

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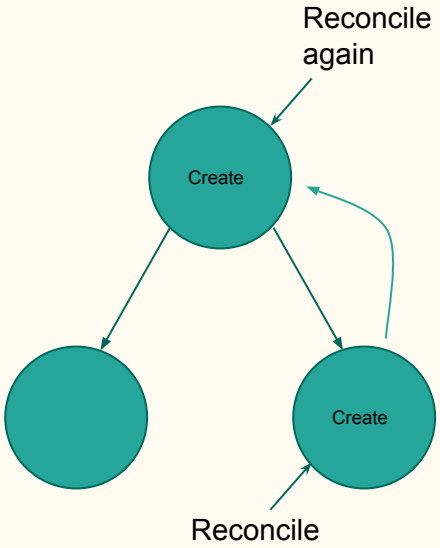

Customizing the Reconcile function

```
// Storing dependencies between CdnClusters

type ParentsList map[string][]string

func (o ParentsList) Add(source, parent string) {
  for _, p := range o[source] {
    if p == parent {
      return
    }
  }
  o[source] = append(o[source], parent)
}

var (
  // Parents is a map of parent CDN clusters for a CDN cluster
  Parents = ParentsList{}
)
```

Customizing the Reconcile function

```
// In Reconcile function

for _, source := range instance.Spec.Sources {
  Parents.Add(source.Name, instance.Name)
}

// Verify that all sources exist
// We do not continue until all sources exist
for _, source := range instance.Spec.Sources {
  sourceInstance := &clusterv1.CdnCluster{}
  err := r.Get(context.TODO(), types.NamespacedName{Name: source.Name, Namespace:
instance.Namespace}, sourceInstance)
  if err != nil {
    if errors.IsNotFound(err) {
      // Source not found, return.
      return reconcile.Result{}, nil
    }
    // Error reading the object - requeue the request.
    return reconcile.Result{}, err
  }
}
```

Customizing the Reconcile function

```
err = c.Watch(

  &source.Kind{Type: &clusterv1.CdnCluster{}},

  &handler.EnqueueRequestsFromMapFunc{
  ToRequests: handler.ToRequestsFunc(
    // Returns the list of parents of the CdnCluster in mapObject
    func(mapObject handler.MapObject) []reconcile.Request {
      v, ok := mapObject.Object.(*clusterv1.CdnCluster)
      if ok {
        var res = []reconcile.Request{}
        for _, parent := range Parents[v.Name] {
          res = append(res, reconcile.Request{
            NamespacedName: types.NamespacedName{Name: parent, Namespace: v.Namespace},
          })
        }
        return res
      }
      return nil
    }),
})
```

Setting Status

The Operator

Setting Status

```
// CdnClusterStatus defines the
observed state of CdnCluster
type CdnClusterStatus struct {

  // State of the CDN cluster
  State string `json:"state,omitempty"`

}
```

Setting Status

```
// setState changes the State of CDN cluster, if necessary
func (r *ReconcileCdnCluster) setState(cdncluster
*clusterv1.CdnCluster, newState string) error {
  if cdncluster.Status.State != newState {
    cdncluster.Status.State = newState
    return r.Update(context.TODO(), cdncluster)
  }
  return nil
}

[...]
err = r.setState(instance, "WaitingSource")
```

Sending Events

The Operator

Sending Events

```
$ kubectl describe cdncluster balancer

Name:         balancer
Namespace:    default
[...]
Events:
  Type    Reason          Age   From        Message
  ----    ------          ----  ----        -------
  Normal  SourceNotFound  3s    CdnCluster  Source
cache-live not found, will retry later
```

Sending Events

1. Add an EventRecorder to the ReconcileCluster structure

```
// ReconcileCdnCluster reconciles a CdnCluster object
type ReconcileCdnCluster struct {
  client.Client
  scheme   *runtime.Scheme
  recorder record.EventRecorder
}
```

Sending Events

2. Instantiates the recorder with manager.GetRecorder

```
func Add(mgr manager.Manager) error {
 return add(mgr, newReconciler(mgr, mgr.GetRecorder("CdnCluster")))
}

func newReconciler(mgr manager.Manager, recorder record.EventRecorder)
reconcile.Reconciler {
  return &ReconcileCdnCluster{
    Client:   mgr.GetClient(),
    scheme:   mgr.GetScheme(),
    recorder: recorder,
  }
}
```

Sending Events

3. Use Event/Eventf to send events

```
if errors.IsNotFound(err) {
  // Source not found, inform with an event and return.
  r.recorder.Eventf(instance, "Normal", "SourceNotFound",
        "Source %s not found, will retry later", source.Name)
  return reconcile.Result{}, nil
}
```

Testing

Testing creation of CdnClusters

```
$ git checkout 285d502

// cdncluster_types_test.go
created := &CdnCluster{
  ObjectMeta: metav1.ObjectMeta{
    Name: "foo", Namespace: "default"
  },
}


$ make test
[...]
spec.sources in body must be of type array: "null"
[...]
```

```
$ git checkout 671d726
created := &CdnCluster{
 ObjectMeta: metav1.ObjectMeta{
  Name: "foo", Namespace: "default"
 },
 Spec: CdnClusterSpec{
   Role: "balancer",
   Sources: []CdnClusterSource{
   { Name: "cache-live", PathCondition: "^/live/" },
   { Name: "cache-vod", PathCondition: "^/vod/" },
   },
 },
}

$ make test
ok github.com/feloy/operator/pkg/apis/cluster/v1
```

Testing the Reconcile function

```
// Prepare the environment

func TestReconcile(t *testing.T) {
  g := gomega.NewGomegaWithT(t)

  // Setup the Manager and Controller.
  // Wrap the Controller Reconcile function
  // so it writes each request to a channel when it is finished.
  mgr, err := manager.New(cfg, manager.Options{})
  g.Expect(err).NotTo(gomega.HaveOccurred())
  c := mgr.GetClient()

  recFn, requests := SetupTestReconcile(newReconciler(mgr))
  g.Expect(add(mgr, recFn)).NotTo(gomega.HaveOccurred())
  defer close(StartTestManager(mgr, g))

  [...]
}
```

Testing the Reconcile function

```
// Create an instance and test that the Reconcile function is called

instance := &clusterv1.CdnCluster{
  ObjectMeta: metav1.ObjectMeta{Name: "foo",Namespace: "default"},
  Spec:       clusterv1.CdnClusterSpec{Sources: []clusterv1.CdnClusterSource{}},
}

// Create the CdnCluster object
err = c.Create(context.TODO(), instance)
g.Expect(err).NotTo(gomega.HaveOccurred())
defer c.Delete(context.TODO(), instance)

// expect the Reconcile to be called with the instance namespace and name as parameter
var expectedRequest = reconcile.Request{
  NamespacedName: types.NamespacedName{Name: "foo",Namespace: "default"},
}
const timeout = time.Second * 5

g.Eventually(requests, timeout)
 .Should(gomega.Receive(gomega.Equal(expectedRequest)))
```

Testing the Reconcile function

```
// Then expect that a deployment is created with the expected name

deploy := &appsv1.Deployment{}

var depKey = types.NamespacedName{
  Name:      "foo-deployment",
  Namespace: "default",
}

g.Eventually(func() error {
  return c.Get(context.TODO(), depKey, deploy)
}, timeout).Should(gomega.Succeed())
```

Testing Status is set

```
// Get CDN cluster and expect the state to be "Deploying"

c.Get(context.TODO(), types.NamespacedName{
  Name:      "foo2",
  Namespace: "default",
}, instance)

g.Expect(instance.Status.State).To(gomega.Equal("Deploying"))
```

Testing Sending Events

```
// Prepare the environment

func TestReconcile(t *testing.T) {
  g := gomega.NewGomegaWithT(t)

  // Setup the Manager and Controller.
  // Wrap the Controller Reconcile function
  // so it writes each request to a channel when it is finished.
  mgr, err := manager.New(cfg, manager.Options{})
  g.Expect(err).NotTo(gomega.HaveOccurred())
  c := mgr.GetClient()

  eventRecorder := record.NewFakeRecorder(1024)
  recFn, requests := SetupTestReconcile(newReconciler(mgr, eventRecorder))
  g.Expect(add(mgr, recFn)).NotTo(gomega.HaveOccurred())
  defer close(StartTestManager(mgr, g))
```

Testing Sending Events

```
var eventReceived string

select {
case eventReceived = <-eventRecorder.Events:
}

g.Expect(eventReceived).To(gomega.Equal("Normal SourceNotFound
Source asource not found, will retry later"))
```

The END

Thanks!

Resources

Kubebuilder Documentation:

https://book.kubebuilder.io/

GitHub repository with complete source code and more documentation:

https://github.com/feloy/operator

My Medium blog (about Angular, Kubernetes):

https://medium.com/@feloy

Operator SDK (another way to build operators):

https://github.com/operator-framework/operator-sdk