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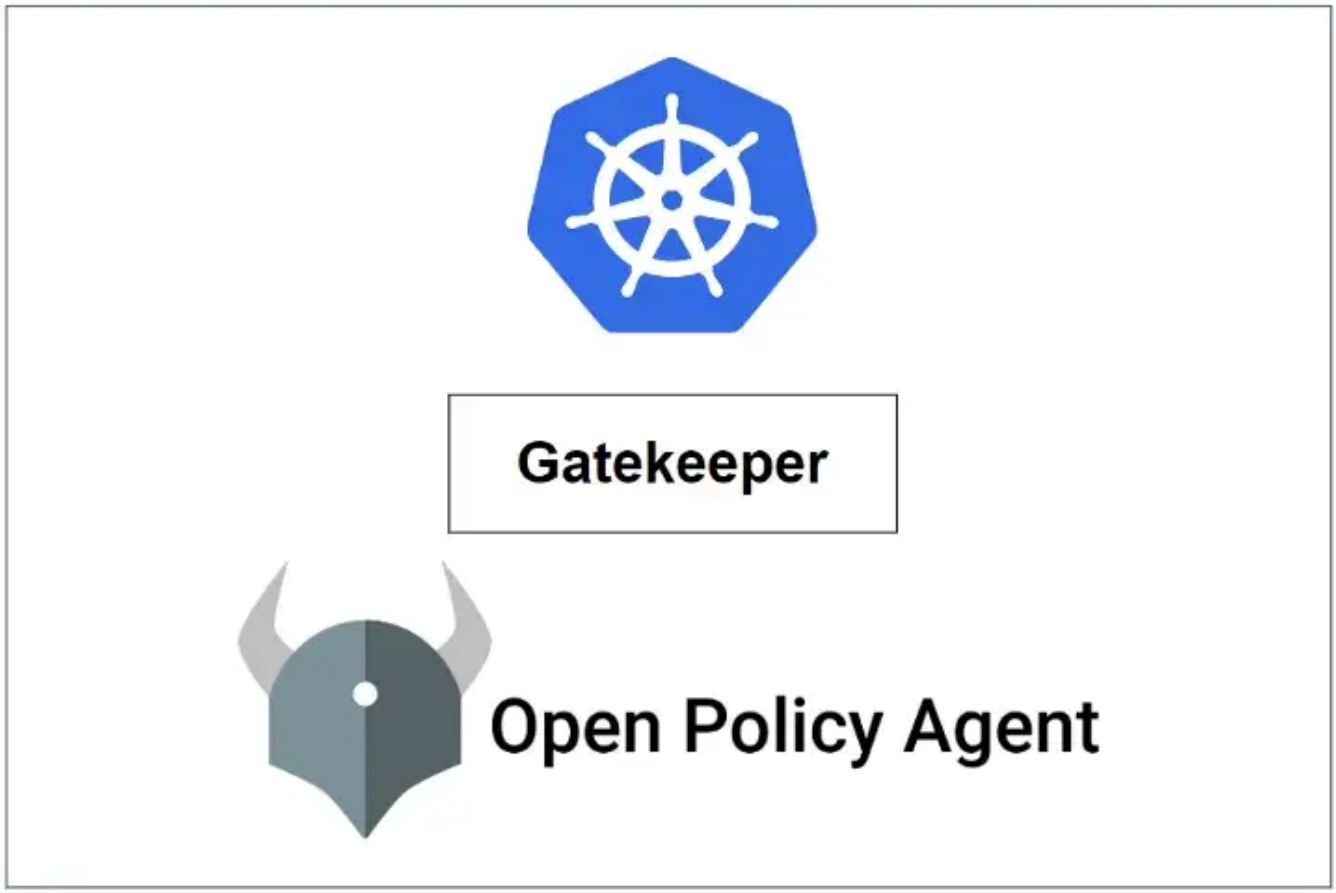
OPA Gatekeeper on Kubernetes

OPA Gatekeeper: Policy and Governance for Kubernetes



What is OPA:

The Open Policy Agent (OPA) is an open-source, general-purpose policy engine that unifies policy enforcement across the stack. OPA provides a high-level declarative language that lets us specify policies as code and simple APIs to offload policy

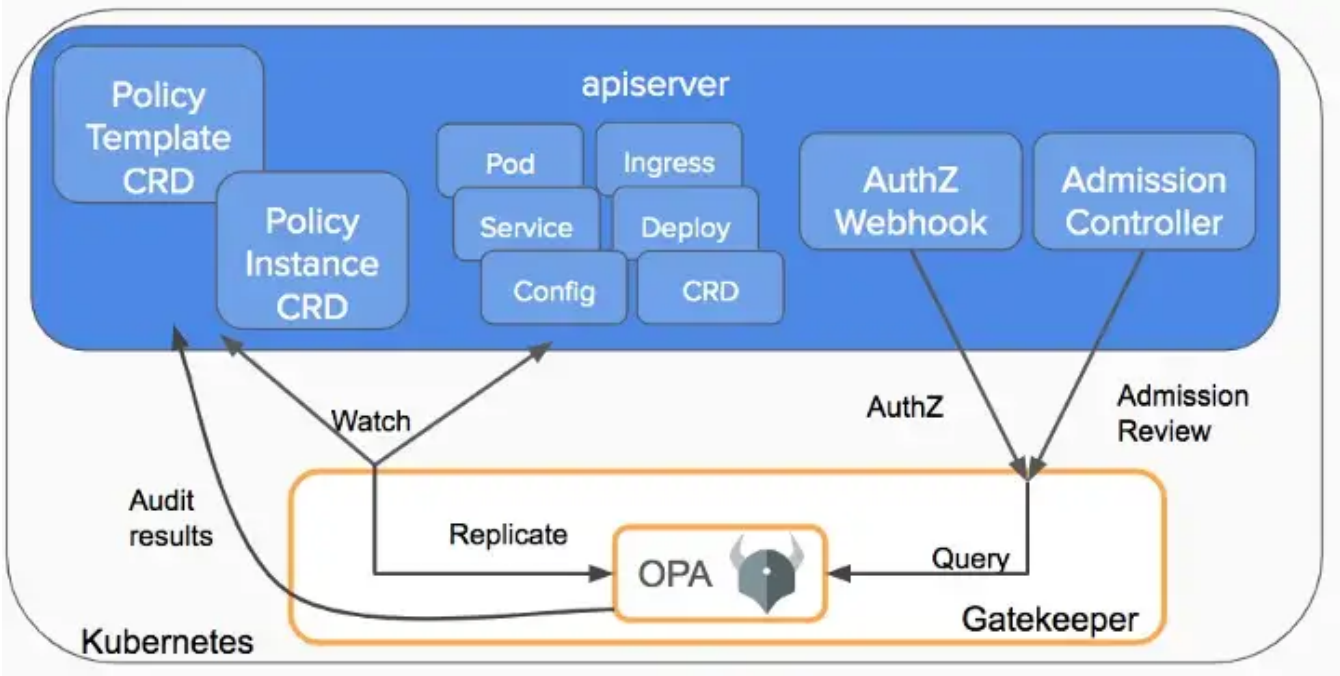
decision-making from our software. We can use OPA to enforce policies in microservices, Kubernetes, CI/CD pipelines, API gateways, and more. **In kubernetes, OPA uses admission controllers.**

What is OPA Gatekeeper?

OPA Gatekeeper is a specialized project providing first-class integration between OPA and Kubernetes.

OPA Gatekeeper adds the following on top of plain OPA:

- An extensible, parameterized policy library.
- Native Kubernetes CRDs for instantiating the policy library (aka "**constraints**").
- Native Kubernetes CRDs for extending the policy library (aka "**constraint templates**").
- Audit functionality.



From: Kubernetes Blog

Gatekeeper Installation:

```
>> kubectl apply -f https://raw.githubusercontent.com/open-policy-agent/gatekee
```

Following are the objects created as part of the gatekeeper installation:

```
>> kubectl get all -n gatekeeper-system

NAME                                             READY   STATUS    RESTARTS
pod/gatekeeper-audit-56ddcd8749-mlvjv            1/1     Running   0
pod/gatekeeper-controller-manager-64fd6c8cfd-cqvnw   1/1     Running   0
pod/gatekeeper-controller-manager-64fd6c8cfd-xgmxv   1/1     Running   0
pod/gatekeeper-controller-manager-64fd6c8cfd-znxfh   1/1     Running   0

NAME                                TYPE        CLUSTER-IP     EXTERNAL-IP   P
service/gatekeeper-webhook-service   ClusterIP   10.245.56.27   <none>        4

NAME                                          READY   UP-TO-DATE   AVAILABLE
deployment.apps/gatekeeper-audit              1/1     1            1
deployment.apps/gatekeeper-controller-manager   3/3     3            3

NAME                                                   DESIRED   CURRENT
replicaset.apps/gatekeeper-audit-56ddcd8749            1         1
replicaset.apps/gatekeeper-controller-manager-64fd6c8cfd   3         3
```

Validating Admission Control

Once all the Gatekeeper components have been installed in our cluster, the API server will trigger the Gatekeeper admission webhook to process the admission request whenever a resource in the cluster is created, updated, or deleted.
During the validation process, Gatekeeper acts as a bridge between the API server and OPA. The API server will enforce all policies executed by OPA.

CustomResourceDefinition

The **CustomResourceDefinition** (CRD) API allows us to define custom resources. Defining a CRD object creates a new custom resource with a name and schema that we specify. The Kubernetes API serves and handles the storage of your custom resources.

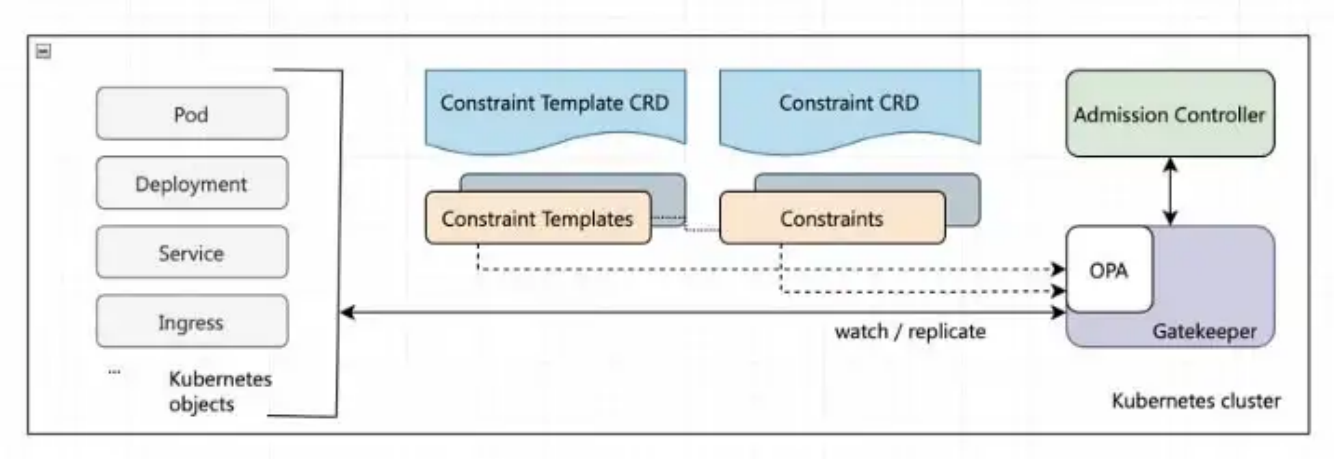
Gatekeeper uses CustomResourceDefinitions internally and allows us to define **ConstraintTemplates** and **Constraints** to enforce policies on Kubernetes resources such as Pods, Deployments, and Jobs.

Gatekeeper creates several CRDs during the installation process :

```
>> kubectl get crd | grep -i gatekeeper
```

```
assign.mutations.gatekeeper.sh                          2022-11-29T07:04:42Z
assignmetadata.mutations.gatekeeper.sh                  2022-11-29T07:04:43Z
configs.config.gatekeeper.sh                            2022-11-29T07:04:43Z
constraintpodstatuses.status.gatekeeper.sh              2022-11-29T07:04:43Z
constrainttemplatepodstatuses.status.gatekeeper.sh      2022-11-29T07:04:43Z
constrainttemplates.templates.gatekeeper.sh             2022-11-29T07:04:44Z #<---
expansiontemplate.expansion.gatekeeper.sh               2022-11-29T07:04:44Z
modifyset.mutations.gatekeeper.sh                       2022-11-29T07:04:44Z
mutatorpodstatuses.status.gatekeeper.sh                 2022-11-29T07:04:44Z
providers.externaldata.gatekeeper.sh                    2022-11-29T07:04:44Z
```

One of them is **“constrainttemplates.templates.gatekeeper.sh”** using that we can create **Constraints** and **Constraint Templates** to work with gatekeeper:

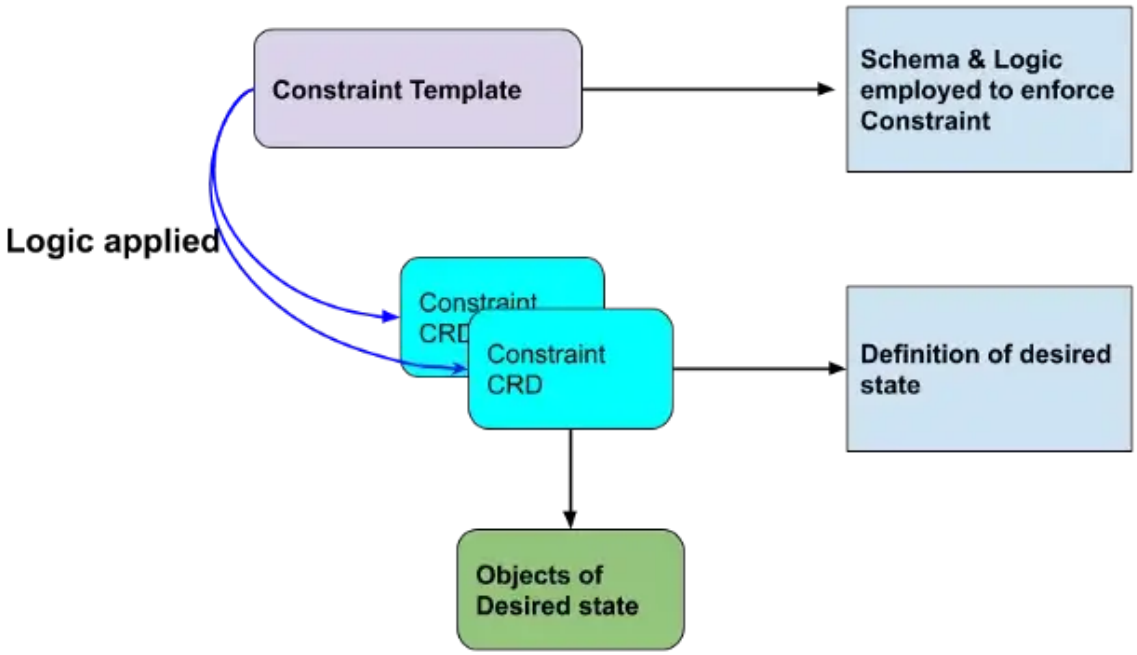


From: https://dev.to/ashokan/kubernetes-policy-management-ii-opa-gatekeeper-465g

● **ConstraintTemplates** define a way to validate some set of Kubernetes objects in Gatekeeper’s Kubernetes admission controller. They are made of two main elements:

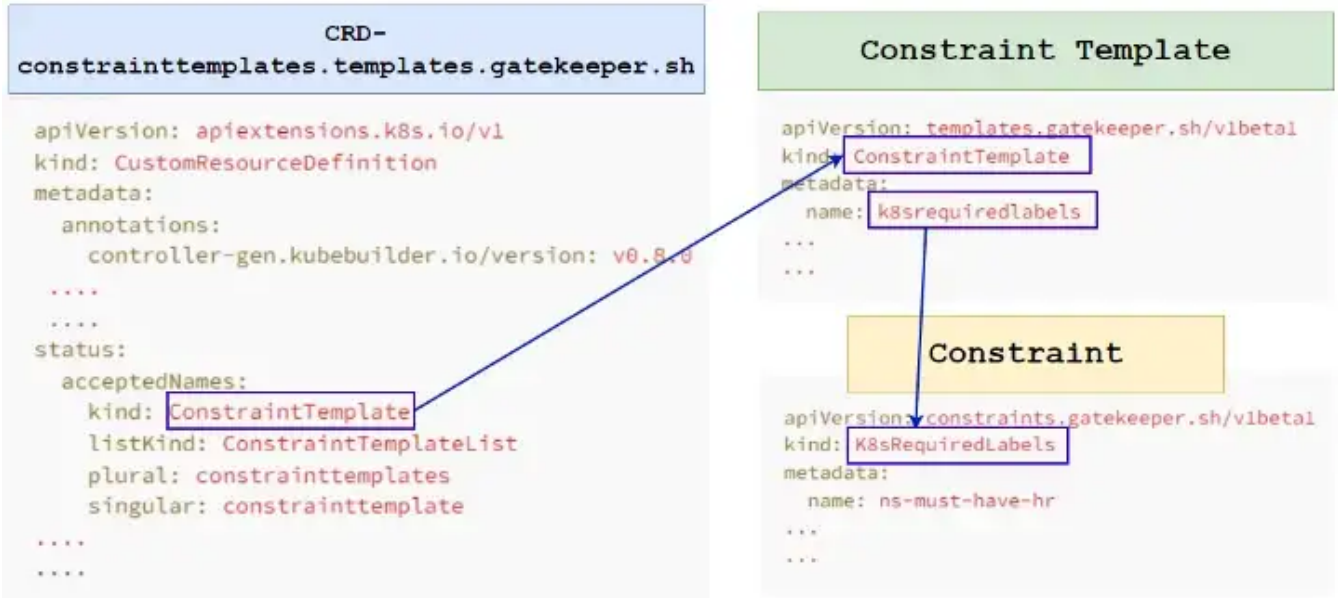
1. Rego code that defines a policy violation
2. The schema of the accompanying `Constraint` object, which represents an instantiation of a `ConstraintTemplate`

● A **Constraint** is a declaration of requirements that a system needs to meet. In another word, **Constraints** are used to inform Gatekeeper that the admin wants a ConstraintTemplate to be enforced, and how.



From: https://grumpygrace.dev/posts/intro-to-gatekeeper-policies/

Following is an illustration of how CRD, Contraint Template, and Constraint connect with each other:



Walkthrough

Now let's say we want to enforce a policy so that a kubernetes resource (such as a pod, namespace, etc) must have a particular label defined. To achieve that let's create a `ConstraintTemplate` first and then create a `Constraint` :

ConstraintTemplate:

Following is the `ConstraintTemplate.yaml` file, we will use this file to create an `ConstraintTemplate` on our k8s cluster:

```
# ConstraintTemplate.yaml
# ------------------------------------------------------------
apiVersion: templates.gatekeeper.sh/v1
kind: ConstraintTemplate                    # Template Identifying Info
metadata:
  name: k8srequiredlabels
# ------------------------------------------------------------
spec:
  crd:
    spec:
      names:
        kind: K8sRequiredLabels        # Template values for constraint crd's
      validation:
        # Schema for the `parameters` field
        openAPIV3Schema:
          type: object
          properties:
            labels:
              type: array
              items:
                type: string
# ------------------------------------------------------------
  targets:
    - target: admission.k8s.gatekeeper.sh
      rego: |                                       # Rego
        package k8srequiredlabels

        violation[{"msg": msg, "details": {"missing_labels": missing}}] {
          provided := {label | input.review.object.metadata.labels[label]}
          required := {label | label := input.parameters.labels[_]}
          missing := required - provided
          count(missing) > 0
          msg := sprintf("you must provide labels: %v", [missing])
        }
# ------------------------------------------------------------
```

Create the `ConstraintTemplate` using the above-defined manifests :

```
>> kubectl create -f ConstraintTemplate.yaml

#  List the available ConstraintTemplate's
>> kubectl get ConstraintTemplate
NAME                AGE
k8srequiredlabels   29s
```

Constraint: pod label

Now, let's create a `Constraint` that will enforce that a pod must have a policy named "**app**" every time a pod is created. Following is the `Constraint` file named "**pod-must-have-app-level.yaml**"

```
# pod-must-have-app-level.yaml

apiVersion: constraints.gatekeeper.sh/v1beta1
kind: K8sRequiredLabels
metadata:
  name: pod-must-have-app-level
spec:
  match:
    kinds:
      - apiGroups: [""]
        kinds: ["Pod"]
  parameters:
    labels: ["app"]
```

Create the `Constraint` on our kubernetes cluster and list the available constraints:

```
>> kubectl create -f pod-must-have-app-level.yaml

# List the available Constraint's
>> kubectl get constraints

NAME                       ENFORCEMENT-ACTION   TOTAL-VIOLATIONS
pod-must-have-app-level                         13
```

Now, let's create a pod without defining the label and observe what happens:

```
# Create a pod without labels
>> kubectl run nginx --image=nginx
Error from server (Forbidden): admission webhook "validation.gatekeeper.sh" der
```

As we can see in the above demonstration, a pod creation request is being denied because the required “label” is not provided while creating the pod.

Now, let’s create a pod with the “**app**” label and observe the behavoiur:

```
# Create a pod with label
>> kubectl run nginx --image=nginx --labels=app=test
pod/nginx created
```

In the above demonstration, we can see that pod is deployed without any issues because we specified the required label while creating the pod.

Constraint: namespace label

A `ConstraintTemplate` can be used by several `Constraint`. In the previous phase, we specified a `Constraint` so that a pod must have a particular label. If required we can create another `Constraint` using the same `ConstraintTemplate` but this time it will be for a namespace. We can write a `Constraint` so that a namespace must have a particular label.

Following is the `Constraint` file named “**ns-must-label-state.yaml**” for enforcing the namespaces to have a particular label called “**state**”:

```
# ns-must-label-state.yaml

apiVersion: constraints.gatekeeper.sh/v1beta1
kind: K8sRequiredLabels
metadata:
  name: ns-must-label-state
spec:
  match:
    kinds:
      - apiGroups: [""]
```

```
        kinds: ["Namespace"]
  parameters:
    labels: ["state"]
```

Let's create **`Constraint`** using the above-defined "**ns-must-label-state.yaml**" :

```
>> kubectl create -f ns-must-label-state.yaml

# List the available Constraint's
>> kubectl get constraints

NAME                        ENFORCEMENT-ACTION   TOTAL-VIOLATIONS
ns-must-label-state                              5
pod-must-have-app-level                          13
```

And then create a **namespace** without defining the required label which is "**state**" in the current case:

```
>> kubectl create ns test

Error from server (Forbidden): admission webhook "validation.gatekeeper.sh" der
```

Now, create a namespace using the required label and see what happens:

```
# test-ns.yaml

apiVersion: v1
kind: Namespace
metadata:
  name: test
  labels:
    state: dev    #<---

---
```

```
>> kubectl create -f test-ns.yaml
namespace/test created
```

In the above demonstration, we can see that the namespace is created without any issues because we specified the required label.

Check for Violations

We can describe or inspect a **`Constraint`** to find out policy violations by the existing kubernetes resources :

```
# To describe a Constraint
>> kubectl describe <ConstraintTemplate>  <Constraint>
```

Let's describe the "**ns-must-label-state**" constraint:

```
                    [ConstraintTemplate]  [Constraint]
>> kubectl describe  k8srequiredlabels     ns-must-label-state

#--------------------------------------------------------------------------

Name:         ns-must-label-state
Namespace:
...
...
Status:
  Audit Timestamp:  2022-11-30T02:32:48Z
  By Pod:
    Constraint UID:       846a2d86-5d00-4eba-bd6a-669cd27fc703
    Enforced:             true
    Id:                   gatekeeper-audit-56ddcd8749-htgk5
    Observed Generation:  1
    Operations:
      audit
      mutation-status
      status
    Constraint UID:       846a2d86-5d00-4eba-bd6a-669cd27fc703
    Enforced:             true
    Id:                   gatekeeper-controller-manager-64fd6c8cfd-jh7qr
    Observed Generation:  1
    Operations:
      mutation-webhook
      webhook
```

```
    Constraint UID:       846a2d86-5d00-4eba-bd6a-669cd27fc703
    Enforced:             true
    Id:                   gatekeeper-controller-manager-64fd6c8cfd-q6ds9
    Observed Generation:  1
    Operations:
      mutation-webhook
      webhook
    Constraint UID:       846a2d86-5d00-4eba-bd6a-669cd27fc703
    Enforced:             true
    Id:                   gatekeeper-controller-manager-64fd6c8cfd-rbvsz
    Observed Generation:  1
    Operations:
      mutation-webhook
      webhook
  Total Violations:  5        #<-------------
  Violations:
    Enforcement Action:  deny
    Group:
    Kind:                Namespace
    Message:             you must provide labels: {"state"}
    Name:                kube-public
    Version:             v1
    Enforcement Action:  deny
    Group:
    Kind:                Namespace
    Message:             you must provide labels: {"state"}
    Name:                kube-node-lease
    Version:             v1
    Enforcement Action:  deny
    Group:
    Kind:                Namespace
    Message:             you must provide labels: {"state"}
    Name:                gatekeeper-system
    Version:             v1
    Enforcement Action:  deny
    Group:
    Kind:                Namespace
    Message:             you must provide labels: {"state"}
    Name:                kube-system
    Version:             v1
    Enforcement Action:  deny
    Group:
    Kind:                Namespace
    Message:             you must provide labels: {"state"}
    Name:                default
    Version:             v1
Events:                  <none>
```

In the above illustration, we can see that there are several namespaces that violate the policy, It is because they (namespaces) were created before the “**ns-must-label-state**” constraint is created.

OPA Gatekeeper Library

There is a community-owned library of policies for OPA gatekeeper projects.

- OPA Gatekeeper Library

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