Introduction to Kubernetes Extensions

IBM Developer

IBM

Kubernetes

A *Custom Resource (CR)* is an extension of the Kubernetes API. To understand Custom Resource Definitions (CRD) and Operators, you have to understand the Kubernetes API, the resource controller watch loop that Kubernetes uses to control the system, and how it is replicated by an operator.

Kubernetes provides two ways to add custom resources to your cluster:

- CRDs are simple and can be created without programming an Operator,
- API Aggregation (AA) requires programming an Operator, but allows more control over API behaviors like how data is stored and conversion between API versions.

Kubernetes Architecture

- At its core, Kubernetes is a database (etcd) with "watchers" and "controllers" that react to changes in etcd,
- The kube-api-server is an API server that exposes the Kubernetes API,
- The kube-scheduler watches for new Pods not assigned to a node and selects a node to run the Pod on,
- The kube-controller-manager runs the controller loops that make Kubernetes,
- The cloud-controller-manager interacts with the underlying cloud provider,
- The etcd key-value store represents the user defined desired state of the objects,
- The kubelet makes sure that containers are running in a Pod,
- The kube-proxy is a network proxy that maintains network rules on nodes,

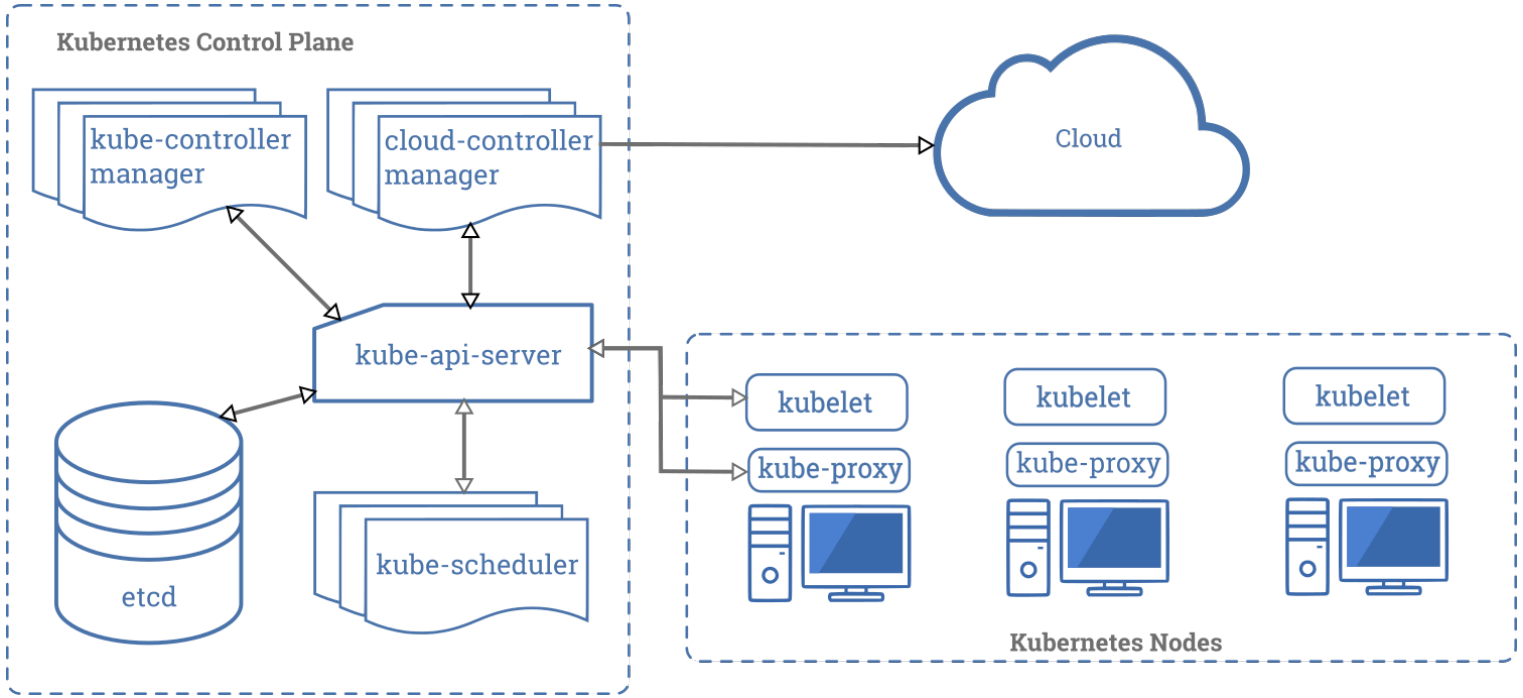


image source: https://kubernetes.io/docs/concepts/overview/components/

API Groups

All Kubernetes objects are considered an API resource and have a corresponding endpoint in the Kubernetes API.

The Kubernetes API is divided into API Groups to make it easier to extend the API, disabling APIs, supporting different versions, support API Plugin.

API groups:

- core,
- apps,
- extensions,
- batch,
- autoscaling,
- storage.k8s.io,
- admissionregistration.k8s.io,
- apiextensions.k8s.io,
- policy,
- scheduling.k8s.io,
- settings.k8s.io,
- apiregistration.k8s.io,
- certificates.k8s.io,
- rbac.authorization.k8s.io,
- authorization.k8s.io,
- networking.k8s.io,
- auditregistration.k8s.io

apiextensions.k8s.io

- MetaData APIs
  - CustomResourceDefinition

Extending Kubernetes

Customization can be divided into:
- configuration,
- Extensions.

You can extend the Kubernetes by using the Controller pattern or the webhook model.
Controllers read a “spec”, do work, and then update the “status”.
When Kubernetes is the client that calls out to a remote service, it is called a Webhook and the remote service is the Webhook Backend.

Extension points:
1. Kubectl, kubectl plugins,
2. Extensions in the apiserver allow authenticating or blocking requests, editing content and handling deletion,
3. Custom Resources (CR) using CustomResourceDefinition API and Operators,
4. Scheduler Extensions,
5. Controllers are often used with CR,
6. Node-level Network Plugins, CNI Plugins or Kubenet plugins,
7. Storage Plugins,

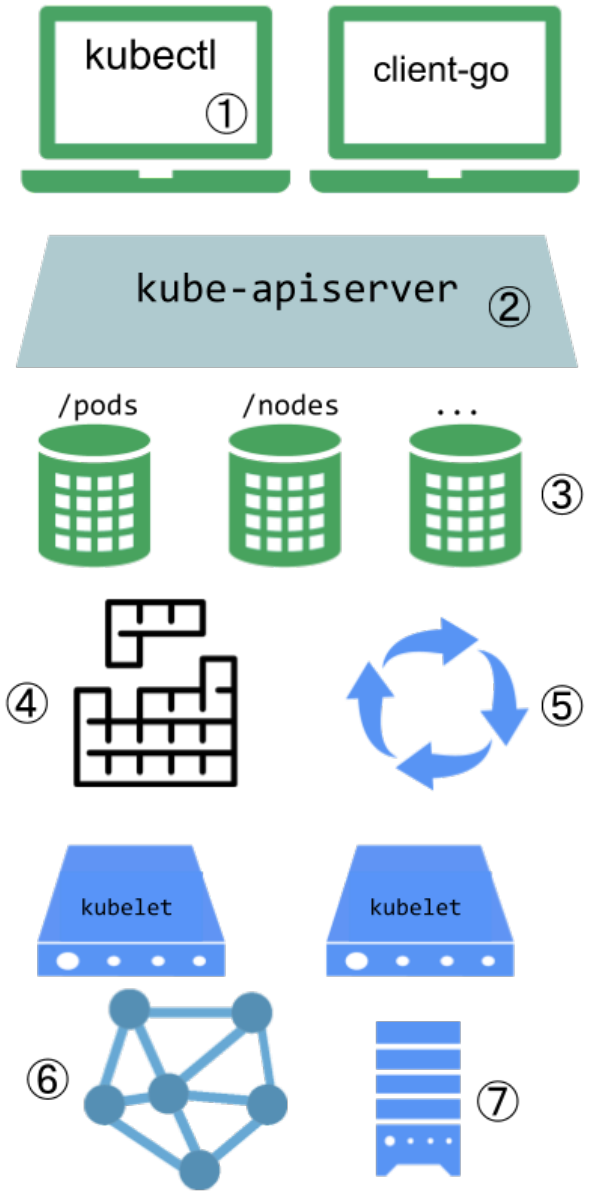


image source: https://kubernetes.io/docs/concepts/extend-kubernetes/extend-cluster/

Custom Resource Definition (CRD)

In June 2017, Kubernetes v1.7 introduced Custom Resource Definitions (CRD).

A *Custom Resource (CR)* is an extension of the Kubernetes API that allows you to store an API object of a kind. Even many core Kubernetes functions are now built using custom resources.

A *Custom Resource Definition* (CRD) file defines your own object kinds and lets the API Server handle its lifecycle.

Example: CRD

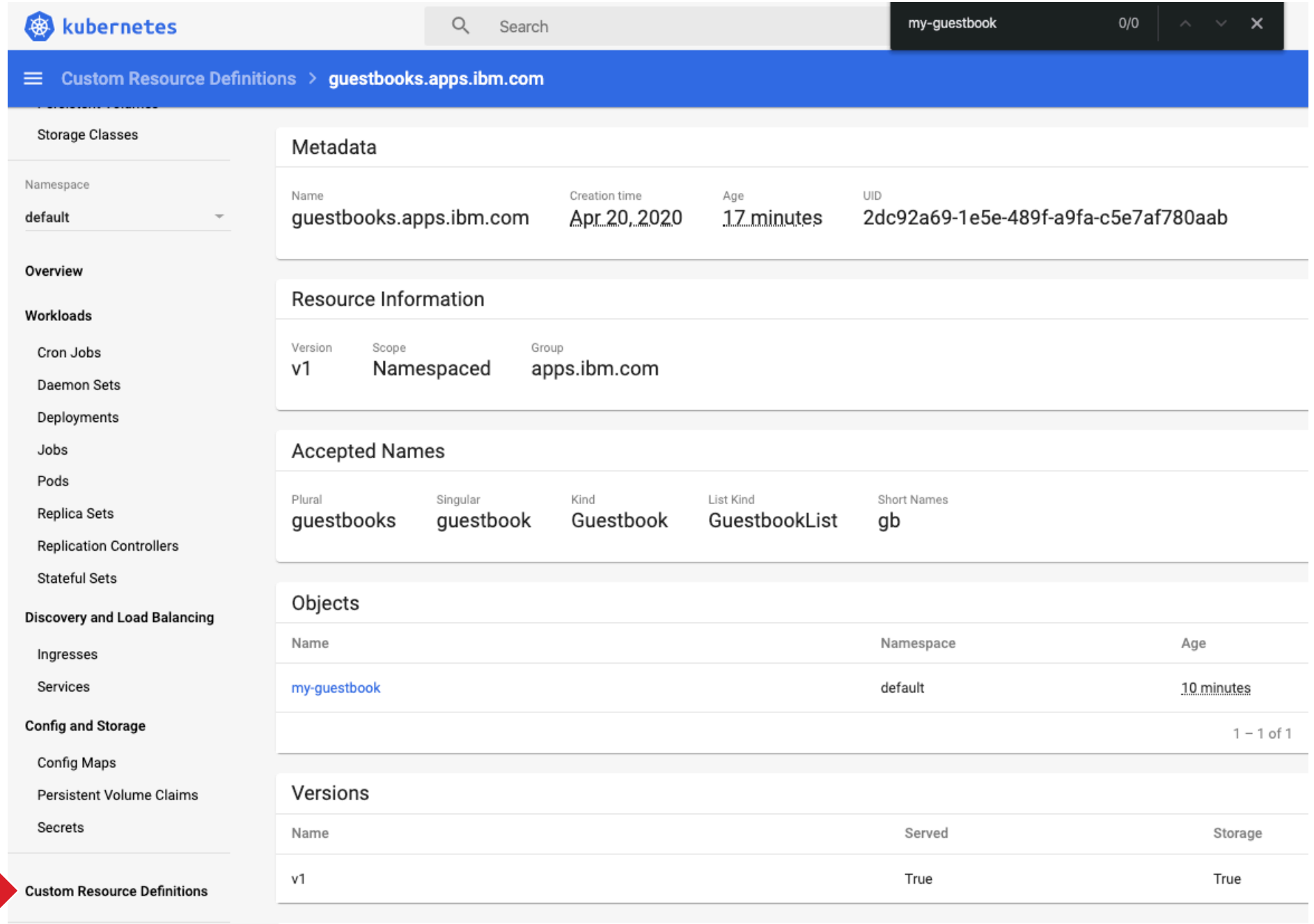
guestbook.yaml

```
apiVersion: apiextensions.k8s.io/v1
kind: CustomResourceDefinition
metadata:
  name: guestbooks.apps.ibm.com
spec:
  group: apps.ibm.com
  versions:
    - name: v1
      served: true
      storage: true
      schema:
        openAPIV3Schema:
          type: object
          properties:
            spec:
              type: object
              properties:
                guestbookTitle:
                  type: string
                guestbookSubtitle:
                  type: string
  scope: Namespaced
  names:
    plural: guestbooks
    singular: guestbook
    kind: Guestbook
    shortNames:
    - gb
```

my-guestbook.yaml

```
apiVersion: "apps.ibm.com/v1"
kind: Guestbook
metadata:
  name: my-guestbook
spec:
  guestbookTitle: "The Chemical Wedding of Remko"
  guestbookSubtitle: "First Day"
```

```
% kubectl create -f guestbook-crd.yaml
customresourcedefinition.apiextensions.k8s.io/guestbooks.apps.ibm.com created
% kubectl create -f my-guestbook.yaml
guestbook.apps.ibm.com/my-guestbook created
% kubectl get guestbooks
NAME          AGE
my-guestbook   3m51s
% kubectl describe guestbook my-guestbook
Name:        my-guestbook
Namespace:    default
Labels:      <none>
Annotations:  <none>
API Version:  apps.ibm.com/v1
Kind:        Guestbook
Metadata:
  Creation Timestamp:  2020-04-20T05:40:46Z
  Generation:         1
  Resource Version:    295507
  Self Link:          /apis/apps.ibm.com/v1/namespaces/default/guestbooks/my-guestbook
  UID:               e683caef-33f5-4f83-b54e-85ee163e0abf
Spec:
  Guestbook Subtitle:  First Day
  Guestbook Title:     The Chemical Wedding of Remko
Events:              <none>
```



Operator Pattern

Custom Resources alone let you store and retrieve structured data. The Operator pattern combines custom resources and custom controllers. Combined with a *custom controller*, custom resources provide a true *Declarative API*. You can use custom controllers to encode domain knowledge for specific applications into an extension of the Kubernetes API.

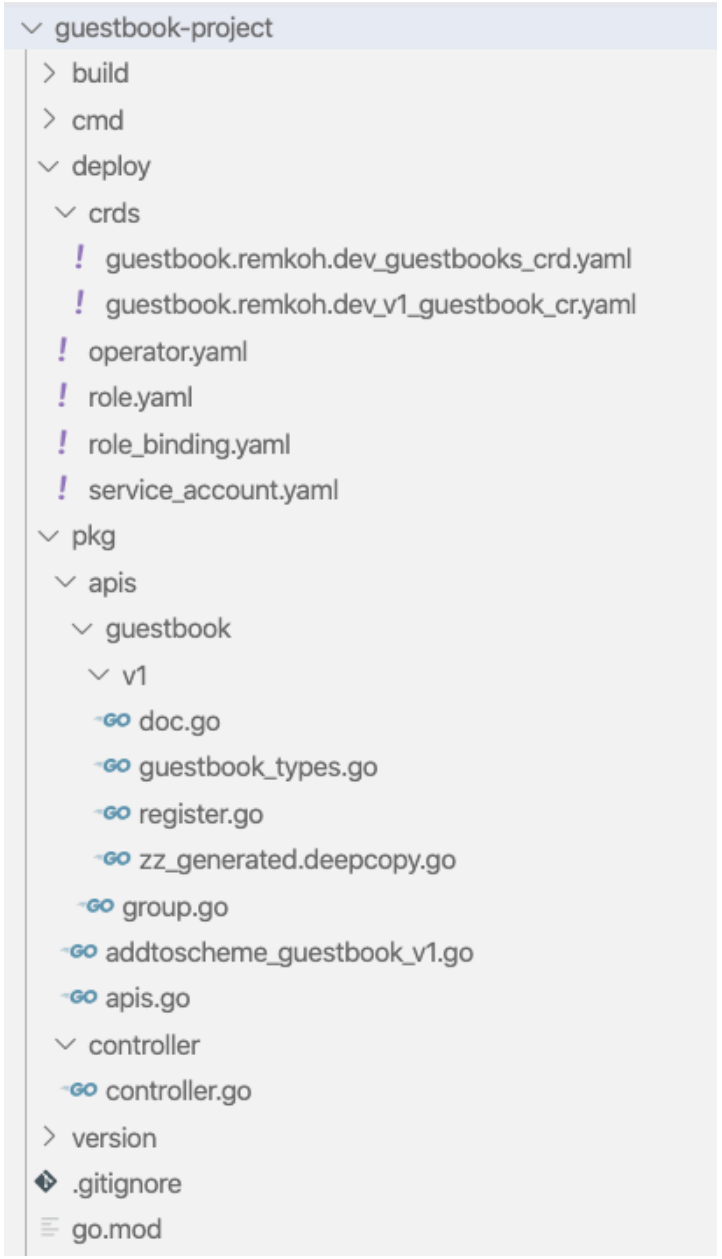
Consider API aggregation if:	Prefer a stand-alone API if:
Your API is Declarative.	Your API does not fit the Declarative model.
Read and write your new types using kubectl.	kubectl support is not required
View your new types in a Kubernetes UI, such as dashboard, alongside built-in types.	Kubernetes UI support is not required.
You are developing a new API.	You already have a program that serves your API and works well.
Accept the format restriction that Kubernetes puts on REST resource paths, such as API Groups and Namespaces. (See the API Overview.)	You need to have specific REST paths to be compatible with an already defined REST API.
Your resources are naturally scoped to a cluster or namespaces of a cluster.	Cluster or namespace scoped resources are a poor fit; you need control over the specifics of resource paths.
You want to reuse Kubernetes API support features.	You don't need those features.

Operator Framework SDK

```
operator-sdk new $OPERATOR_PROJECT --type go --repo github.com/$DOCKER_USERNAME/$OPERATOR_NAME
operator-sdk add api --api-version=$OPERATOR_GROUP/$OPERATOR_VERSION --kind=$CRD_KIND
operator-sdk add controller --api-version=$OPERATOR_GROUP/$OPERATOR_VERSION --kind=$CRD_KIND
operator-sdk build docker.io/$DOCKER_USERNAME/$OPERATOR_NAME
docker login docker.io -u $DOCKER_USERNAME
docker push docker.io/$DOCKER_USERNAME/$OPERATOR_NAME
sed -i "s|REPLACE_IMAGE|docker.io/$DOCKER_USERNAME/$OPERATOR_NAME|g" deploy/operator.yaml
oc create sa $OPERATOR_PROJECT
oc create -f deploy/role.yaml
oc create -f deploy/role_binding.yaml
oc create -f deploy/crds/${OPERATOR_GROUP}_${CRD_KIND,,}s_crd.yaml
oc create -f deploy/operator.yaml
oc create -f deploy/crds/${OPERATOR_GROUP}_${OPERATOR_VERSION}_${CRD_KIND,,}_cr.yaml
oc get deployment $OPERATOR_PROJECT
oc get pod -l app=example-${CRD_KIND,,}
oc describe ${CRD_KIND,,}s.${OPERATOR_GROUP} example-${CRD_KIND,,}
```

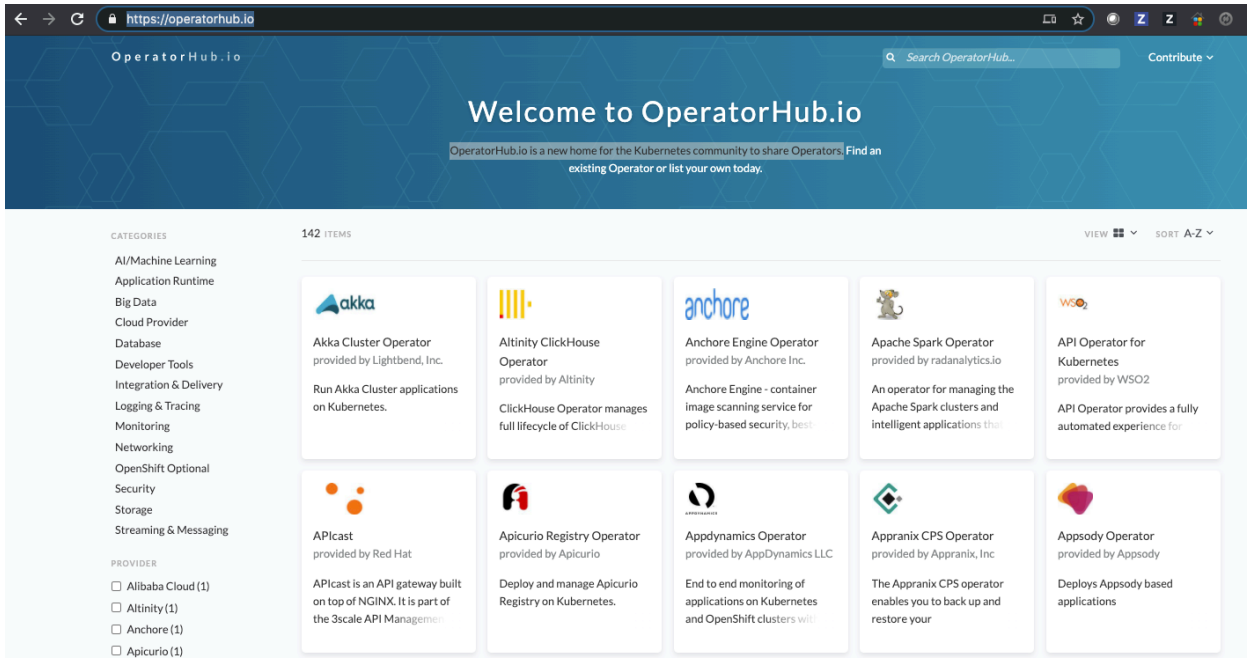
Operator Framework SDK

```
// Reconcile reads state of the cluster for a Guestbook object and makes changes based on the state read and what is in the Guestbook.Spec
// TODO(user): User must modify this Reconcile function to implement their own Controller logic. This example creates a Pod as an example
func (r *ReconcileGuestbook) Reconcile(request reconcile.Request) (reconcile.Result, error) {
    ...
    // Fetch the Guestbook instance
    instance := &guestbookv1.Guestbook{}
    ...
    // Define a new Pod object
    pod := newPodForCR(instance)
    ...
}
```



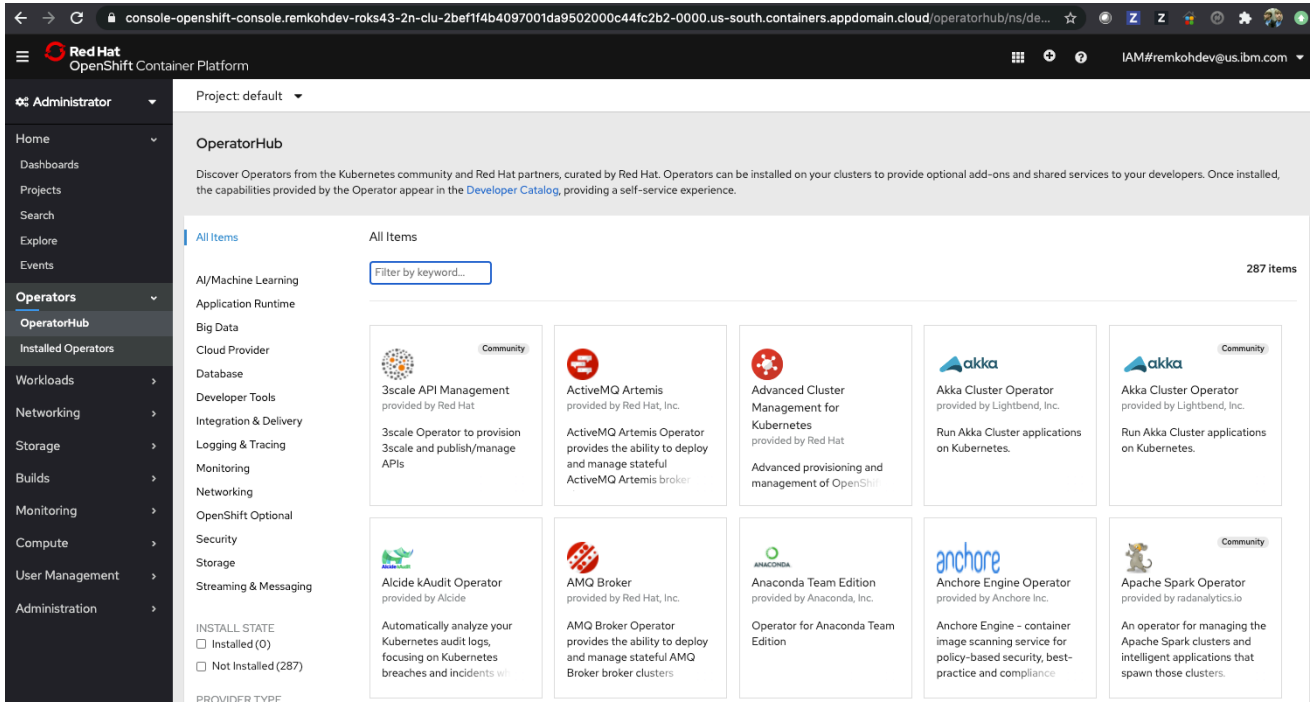
OperatorHub

OperatorHub.io is the central location for the Kubernetes community to share operators that have been built by the community. OperatorHub.io also ensures that the set of Operators are packaged for easy deployment and management on any Kubernetes cluster. Packaging of the Operators indexed in OperatorHub.io relies on the Operator Lifecycle Manager (OLM) to install, manage and update Operators consistently on any Kubernetes cluster.



OpenShift 4 introduced the OperatorHub, a catalog of applications that can be installed by the administrator and added to individual projects by developers. The list of operators at the OpenShift 4 OperatorHub is a list of Operators from the Kubernetes community and Red Hat partners, curated by Red Hat, from the following operator sources:

- Red Hat Operators
- Certified Operators (from ISVs certified by Red Hat)
- Community Operators from operator-framework/community-operators
- Custom Operators



Operator Lifecycle Manager (OLM)

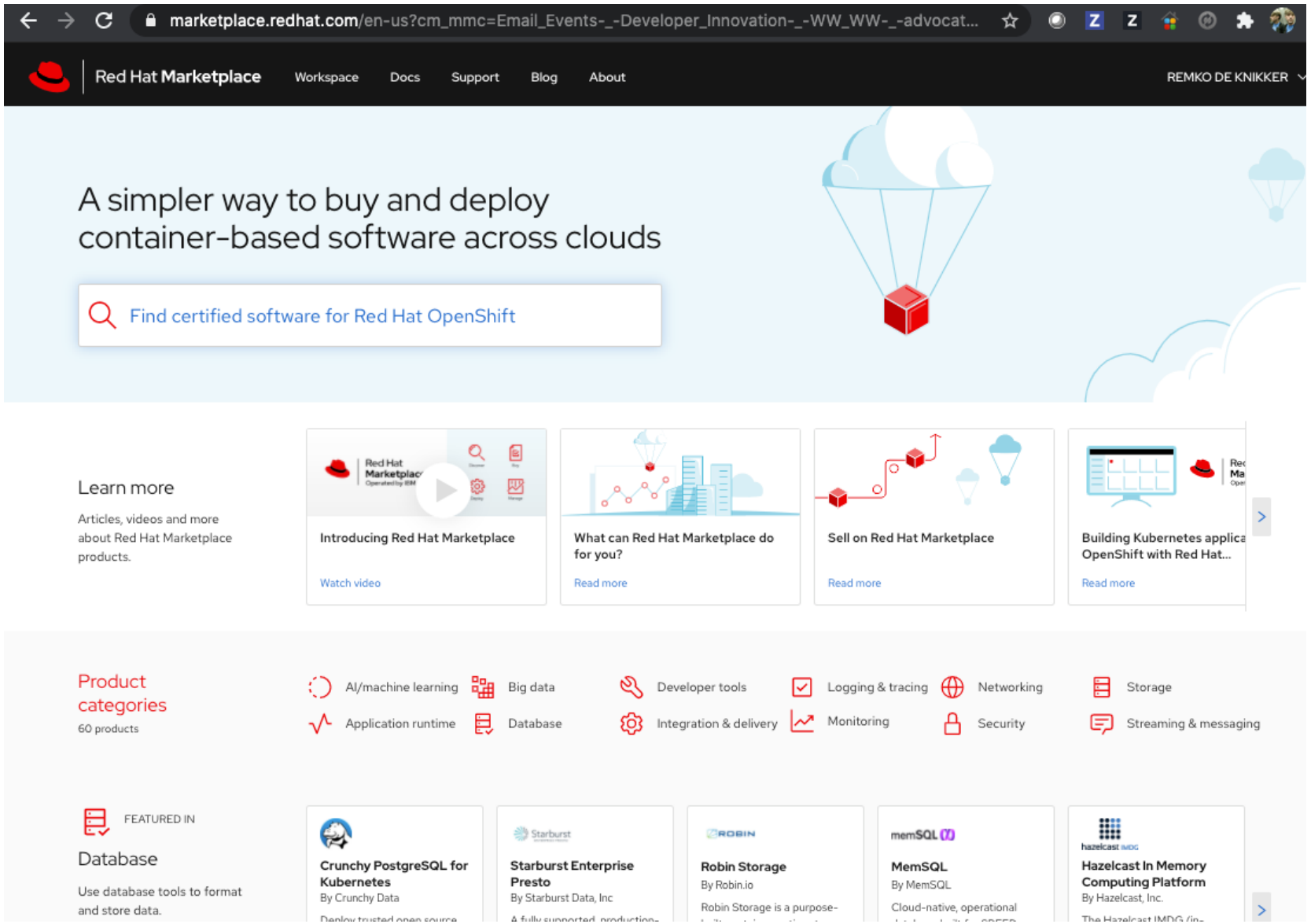
https://github.com/operator-framework/operator-lifecycle-manager/blob/master/doc/design/architecture.md

OLM extends Kubernetes to provide a declarative way to install, manage, and upgrade Operators and their dependencies in a cluster.

- OLM has a concept of catalogs from which Operators are available to install and being kept up to date. It gives vendors a flexible publishing mechanism using channels.
- With OLMs packaging format Operators can express dependencies.

Red Hat Marketplace

http://ibm.biz/clientrhm



IBM Cloud Paks

IBM Cloud Paks: https://github.com/IBM/cloud-pak

Beyond containers and Kubernetes, enterprises need to orchestrate their production topology, and to provide management, security and governance of their applications. Features such as pre-configured deployments based on product expertise, rolling upgrades, rollbacks, security/vulnerability testing and integrations with management services for logging, monitoring, metering and security provide control and management of production workloads.

IBM Cloud Paks packages container images using Helm charts with defaults for configuration and management and Security Context Constraints (SCC) to control permissions, and can include additional assets such as Operators that define custom deployment and life-cycle management functionality in a single archive from a trusted source.

IBM Cloud Paks are required to complete Red Hat container certification, which is complementary to IBM's certification process.

Kubernetes Applications

https://github.com/kubernetes-sigs/application

```
apiVersion: app.k8s.io/v1beta1
kind: Application
metadata:
  name: "guestbook"
  labels:
    app.kubernetes.io/name: "guestbook"
spec:
selector:
matchLabels:
app.kubernetes.io/name: "guestbook"
componentKinds:
- group: v1
kind: Deployment
- group: v1
kind: Service
descriptor:
type: "guestbook"
keywords:
- "gb"
- "guestbook"
links:
- description: Github
url: "https://github.com/IBM/guestbook"
version: "0.1.0"
description: "The Guestbook application is an example app to demonstrate key Kubernetes functionality."
maintainers:
- name: IBM Developer
email: developer@ibm.com
owners:
- name: IBM Developer
email: developer@ibm.com
```

Lab Time

Kubernetes Operators lab: https://github.com/remkohdev/kubernetes-extensions