

Release G: Coordinated Service Exposure

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JIRA Ticket

[NONRTRIC-634](#) - Getting issue details...

STATUS

ISTIO

Istio is a service mesh which provides a dedicated infrastructure layer that you can add to your applications. It adds capabilities like observability, traffic management, and security, without adding them to your own code.

To populate its own **service** registry, **Istio** connects to a **service discovery** system. For example, if you've installed **Istio** on a Kubernetes cluster, then **Istio** automatically detects the services and endpoints in that cluster. Using this **service registry**, the Envoy proxies can then direct traffic to the relevant services.

Istio Ingress Gateway can be used as a **API-Gateway** to securely expose the APIs of your micro services. It can be easily configured to provide access control for the APIs i.e. allowing you to apply policies defining who can access the APIs, what operations they are allowed to perform and much more conditions.

The Istio API traffic management features available are: Virtual services: **Configure request routing to services within the service mesh**. Each virtual service can contain a series of routing rules, that are evaluated in order. Destination rules: Configures the destination of routing rules within a virtual service.

Destination Rule

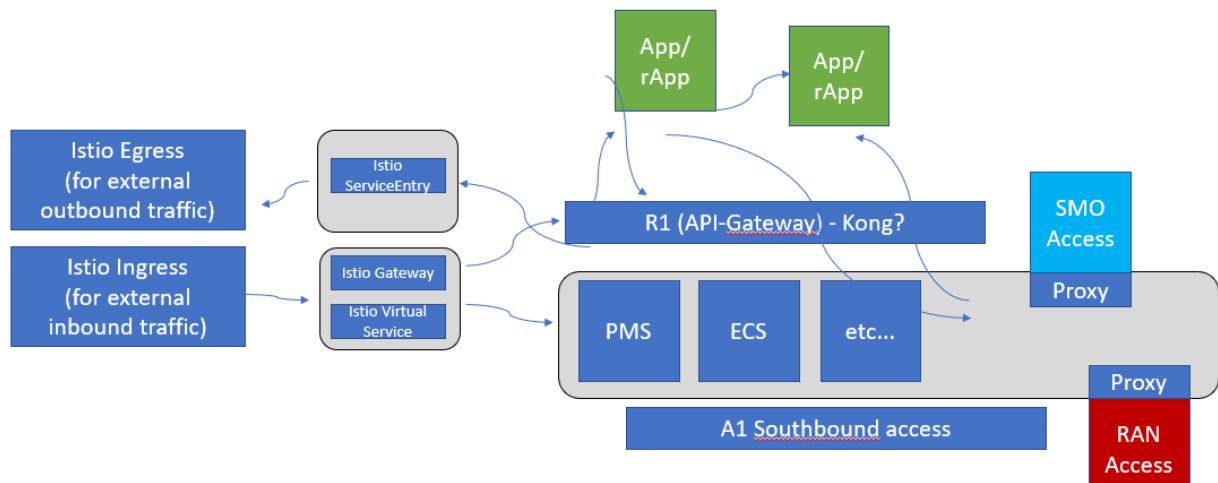
```
apiVersion: networking.istio.io/v1alpha3
kind: DestinationRule
metadata:
  name: bookinfo-ratings
spec:
  host: ratings.prod.svc.cluster.local
  trafficPolicy:
    loadBalancer:
      simple: LEAST_CONN
  subsets:
    - name: testversion
      labels:
        version: v3
      trafficPolicy:
        loadBalancer:
          simple: ROUND_ROBIN
```

Istio provisions the DNS names and **secret** names for the DNS **certificates** based on configuration you provide. The DNS **certificates** provisioned are signed by the **Kubernetes** CA and stored in the **secrets** following your configuration. **Istio** also manages the lifecycle of the DNS **certificates**, including their rotations and regenerations.

With Mutual TLS (mTLS) the client and server both verify each other's certificates and use them to encrypt traffic using TLS.. With Istio, you can enforce mutual TLS automatically.

PeerAuthentication

```
apiVersion: "security.istio.io/v1beta1"
kind: "PeerAuthentication"
metadata:
  name: "default"
  namespace: "istio-system"
spec:
  mTLS:
    mode: STRICT
```



JWT

JSON Web Token (JWT) is an open standard (RFC 7519) that defines a compact and self-contained way for securely transmitting information between parties as a JSON object.

JWT is mostly used for Authorization. Once the user is logged in, each subsequent request will include the JWT, allowing the user to access routes, services, and resources that are permitted with that token (User context). You can pass the original jwt as an embedded jwt or pass original jwt in the http header ([Istio / JWTRule](#)).

JWT can also contain information about the client that sent the request (client context).

We can use **Istio's** RequestAuthentication resource to configure **JWT** policies for your services.

Request Authentication

```

apiVersion: security.istio.io/v1beta1
kind: RequestAuthentication
metadata:
  name: httpbin
  namespace: foo
spec:
  selector:
    matchLabels:
      app: httpbin
  jwtRules:
    - issuer: "issuer-foo"
      jwksUri: https://example.com/.well-known/jwks.json
---
apiVersion: security.istio.io/v1beta1
kind: AuthorizationPolicy
metadata:
  name: httpbin
  namespace: foo
spec:
  selector:
    matchLabels:
      app: httpbin
  rules:
    - from:
      - source:
          requestPrincipals: ["*"]

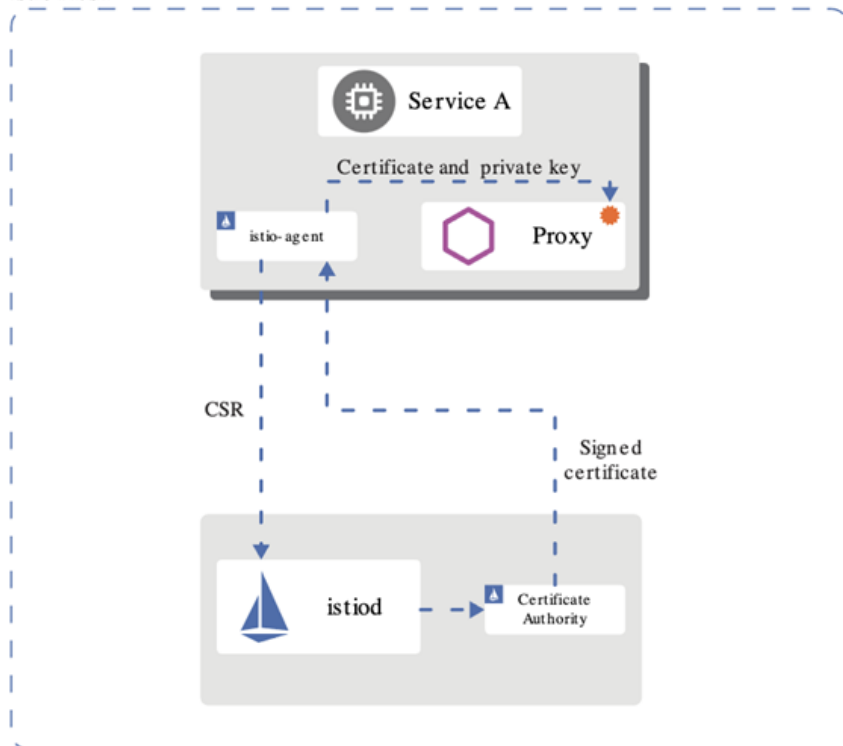
```

JWT can also be used for service level authorization (SLA)

Authorization Policy

```
apiVersion: security.istio.io/v1beta1
kind: AuthorizationPolicy
metadata:
  name: httpbin
  namespace: foo
spec:
  selector:
    matchLabels:
      app: httpbin
  rules:
    - from:
      - source:
          requestPrincipals: ["*"]
    - to:
      - operation:
          paths: ["/healthz"]
```

Istio Mesh



Use Case

1. A client makes a request on a specific port.
2. The **Load Balancer** listens on this port and forwards the request to one of the workers in the cluster (on the same or a new port).
3. Inside the cluster the request is routed to the **Istio IngressGateway Service** which is listening on the port the load balancer forwards to.
4. The **Service** forwards the request (on the same or a new port) to an **Istio IngressGateway Pod** (managed by a Deployment).
5. The **IngressGateway Pod** is configured by a **Gateway (!)** and a **VirtualService**.
6. The **Gateway** configures the ports, protocol, and certificates.
7. The **VirtualService** configures routing information to find the correct **Service**.
8. The **Istio IngressGateway Pod** routes the request to the **application Service**.
9. And finally, the **application Service** routes the request to an **application Pod** (managed by a deployment).

KUBERNETES

K8S RBAC (Role Based Access Control) - supported by default in kubernetes.

K8S Service Account

- Kube use service account (sa) to validate api access
- SAs can be linked to a role via a binding
- A default sa, with no permissions (no bindings), is created in each namespace – pods uses this namespace unless otherwise specified
- Pods can be specified to run with a specific sa
- The helm manager needs a SA with cluster wide permission (to be able to list installed charts etc)
However, during installation the pod running the helm install/upgrade/delete should run with a sa with only namespace permission to ensure not other modification is made to kube objects outside the namespace

K8S RBAC - controlling access to kubernetes resources

- Role and rolebinding objects defines who (sa, user or group) is allowed to do what in the kubernetes api
- **Role** object
 - Sets permissions on resources in a specific namespace
- **ClusterRole** object
 - Sets permission on non-namespaced resources or across namespaces
- **RoleBinding** object
 - Binds one or more Role or a ClusterRole object(s) to a user, group or service account
- **ClusterRoleBinding** object
 - Binds one or more ClusterRole object(s) to a user, group or service account
- No installation required – RBAC enabled by default

Network Policies

- K8S supports Network Policy objects but a provider need to be install for the policies to take effect, e.g. Calico
 - Network policies can control ingress and/or egress traffic by selecting applicable pods - basically controlling traffic between pods and/or network endpoints
 - Several providers: Calico, Cilium etc
-
- Allow traffic from ns: **kong** (the gateway), **nonrtic** and **onap**
 - Deny traffic from any other ns

```

apiVersion: networking.k8s.io/v1
kind: NetworkPolicy
metadata:
  name: np-nrt-ingress
  namespace: nonrtric
spec:
  podSelector: {}
  policyTypes:
  - Ingress
  ingress:
  - from:
    - namespaceSelector:
        matchLabels:
          kubernetes.io/metadata.name: kong
    - namespaceSelector:
        matchLabels:
          kubernetes.io/metadata.name: onap
    - namespaceSelector:
        matchLabels:
          kubernetes.io/metadata.name: nonrtric

```

KONG

Kong is Orchestration Microservice API Gateway. Kong provides a flexible abstraction layer that securely manages communication between clients and microservices via API. Also known as an API Gateway, API middleware or in some cases Service Mesh.

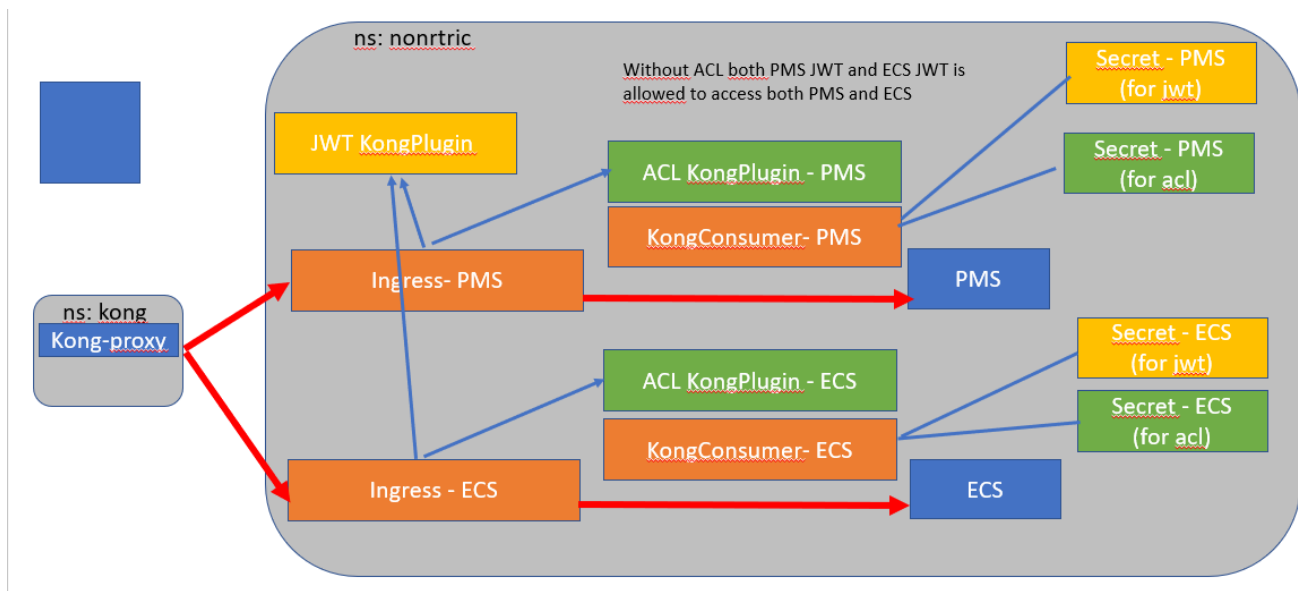
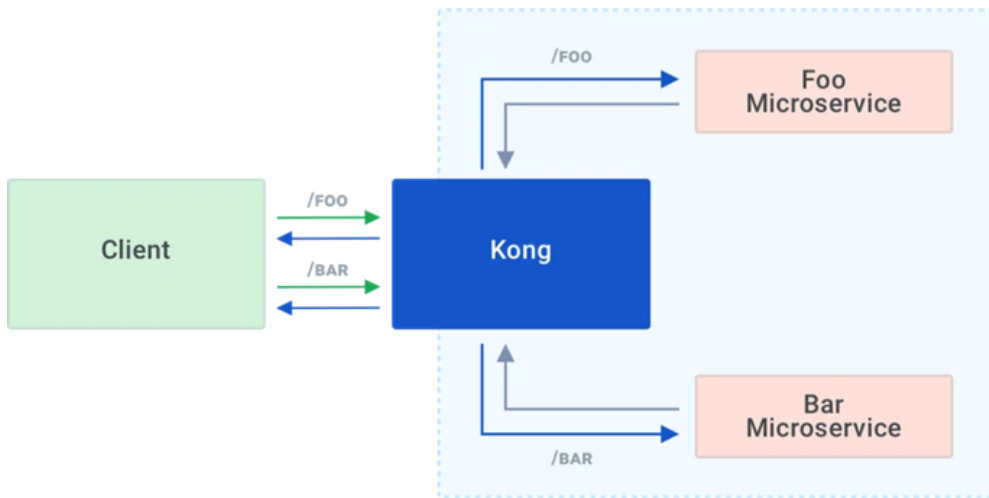
- Kong can be used as an API gateway:
- Hiding internal microservice structure
- Could be used as R1 API front-end

Kong acts as the service registry, **keeping a record of the available target instances for the upstream services**. When a target comes online, it must register itself with Kong by sending a request to the Admin API. Each upstream service has its own ring balancer to distribute requests to the available targets.

With client-side discovery, the client or API gateway making the request is responsible for identifying the location of the service instance and routing the request to it. The client begins by querying the service registry to identify the location of the available instances of the service and then determines which instance to use. See <https://konghq.com/learning-center/microservices/service-discovery-in-a-microservices-architecture/>

Kong datastore

Kong uses an external datastore to store its configuration such as registered APIs, Consumers and Plugins. Plugins themselves can store every bit of information they need to be persisted, for example rate-limiting data or Consumer credentials. See <https://konghq.com/faqs/#:~:text=PostgreSQL%20is%20an%20established%20SQL%20database%20for%20use,Cassandra%20or%20PostgreSQL%2C%20Kong%20maintains%20its%20own%20cache.>



Kong Demo

Demo of Kong gateway access control already available.

JWT tokens are used to grant access to particular services for different users.

See also <https://konghq.com/blog/jwt-kong-gateway>

Kube objects for Kong

```
echo "Create JWT KongPlugin in nonrtrc namespace"
echo "
apiVersion: configuration.konghq.com/v1
kind: KongPlugin
metadata:
  name: app-jwt
  namespace: nonrtrc
plugin: jwt
" | kubectl apply -f -
```

```
echo "Create secret, public key, for pms-user JWT"
kubectl create secret \
  generic pms-jwt --nonrtrc \
  --from-literal=key=redtypejwt \
  --from-literal=key=pms-user \
  --from-literal=valgr1thmRQ256 \
  --from-literal=public_key=-----BEGIN PUBLIC KEY-----
MIIDBJANBgkqhkiG9w0BAQEFAAACBAQwAQAQAAEAA57a30vz50/30vbs+P
N0V0jgntg6e50mpC7xXZK2HJLAVLPyd5A9pCqBm3abfzQ04yLhb/X
q2AmG7Vx/n20PT1gr1Q04p9B0b0P7M6N21v3r5Lx0B0M0C1201r0p0T0R
W0Zu3PyyVAKAS06ue10MLt72p0chetaM0L31r2740K2y7Y0Du0M7dHr5K8U20f
CG1au1xDT1v20u0M0P0rFE7q3B0K0Q0A020ba0R0yK1a0S1xV0x0u0y0h0B0K
c10x0B0M0L1x350A0u0p3B0ZC0d0a0etF0b0b0Y0B0C0B0Z70S0T0at0ar1L0aJ
tw0DA0AB
-----END PUBLIC KEY-----"

echo "Create secret, public key, for ecs-user JWT"
kubectl create secret \
  generic ECS0J06 --nonrtrc \
  --from-literal=key=redtypejwt \
  --from-literal=key=ecs-user \
  --from-literal=valgr1thmRQ256 \
  --from-literal=public_key=-----BEGIN PUBLIC KEY-----
MIIDBJANBgkqhkiG9w0BAQEFAAACBAQwAQAQAAEAA57a30vz50/30vbs+P
N0V0jgntg6e50mpC7xXZK2HJLAVLPyd5A9pCqBm3abfzQ04yLhb/X
q2AmG7Vx/n20PT1gr1Q04p9B0b0P7M6N21v3r5Lx0B0M0C1201r0p0T0R
W0Zu3PyyVAKAS06ue10MLt72p0chetaM0L31r2740K2y7Y0Du0M7dHr5K8U20f
CG1au1xDT1v20u0M0P0rFE7q3B0K0Q0A020ba0R0yK1a0S1xV0x0u0y0h0B0K
c10x0B0M0L1x350A0u0p3B0ZC0d0a0etF0b0b0Y0B0C0B0Z70S0T0at0ar1L0aJ
tw0DA0AB
-----END PUBLIC KEY-----"
```

```
echo "Create ACL KongPlugin for PMS group"
echo "
apiVersion: configuration.konghq.com/v1
kind: KongPlugin
metadata:
  name: pms-group-acl
  namespace: nonrtrc
plugin: acl
config:
  whitelist: ['pms-group']
" | kubectl apply -f -
```

```
echo "Create secret for PMS group"
kubectl create secret \
  generic pms-group-acl --nonrtrc \
  --from-literal=kongCredTypeacl \
  --from-literal=group=pms-group
```

```
echo "Create ACL KongPlugin for ECS group"
echo "
apiVersion: configuration.konghq.com/v1
kind: KongPlugin
metadata:
  name: ecs-group-acl
  namespace: nonrtrc
plugin: acl
config:
  whitelist: ['ecs-group']
" | kubectl apply -f -
```

```
echo "Create secret for ECS group"
kubectl create secret \
  generic ecs-group-acl --nonrtrc \
  --from-literal=kongCredTypeacl \
  --from-literal=group=ecs-group
```

```
echo "Create KongConsumer for pms-user"
echo "
apiVersion: configuration.konghq.com/v1
kind: KongConsumer
metadata:
  name: pms-user
  namespace: nonrtrc
annotations:
  konghq.com/ingress.class: kong
username: pms-user
credentials:
  - pms-jwt
  - pms-group-acl
" | kubectl apply -f -
```

```
echo "Create KongConsumer for ecs-user"
echo "
apiVersion: configuration.konghq.com/v1
kind: KongConsumer
metadata:
  name: ecs-user
  namespace: nonrtrc
annotations:
  konghq.com/ingress.class: kong
username: ecs-user
credentials:
  - ECS0J06
  - ecs-group-acl
" | kubectl apply -f -
```

```
echo "Create Ingress for PMS"
echo "
apiVersion: extensions/v1beta1
kind: Ingress
metadata:
  name: v1-ing-pms
  namespace: nonrtrc
annotations:
  konghq.com/plugins: app-jwt,pms-group-acl
  konghq.com/strip-path: "false"
  konghq.com/ingress.class: kong
spec:
  rules:
  - http:
      paths:
      - path: /at-policy
        backend:
          serviceName: policymanagementservice
          servicePort: 8001
" | kubectl apply -f -

echo "Create Ingress for ECS"
echo "
apiVersion: extensions/v1beta1
kind: Ingress
metadata:
  name: v1-ing-ecs
  namespace: nonrtrc
annotations:
  konghq.com/plugins: app-jwt,ecs-group-acl
  konghq.com/strip-path: "false"
  konghq.com/ingress.class: kong
spec:
  rules:
  - http:
      paths:
      - path: /data-consumer
        backend:
          serviceName: enrichmentservice
          servicePort: 8003
      - path: /data-producer
        backend:
          serviceName: enrichmentservice
          servicePort: 8003
" | kubectl apply -f -
```

Network Policy

```
apiVersion: networking.k8s.io/v1
kind: NetworkPolicy
metadata:
  name: networkpolicy-nr
  namespace: nonrtrc
spec:
  podSelector: {}
  policyTypes:
  - Ingress
  ingress:
  - from:
    - namespaceSelector:
        matchLabels:
          kongq.com/metadata.name: kong
    - namespaceSelector:
        matchLabels:
          kongq.com/metadata.name: onap
    - namespaceSelector:
        matchLabels:
          kongq.com/metadata.name: nonrtrc
```

Kong Gateway JWT

```
apiVersion: configuration.konghq.com/v1
kind: KongPlugin
metadata:
  name: app-jwt-kp
  namespace: nonrtrc
plugin: jwt
---
apiVersion: v1
```



```
kind: Secret
metadata:
  name: pms-jwt-sec
  namespace: nonrtric
type: Opaque
stringData:
  kongCredType: jwt
  key: pms-issuer
  algorithm: RS256
  rsa_public_key: |
    -----BEGIN PUBLIC KEY-----
    MIIBIjANBgkqhkiG9w0BAQEFAAOCAQ8AMIIBCgKCAQEAwetu4+suoz6c7e1kQz7I
    Jmujc18zHpp4qh3nsmEL8e3Q0KzMVSLuQPcF8l01bBoChSA+KMNJ5rEixGWSxClp
    9XroBSgrvjDsKtpPIlBQMnyOUYRSXWnIodmN+7wA72pTxo7JtAypPzRscSgi00Zt
    9dtmv50RLr9Wph5cI+IE90tgW580KtdFRGigGHfdUEwrT/MPw2r0U85YRFaEgT/i
    wcuQCe+Zmf2S2gVgK62u51ZFFn2VycJT1Lc0t9cdqrSXYZAPfVKnQ/EgYvDdzFL1
    x73JkrrSEP3pfrN4bX0nc7cS/S9Y2qk/I+QCR6a6XKmqk5SnWJSyXvKdYQJrgxJp
    lQIDAQAB
    -----END PUBLIC KEY-----
  ---
apiVersion: v1
kind: Secret
metadata:
  name: ecs-jwt-sec
  namespace: nonrtric
type: Opaque
stringData:
  kongCredType: jwt
  key: ecs-issuer
  algorithm: RS256
  rsa_public_key: |
    -----BEGIN PUBLIC KEY-----
    MIIBIjANBgkqhkiG9w0BAQEFAAOCAQ8AMIIBCgKCAQEAtminztNs5oqPCbg4uC1
    L7MfR3B+uyYvkSKr3NFieRCxp6VhrgodJJXYc3SqXbaTVBkTwU24wG4UvJCnoRQd
    0VhSawtLkN8XNAdCiD831dKUyMJPs43ZY/g05CHVqUMdSHlp8dn7jnren59dvRRS
    3xC1D3etXuEU01XGuLi/5qJLAKqDbYs3bH1vsLTjndg1WTsrkU8GEIT1NphSYg25
    s6rSLTIBfk8FjKquYHw3wYVSQK9rg2mqddJpRWkfZnazMHTmSNj0JpiNb77VLGSx
    9qDbblJurCl2mAG5Z+w76uKfKGg0o68SU0TL1sPybsKhAoZZg1gF06mvMln5eq5C
    RQIDAQAB
    -----END PUBLIC KEY-----
  ---
apiVersion: configuration.konghq.com/v1
kind: KongPlugin
metadata:
  name: pms-group-acl-kp
  namespace: nonrtric
plugin: acl
config:
  whitelist: ['pms-group']
  ---
apiVersion: v1
kind: Secret
metadata:
  name: pms-group-acl-sec
  namespace: nonrtric
type: Opaque
stringData:
  kongCredType: acl
  group: pms-group
  ---
apiVersion: configuration.konghq.com/v1
kind: KongPlugin
metadata:
  name: ecs-group-acl-kp
  namespace: nonrtric
plugin: acl
config:
  whitelist: ['ecs-group']
  ---
apiVersion: v1
kind: Secret
```

```

metadata:
  name: ecs-group-acl-sec
  namespace: nonrtric
type: Opaque
stringData:
  kongCredType: acl
  group: ecs-group
---
apiVersion: configuration.konghq.com/v1
kind: KongPlugin
metadata:
  name: all-group-acl-kp
  namespace: nonrtric
plugin: acl
config:
  whitelist: ['ecs-group', 'pms-group']
---
apiVersion: configuration.konghq.com/v1
kind: KongConsumer
metadata:
  name: pms-user-kc
  namespace: nonrtric
  annotations:
    kubernetes.io/ingress.class: kong
username: pms-user
credentials:
  - pms-jwt-sec
  - pms-group-acl-sec
---
apiVersion: configuration.konghq.com/v1
kind: KongConsumer
metadata:
  name: ecs-user-kc
  namespace: nonrtric
  annotations:
    kubernetes.io/ingress.class: kong
username: ecs-user
credentials:
  - ecs-jwt-sec
  - ecs-group-acl-sec
---
apiVersion: networking.k8s.io/v1
kind: Ingress
metadata:
  name: r1-pms-ing
  namespace: nonrtric
  annotations:
    konghq.com/plugins: app-jwt-kp,pms-group-acl-kp
    konghq.com/strip-path: "false"
spec:
  ingressClassName: kong
  rules:
  - http:
      paths:
      - path: /a1-policy
        pathType: ImplementationSpecific
        backend:
          service:
            name: policymanagementservice
            port:
              number: 8081
---
apiVersion: networking.k8s.io/v1
kind: Ingress
metadata:
  name: r1-ecs-ing
  namespace: nonrtric
  annotations:
    konghq.com/plugins: app-jwt-kp,ecs-group-acl-kp
    konghq.com/strip-path: "false"
spec:

```

```

ingressClassName: kong
rules:
- http:
  paths:
  - path: /data-consumer
    pathType: ImplementationSpecific
    backend:
      service:
        name: enrichmentservice
        port:
          number: 8083
  - path: /data-producer
    pathType: ImplementationSpecific
    backend:
      service:
        name: enrichmentservice
        port:
          number: 8083
---
apiVersion: networking.k8s.io/v1
kind: Ingress
metadata:
  name: r1-echo-ing
  namespace: nonrtric
  annotations:
    konghq.com/plugins: app-jwt-kp,all-group-acl-kp
    konghq.com/strip-path: "true"
spec:
  ingressClassName: kong
  rules:
  - http:
    paths:
    - path: /echo
      pathType: ImplementationSpecific
      backend:
        service:
          name: httppecho
          port:
            number: 80

```

[Kong-Gateway-JWT.zip](#)

ISTIO Demo

1. Install ISTIO on minikube using instruction here: [Istio Installation - Simplified Learning \(waytoeasylearn.com\)](#)
2. cd to the istio directory and install the demo application
 - a. `kubectl create ns foo`
 - b. `kubectl apply -f <(istioctl kube-inject -f samples/httpbin/httpbin.yaml) -n foo`
3. Create a python script to generate a JWT token using the code from here: <https://medium.com/intelligentmachines/istio-jwt-step-by-step-guide-for-micro-services-authentication-690b170348fc> . Install `python_jwt` using pip if it's not already installed.
4. Create `jwt-example.yaml` using the public key generated by the python script:


```
kubectl create -f jwt-example.yaml
```

jwt-example.yaml

```
apiVersion: "security.istio.io/v1beta1"
kind: "RequestAuthentication"
metadata:
  name: "jwt-example"
  namespace: istio-system
spec:
  selector:
    matchLabels:
      istio: ingressgateway
  jwtRules:
  - issuer: "ISSUER"
    jwks: |
      { "keys": [{ "e": "AQAB", "kty": "RSA", "n": "x_yYl4uw5c6NH0A-bDDh0MThFggBwL-
vYJr77b9F1LmAtTLJVM0rL5kltFv2DmlAmD9eZPrWeU0o0GhSpe58XiSAvxyea0rZhtyUjT3aglrSys0YBsB19ItNGMuoiuzPpW0rDtKw
Ha9rPbrdc6q7vb93qu2UVaIz-3FJmGFtSA5t8FK_5bZKF-o0zRLwqeVQ3n0Bu_dFDuGeZjQWMZF32QupaA-GF-
tDGGriPLy9sutlB1NqYz4qiSZx5UMxcFLwsWfQxHemdwLeZXWkWNBoV8RmbZy2Jz-dwg6XjHBWAjTnCGG9p-
bp63nUlnELI3LcEGhG0ugZBqcpNT5dEAQ0fQ"}]} }
```

5. Export the JWT token generated by the python script as an environment variable:
export TOKEN="eyJhbGciOiJSUzI1NiIsInR5cCI6IkpXVCJ9.
eyJhdWQiOiJBVURJRlU5DRSislmV4cCI6MTYzNzI1NDkxNSwiaWF0IjoxNjM3MjUxOTE1LCJpc3MiOiJJU1NVRVliLCJqdGkiOiJCcmhDdEstcC00
ZTF0RlBrZmpuSmhRliwibmJmIjoxNjM3MjUxOTE1LCJwZXJtaXNzaW9uIjoicmVhZCIsInJvbGUoiOiJ1c2Vylwiw3ViljoiU1VCSkvDVCJ9.
HrQCLPZXf0VkfFe7JUVGXq-sHJQhVibqhToG4r63py-iwHWIUL02_WfoWRoxapggGwlmDdSlt1uG8RR-
6VMqzWwGlcqBIRhFTG0nmzmtQjnOUs6QAKSUpA3PyWBIYHV0BwZbpo8Zq1Bo-sELy400fU-
MCQ_054fSsG7JMBMmrnj8NyJmD2INN0VSFG053SPI2tQSVlc9OwAr8Uu0jflPfUmh6yq43qFuxnVRFBGLLPNot29aOfAetKLc72qlphtnbDx2a9te
P5AlbkiWylIhTytEnQRCwU4x8gDrEdkrHui4qCtzip_uoITSwPe3AFsi7gQHB6rJoDj-j2zPc4rUTAA"
6. export INGRESS_HOST=\$(minikube ip)
7. export INGRESS_PORT=\$(kubectl -n istio-system get service istio-ingressgateway -o jsonpath='{.spec.ports[?(@.name=="http2")].nodePort}')
8. Test the service:
curl --header "Authorization: Bearer \$TOKEN" \$INGRESS_HOST:\$INGRESS_PORT/headers -s -o /dev/null -w "%{http_code}\n"
9. You should get a response code of 200
10. Update the token to something invalid
11. The response will be 401

Istio Service JWT Test

[istio-test.yaml](#) (uses the default namespace)

```
export TOKEN="eyJhbGciOiJSUzI1NiIsInR5cCI6IkpXVCJ9.  
eyJhdWQiOiJBVURJRlU5DRSislmV4cCI6MTYzODQ4ODYzOSwiaWF0IjoxNjM3NjU2NjM5LCJpc3MiOiJJU1NVRVliLCJqdGkiOiJXMTI1dEJISTIQWnJLZ  
GZuTG54V0ZBlwibmJmIjoxNjM3NjU2NjM5LCJwZXJtaXNzaW9uIjoicmVhZCIsInJvbGUoiOiJ1c2Vylwiw3ViljoiU1VCSkvDVCJ9.C8zVi4XpqaK-  
VVhDviCGO5SChNsUWe_WmP2Z-JXkM3VzMVQnc2w7ResUI-  
g8DxXQLXojc7BZiDA74VCRrdzSxtDrBbikd9riCN1D9UVXWacdlv0gU9b23mOp2jUP7G8FgdKJtjcyx3pPmliHH1OnDhrsQUeTMezRurBa96sRf_9XF5B_  
SBXiTy65UhzL-  
kKmbaTCXWO6F5d4mJ8gPJQ4BGQdl1CMfytg0RB1Tuyj72dDTetfWMStqRw0nEh76oAC5bDZAUhwpAUMBXTG0Iba9MSAhlmha6grthU1_VY39LbmbZ7  
W7OfRV1mAI9PrDI0nwVWvobvJ-ilg93luqvGrIA"
```

kubectl label namespace default istio-injection=enabled --overwrite

export INGRESS_HOST=\$(minikube ip)

export INGRESS_PORT=\$(kubectl -n istio-system get service istio-ingressgateway -o jsonpath='{.spec.ports[?(@.name=="http2")].nodePort}')

curl --header "Authorization: Bearer \$TOKEN" \$INGRESS_HOST:\$INGRESS_PORT/data-producer

curl --header "Authorization: Bearer \$TOKEN" \$INGRESS_HOST:\$INGRESS_PORT/a1-policy

curl --header "Authorization: Bearer \$TOKEN" \$INGRESS_HOST:\$INGRESS_PORT/data-consumer

You can use different tokens for different deployments.

Currently we use the same token for both jwt-ecs and jwt-pms. They match on the deployment labels nontritic-ecs and nontritic-pms.

You can also change the token issuer to one for your particular service(s).

You can also change the expiry time.

Please refer to the python script in the link above.

You can move these objects to their own namespace if you prefer:

e.g.

```
kubectl create ns istio-nonrtic
namespace/istio-nonrtic created
```

```
kubectl label namespace istio-nonrtic istio-injection=enabled --overwrite
namespace/istio-nonrtic labeled
```

replace the default name space in the yaml above with the new ns name.

You can also update the AuthorizationPolicy to check the JWT issuer/subject

e.g.

```
rules:
- from:
- source:
requestPrincipals: ["ECSISSUER/SUBJECT"]
```

See the latest version here: [istio-test-latest.yaml](#)

Istio with Keycloak

If you are using minikube on Ubuntu WSL you need to run "minikube service keycloak" to see keycloak ui.

Run the following command to get the keycloak URLs:

```
KEYCLOAK_URL=http://$(minikube ip):$(kubectl get services/keycloak -o go-template='{{(index .spec.ports 0).nodePort}}')/auth &&
o "" &
```

```
echo "" &&
echo "Keycloak: $KEYCLOAK_URL" &&
```

```
echo "Keycloak Admin Console: $KEYCLOAK_URL/admin" &&
```

```
echo "Keycloak Account Console: $KEYCLOAK_URL/realms/myrealm/account" &&
echo ""
```

Retrieve public key using : `http(s)://<hostname>/auth/realms/<realm name>`

Enable keycloak with Istio

Setup a new realm, user and client as shown here : <https://www.keycloak.org/getting-started/getting-started-kube>

Note the id of the new user, this will be used as the sub field in the token e.g. 81b2051b-52d9-4e4e-88a6-00ca04b7b73d"

The iss field is url of the realm e.g. <http://192.168.49.2:30869/auth/realms/myrealm>

Edit the jwt-pms RequestAuthentication definition above, replace the issuer with the keycloak iss and remove the jwks field and replace it with the jwksUri pointing to your keycloak certs

RequestAuthentication

```
apiVersion: security.istio.io/v1beta1
kind: RequestAuthentication
metadata:
  name: "jwt-pms"
  namespace: istio-nonrtric
spec:
  selector:
    matchLabels:
      apptype: nonrtric-pms
  jwtRules:
  - issuer: "http://192.168.49.2:30869/auth/realms/myrealm"
    jwksUri: "http://192.168.49.2:30869/auth/realms/myrealm/protocol/openid-connect/certs"
```

Modify the AuthorizationPolicy named pms-policy, change the issuer and subject to the keycloak iss/sub

AuthorizationPolicy

```
apiVersion: "security.istio.io/v1beta1"
kind: "AuthorizationPolicy"
metadata:
  name: "pms-policy"
  namespace: istio-nonrtric
spec:
  selector:
    matchLabels:
      apptype: nonrtric-pms
  action: ALLOW
  rules:
  - from:
    - source:
        requestPrincipals: ["http://192.168.49.2:30869/auth/realms/myrealm/81b2051b-52d9-4e4e-88a6-00ca04b7b73d"]
```

Reapply the yaml file

to generate a token use the following command:

```
curl -X POST "$KEYCLOAK_URL" \
-H "Content-Type: application/x-www-form-urlencoded" \
-d "username=$USERNAME" \
-d "password=$PASSWORD" \
-d 'grant_type=password' \
-d "client_id=$CLIENT_ID" | jq -r '.access_token'
```

e.g.

```
curl -X POST http://192.168.49.2:30869/auth/realms/myrealm/protocol/openid-connect/token \
-H "Content-Type: application/x-www-form-urlencoded" \
-d "username=user" \
-d "password=secret" \
-d 'grant_type=password' \
-d "client_id=myclient" | jq -r '.access_token'
```

Note: you may need to install the jq utility on your system for this to work - `sudo apt-get install jq`

Test the a1-policy service with your new token

```
TOKEN=$(curl -X POST http://192.168.49.2:30869/auth/realms/myrealm/protocol/openid-connect/token -H "Content-Type: application/x-www-form-urlencoded" -d username=user -d password=secret -d 'grant_type=password' -d client_id=myclient | jq -r '.access_token')
```

```
curl --header "Authorization: Bearer $TOKEN" $INGRESS_HOST:$INGRESS_PORT/a1-policy
Hello a1-policy
```

Note: The iss of the token will differ depending on how you retrieve it. If it's retrieved from within the cluster for URL will start with <http://keycloak.default:8080/> otherwise it will be something like : <http://192.168.49.2:31560/> ([http://\(minikube ip\):](http://(minikube ip):) (keycloak service nodePort))

Keycloak database

Keycloak uses the H2 database by default.

To configure keycloak to use a different database follow these steps.

1. Install either postgres or mariadb using these yaml files: [postgres.yaml](#) or [mariadb.yaml](#). These will setup the keycloak db along with the username and password. You just need to change the directory for your persistent storage to an appropriate directory on your host.
2. Update the keycloak installation script <https://raw.githubusercontent.com/keycloak/keycloak-quickstarts/latest/kubernetes-examples/keycloak.yaml>

Keycloak Environment

```
env:
- name: KEYCLOAK_USER
  value: "admin"
- name: KEYCLOAK_PASSWORD
  value: "admin"
- name: PROXY_ADDRESS_FORWARDING
  value: "true"
- name: DB_VENDOR
  value: "postgres"
- name: DB_ADDR
  value: "postgres"
- name: DB_PORT
  value: "5432"
- name: DB_DATABASE
  value: "keycloak"
- name: DB_USER
  value: "keycloak"
- name : DB_PASSWORD
  value: "keycloak"
```

You can also add the following code block to make sure keycloak only start once the database is up and running

Wait For Database

```
initContainers:
- name: init-postgres
  image: busybox
  command: ['sh', '-c', 'until nc -vz postgres 5432; do echo waiting for postgres db; sleep 2; done;']
```

Note: you may also want to update the keycloak service to specify a value for nodePort.

Keycloak Service

```
apiVersion: v1
kind: Service
metadata:
  name: keycloak
  labels:
    app: keycloak
spec:
  ports:
    - name: http
      port: 8080
      targetPort: 8080
      nodePort: 31560
  selector:
    app: keycloak
  type: LoadBalancer
```

You can also add a wait for keycloak to your deployment containers

Wait for Keycloak

```
spec:
  initContainers:
    - name: init-keycloak
      image: busybox
      command: ['sh', '-c', 'until nc -vz keycloak.default 8080; do echo waiting for keycloak; sleep 2;
done;']
  containers:
    - name: a1-policy
      image: hashicorp/http-echo
      ports:
        - containerPort: 5678
      args:
        - -text
        - "Hello a1-policy"
```

See also: [keycloak.yaml](#)

Keycloak Operator

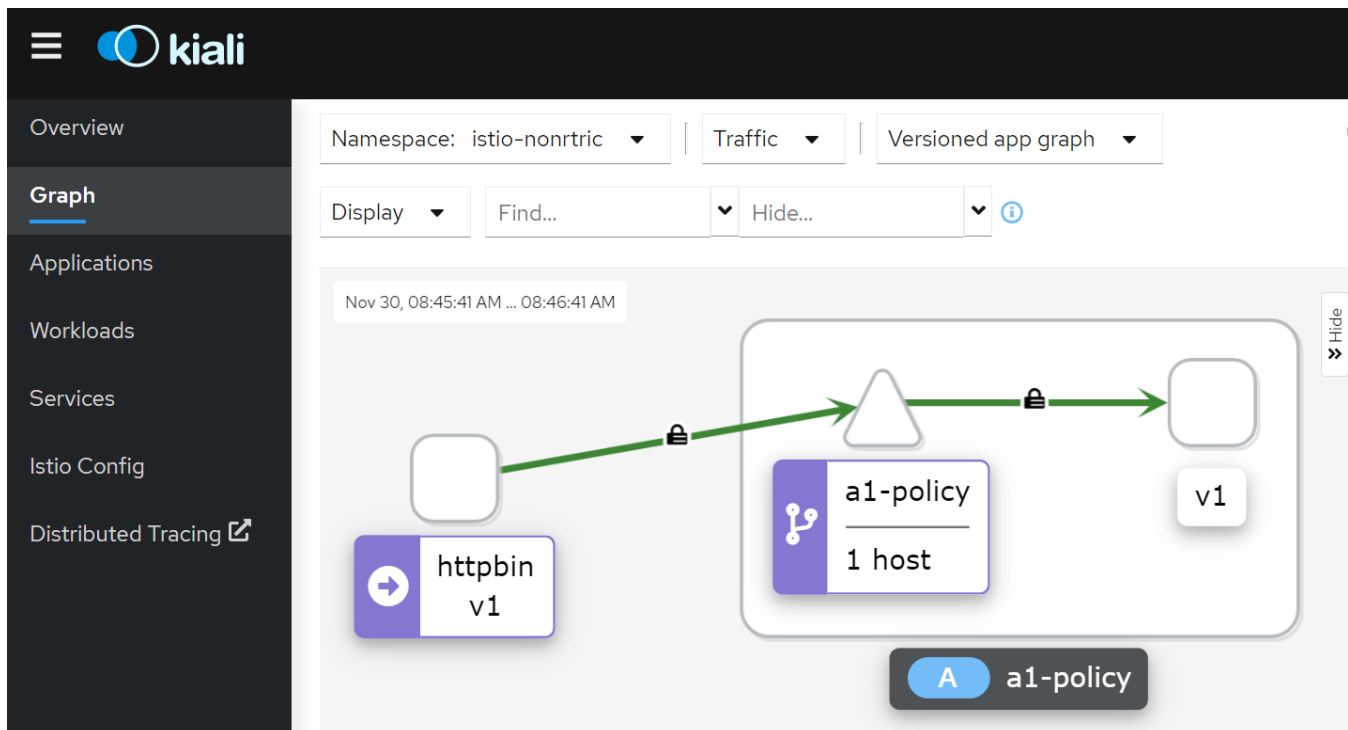
[Keycloak Operator Installation](#)

[Keycloak Operator](#)

Istio mTLS

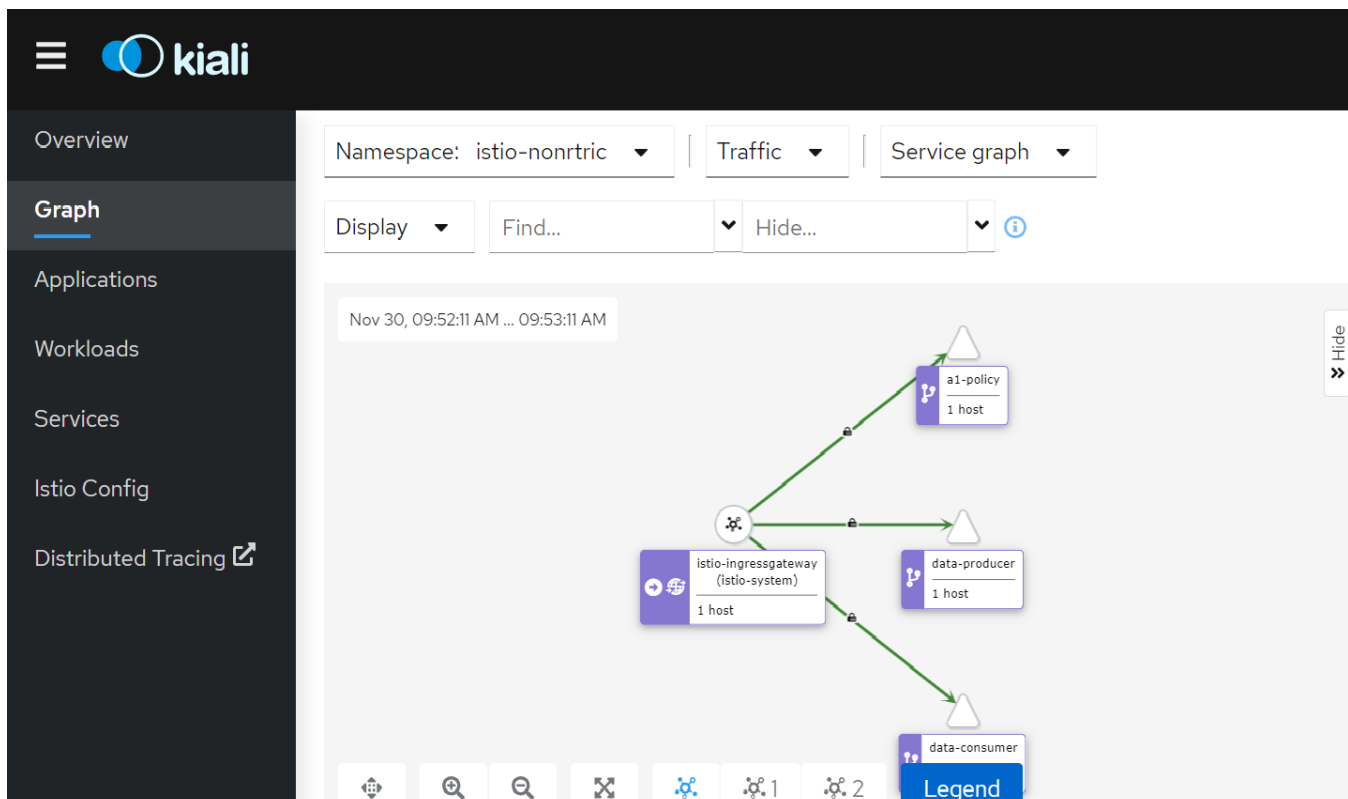
Test: [Istio / Mutual TLS Migration](#)

To see mTLS in kiali go to the display menu and check the security check box.



Running `curl --header "Authorization: Bearer $TOKEN" ai-policy` from the httpbin pod.

The padlock icon indicates mTLS is being used for communication between the pods.



Policy to enforce mTLS between PODs in the istio-nonrtic namespace in STRICT mode:

PeerAuthentication

```
apiVersion: security.istio.io/v1beta1
kind: PeerAuthentication
metadata:
  name: "default"
  namespace: istio-nonrtic
spec:
  mtls:
    mode: STRICT
```

Change the mode to PERMISSIVE to allow communication from pods without istio sidecar.

Change namespace to istio-system to apply mTLS for the entire cluster.

Istio cert manager

<https://istio.io/latest/docs/ops/integrations/certmanager/>

Go Http Request Handler for Testing

nonrtic-server-go

nonrtic-server-go

```

package main

import (
    "fmt"
    "log"
    "github.com/gorilla/mux"
    "net/http"
    "encoding/json"
    "io/ioutil"
    "strings"
)

func requestHandler(w http.ResponseWriter, r *http.Request) {
    w.Header().Set("Content-Type", "application/json")
    params := mux.Vars(r)
    var id = params["id"]
    var data = params["data"]
    var prefix = strings.Split(r.URL.Path, "/")[1]

    switch r.Method {
        case "GET":
            if id == "" {
                fmt.Println("Received get request for "+ prefix +", params: nil\n")
                fmt.Fprintf(w, "Response to get request for "+ prefix +", params: nil\n")
            } else {
                fmt.Println("Received get request for "+ prefix +", params: id=" + id + "\n")
                fmt.Fprintf(w, "Response to get request for "+ prefix +", params: id=" + id +
"\n")
            }
        case "POST":
            body, err := ioutil.ReadAll(r.Body)
            if err != nil {
                panic(err.Error())
            }
            keyVal := make(map[string]string)
            json.Unmarshal(body, &keyVal)
            id := keyVal["id"]
            data := keyVal["data"]
            fmt.Println("Received post request for "+ prefix +", params: id=" + id + ", data=" +
data + "\n")
            fmt.Fprintf(w, "Response to post request for "+ prefix +", params: id=" + id + ", data=" +
+ data + "\n")
        case "PUT":
            fmt.Println("Received put request for "+ prefix +", params: id=" + id + ", data=" + data
+ "\n")
            fmt.Fprintf(w, "Response to put request for "+ prefix +", params: id=" + id + ", data=" +
+ data + "\n")
        case "DELETE":
            fmt.Println("Received delete request for "+ prefix +", params: id=" + id + "\n")
            fmt.Fprintf(w, "Response to delete request for "+ prefix +", params: id=" + id + "\n")
        default:
            fmt.Println("Received request for unsupported method, only GET, POST, PUT and DELETE
methods are supported.")
            fmt.Fprintf(w, "Error, only GET, POST, PUT and DELETE methods are supported.")
    }
}

func main() {
    router := mux.NewRouter()

    var prefixArray [3]string = [3]string{"/a1-policy", "/data-consumer", "/data-producer"}

    for _, prefix := range prefixArray {
        router.HandleFunc(prefix, requestHandler)
        router.HandleFunc(prefix+"/{id}", requestHandler)
        router.HandleFunc(prefix+"/{id}/{data}", requestHandler)
    }

    log.Fatal(http.ListenAndServe(":8080", router))
}

```

Dockerfile

```
FROM golang:1.15.2-alpine3.12 as build
RUN apk add git
RUN mkdir /build
ADD . /build
WORKDIR /build
RUN go get github.com/gorilla/mux
RUN go build -o nonrtric-server-go .

FROM alpine:latest
RUN mkdir /app
WORKDIR /app/

# Copy the Pre-built binary file from the previous stage
COPY --from=build /build .

# Expose port 8080
EXPOSE 8080

# Run Executable
CMD ["/app/nonrtric-server-go"]
```

Testing

Update AuthorizationPolicy to only allow certain operations:

AuthorizationPolicy

```
apiVersion: "security.istio.io/v1beta1"
kind: "AuthorizationPolicy"
metadata:
  name: "pms-policy"
  namespace: istio-nonrtric
spec:
  selector:
    matchLabels:
      apptype: nonrtric-pms
  action: ALLOW
  rules:
    - from:
        - source:
            requestPrincipals: ["http://192.168.49.2:31560/auth/realms/pmsrealm/fab53fd0-3315-4e2f-bd17-6984fb7745f2"]
          to:
            - operation:
                methods: ["GET", "POST", "PUT"]
                paths: ["/a1-policy*"]
```

AuthorizationPolicy

```
apiVersion: "security.istio.io/v1beta1"
kind: "AuthorizationPolicy"
metadata:
  name: "ics-policy"
  namespace: istio-nonrtric
spec:
  selector:
    matchLabels:
      apptype: nonrtric-ics
  action: ALLOW
  rules:
    - from:
        - source:
            requestPrincipals: ["http://192.168.49.2:31560/auth/realms/icsrealm/ad83e4ea-c114-4549-be29-b3aaf92148a5"]
          to:
            - operation:
                methods: ["GET", "PUT", "DELETE"]
                paths: ["/data-*"]
```

Shell script to test AuthorizationPolicy

service_exposure_tests.sh

```
#!/bin/bash
INGRESS_HOST=$(minikube ip)
INGRESS_PORT=$(kubectl -n istio-system get service istio-ingressgateway -o jsonpath='{.spec.ports[?(@.name=="http2")].nodePort}')
TESTS=0
PASSED=0
FAILED=0
TEST_TS=$(date +%F-%T)
TOKEN=""

function get_token
{
    local prefix="${1}"
    url="http://192.168.49.2:31560/auth/realms"
    if [ "$prefix" =~ ^a1-policy* ]; then
        TOKEN=$(curl -s -X POST ${url}/pmsrealm/protocol/openid-connect/token -H \
            "Content-Type: application/x-www-form-urlencoded" -d username=pmsuser -d password=secret \
            -d 'grant_type=password' -d client_id=pmsclient | jq -r '.access_token')
    else
        TOKEN=$(curl -s -X POST $url/icsrealm/protocol/openid-connect/token -H \
            "Content-Type: application/x-www-form-urlencoded" -d username=icsuser -d password=secret \
            -d 'grant_type=password' -d client_id=icsclient | jq -r '.access_token')
    fi
}

function run_test
{
    local prefix="${1}" type=${2} msg="${3}" data=${4}
    TESTS=$((TESTS+1))
    echo "Test ${TESTS}: Testing $type /${prefix}"
    get_token $prefix
    url=$INGRESS_HOST:$INGRESS_PORT/"$prefix
    if [ "$data" != "" ]; then
        result=$(curl -s -X ${type} -H "Content-type: application/json" -H "Authorization: Bearer $TOKEN" -d
${data} $url)
    else
        result=$(curl -s -X ${type} -H "Content-type: application/json" -H "Authorization: Bearer $TOKEN" $url)
    fi
    echo $result
    if [ "$result" != "$msg" ]; then
        echo "FAIL"
        FAILED=$((FAILED+1))
    else
        echo "PASS"
        PASSED=$((PASSED+1))
    fi
    echo ""
}

run_test "a1-policy" "GET" "Received get request for a1-policy, params: nil" ""
run_test "a1-policy/1001" "GET" "Received get request for a1-policy, params: id=1001" ""
run_test "a1-policy/1002/xyz" "PUT" "Received put request for a1-policy, params: id=1002, data=xyz" ""
run_test "a1-policy/1001" "DELETE" "RBAC: access denied" ""
run_test "a1-policy" "POST" "Received post request for a1-policy, params: id=1003, data=abc" '{"id":"1003","data":"abc"}'
run_test "data-consumer" "GET" "Received get request for data-consumer, params: nil" ""
run_test "data-consumer/3001" "DELETE" "Received delete request for data-consumer, params: id=3001" ""
run_test "data-producer/2001/xyz" "PUT" "Received put request for data-producer, params: id=2001, data=xyz" ""
run_test "data-consumer" "POST" "RBAC: access denied" '{"id":"1004","data":"abc"}'
run_test "data-producer" "POST" "RBAC: access denied" '{"id":"1005","data":"abc"}'

echo
echo "-----"
echo "Number of Tests: $TESTS, Tests Passed: $PASSED, Tests Failed: $FAILED"
echo "Date: $TEST_TS"
echo "-----"
```

Results:

./service_exposure_tests.sh

Test 1: Testing /a1-policy GET

Received get request for a1-policy, params: nil

PASS

Test 2: Testing /a1-policy/1001 GET

Received get request for a1-policy, params: id=1001

PASS

Test 3: Testing /a1-policy/1002/xyz PUT

Received put request for a1-policy, params: id=1002, data=xyz

PASS

Test 4: Testing /a1-policy/1001 DELETE

RBAC: access denied

PASS

Test 5: Testing /a1-policy POST

Received post request for a1-policy, params: id=1003, data=abc

PASS

Test 6: Testing /data-consumer GET

Received get request for data-consumer, params: nil

PASS

Test 7: Testing /data-consumer/3001 DELETE

Received delete request for data-consumer, params: id=3001

PASS

Test 8: Testing /data-producer/2001/xyz PUT

Received put request for data-producer, params: id=2001, data=xyz

PASS

Test 9: Testing /data-consumer POST

RBAC: access denied

PASS

Test 10: Testing /data-producer POST

RBAC: access denied

PASS

Number of Tests: 10, Tests Passed: 10, Tests Failed: 0

Date: 2021-12-06-14:48:33

Go Http Client for running inside cluster

nonrtric-client-go

nonrtric-client-go

```
package main
```

```
import (
```

```
    "fmt"
```

```
    "net/http"
```

```
    "net/url"
```

```
    "encoding/json"
```

```
    "time"
```

```
    "io/ioutil"
```

```
    "math/rand"
```

```
    "strings"
```

```
    "bytes"
```

```
    "strconv"
```

```
    "flag"
```

```
)
```

```

type Jwttoken struct {
    Access_token string
    Expires_in int
    Refresh_expires_in int
    Refresh_token string
    Token_type string
    Not_before_policy int
    Session_state string
    Scope string
}

var gatewayHost string
var gatewayPort string
var keycloakHost string
var keycloakPort string
var useGateway string
var letters = []rune("abcdefghijklmnopqrstuvwxyzABCDEFGHIJKLMNOPQRSTUVWXYZ")

func randSeq(n int) string {
    b := make([]rune, n)
    for i := range b {
        b[i] = letters[rand.Intn(len(letters))]
    }
    return string(b)
}

func getToken(user string, password string, clientId string, realmName string) string {
    keycloakUrl := "http://" + keycloakHost + ":" + keycloakPort + "/auth/realms/" + realmName + "/protocol/openid-connect/token"
    resp, err := http.PostForm(keycloakUrl,
        url.Values{"username": {user}, "password": {password}, "grant_type": {"password"}, "client_id": {clientId}})
    if err != nil {
        fmt.Println(err)
        panic("Something wrong with the credentials or url ")
    }
    defer resp.Body.Close()
    body, err := ioutil.ReadAll(resp.Body)
    var jwt Jwttoken
    json.Unmarshal([]byte(body), &jwt)
    return jwt.Access_token;
}

func MakeRequest(client *http.Client, prefix string, method string, ch chan<-string) {
    var id = rand.Intn(1000)
    var data = randSeq(10)
    var service = strings.Split(prefix, "/")[1]
    var gatewayUrl = "http://" + gatewayHost + ":" + gatewayPort
    var token = ""
    var jsonValue []byte = []byte{}
    var restUrl string = ""
    if strings.ToUpper(useGateway) != "Y" {
        gatewayUrl = "http://" + service + ".istio-nonrtrc:80"
        //fmt.Println(gatewayUrl)
    }

    if service == "a1-policy" {
        token = getToken("pmsuser", "secret", "pmsclient", "pmsrealm")
    } else {
        token = getToken("icsuser", "secret", "icsclient", "icsrealm")
    }

    if method == "POST" {
        values := map[string]string{"id": strconv.Itoa(id), "data": data}
        jsonValue, _ = json.Marshal(values)
        restUrl = gatewayUrl + prefix
    } else if method == "PUT" {

```



```

        restUrl = gatewayUrl+prefix+"/"+strconv.Itoa(id)+"/"+data
    } else {
        restUrl = gatewayUrl+prefix+"/"+strconv.Itoa(id)
    }

    req, err := http.NewRequest(method, restUrl, bytes.NewBuffer(jsonValue))
    if err != nil {
        fmt.Printf("Got error %s", err.Error())
    }
    req.Header.Set("Content-type", "application/json")
    req.Header.Set("Authorization", "Bearer "+token)

    resp, err := client.Do(req)
    if err != nil {
        fmt.Printf("Got error %s", err.Error())
    }
    defer resp.Body.Close()
    body, _ := ioutil.ReadAll(resp.Body)
    respString := string(body[:])
    if respString == "RBAC: access denied"{
        respString += " for "+service+" "+strings.ToLower(method)+" request\n"
    }
    ch <- fmt.Sprintf("%s", respString)
}

func main() {
    flag.StringVar(&gatewayHost, "gatewayHost", "192.168.49.2", "Gateway Host")
    flag.StringVar(&gatewayPort, "gatewayPort", "32162", "Gateway Port")
    flag.StringVar(&keycloakHost, "keycloakHost", "192.168.49.2", "Keycloak Host")
    flag.StringVar(&keycloakPort, "keycloakPort", "31560", "Keycloak Port")
    flag.StringVar(&useGateway, "useGateway", "Y", "Connect to services through API gateway")
    flag.Parse()

    client := &http.Client{
        Timeout: time.Second * 10,
    }

    ch := make(chan string)
    var prefixArray [3]string = [3]string{"/a1-policy", "/data-consumer", "/data-producer"}
    var methodArray [4]string = [4]string{"GET", "POST", "PUT", "DELETE"}
    for true {
        for _, prefix := range prefixArray{
            for _, method := range methodArray{
                go MakeRequest(client, prefix, method, ch)
            }
        }

        for i := 0; i < len(prefixArray); i++ {
            for j := 0; j < len(methodArray); j++ {
                fmt.Println(<-ch)
            }
        }
        time.Sleep(30 * time.Second)
    }
}

```

Dockerfile

```
FROM golang:1.15.2-alpine3.12 as build
RUN apk add git
RUN mkdir /build
ADD . /build
WORKDIR /build
RUN go build -o nonrtric-client-go .

FROM alpine:latest
RUN mkdir /app
WORKDIR /app/

# Copy the Pre-built binary file from the previous stage
COPY --from=build /build .

# Expose port 8080
EXPOSE 8080

# Run Executable
ENTRYPOINT [ "/app/nonrtric-client-go", \
    "-gatewayHost", "istio-ingressgateway.istio-system", \
    "-gatewayPort", "80", \
    "-keycloakHost", "keycloak.default", \
    "-keycloakPort", "8080", \
    "-useGateway", "N" ]
```

Update AuthorizationPolicy

AuthorizationPolicy

```
apiVersion: "security.istio.io/v1beta1"
kind: "AuthorizationPolicy"
metadata:
  name: "ics-policy"
  namespace: istio-nonrtric
spec:
  selector:
    matchLabels:
      apptype: nonrtric-ics
  action: ALLOW
  rules:
  - from:
    - source:
      namespaces: ["default"]
    to:
    - operation:
      methods: ["GET", "POST", "PUT", "DELETE"]
      paths: ["/data-*"]
      hosts: ["data-consumer*", "data-producer*"]
      ports: ["8080"]
  ---
apiVersion: "security.istio.io/v1beta1"
kind: "AuthorizationPolicy"
metadata:
  name: "pms-policy"
  namespace: istio-nonrtric
spec:
  selector:
    matchLabels:
      apptype: nonrtric-pms
  action: ALLOW
  rules:
  - from:
    - source:
      principals: ["cluster.local/ns/default/sa/goclient"]
    to:
    - operation:
      methods: ["GET", "POST", "PUT", "DELETE"]
      paths: ["/a1-policy*"]
      hosts: ["a1-policy*"]
      ports: ["8080"]
  when:
  - key: request.auth.claims[preferred_username]
    values: ["pmsuser"]
```



Request are sent from the nonrtic-client-go pod to the services directly from within the cluster.

In the above example I'm using principals and namespaces for authorization.

Both of these require MTLS to be enabled.

If istio is not enabled for the client you can inject the individual pod with the istio proxy : `istioctl kube-inject -f client.yaml | kubectl apply -f -`

I have also included a "when" condition which checks one of the JWT fields, in this case "preferred_username": "icsuser".

The hosts and ports fields refer to the destination host(s) and port(s).

To use JWT inside the cluster you need to update the RequestAuthentication policy to include the internal address for the jwksUri

jwtRules

```
jwtRules:
- issuer: "http://192.168.49.2:31560/auth/realms/pmsrealm"
  jwksUri: "http://192.168.49.2:31560/auth/realms/pmsrealm/protocol/openid-connect/certs"
- issuer: "http://keycloak.default:8080/auth/realms/pmsrealm"
  jwksUri: "http://keycloak.default:8080/auth/realms/pmsrealm/protocol/openid-connect/certs"
```

You also need to update the AuthorizationPolicy to include the internal source

Rules

```
rules:
- from:
  - source:
      requestPrincipals: ["http://192.168.49.2:31560/auth/realms/pmsrealm/fab53fd0-3315-4e2f-bd17-6984fb7745f2"]
  - source:
      requestPrincipals: ["http://keycloak.default:8080/auth/realms/pmsrealm/fab53fd0-3315-4e2f-bd17-6984fb7745f2"]
  to:
  - operation:
      methods: ["GET", "POST", "PUT", "DELETE"]
      paths: ["/a1-policy*"]
```

You can change the contents (fields) of your JWT token by using client mappers.

Create a new roles pms_admin

The assign the role to your user: role mapping(tab) available roles add selected

Then in you client select mappers create Mapper Type: User Realm Role, Token claim name : role

The following field will be added to your JWT:

```
"role": [
  "pms_admin"
],
```

you can then use this in you when clause to allow/block access to cetain endpoints:

```
- key: request.auth.claims[role]
values: ["pms_admin"]
```

Create another role pms_viewer and assign it to a second user pmsuser2

We can then configure the AuthorizationPolicy to grant differnt access to different roles

AuthorizationPolicy

```
apiVersion: "security.istio.io/v1beta1"
kind: "AuthorizationPolicy"
metadata:
  name: "pms-policy"
  namespace: istio-nonrtric
spec:
  selector:
    matchLabels:
      apptype: nonrtric-pms
  action: ALLOW
  rules:
    - from:
      - source:
          requestPrincipals: ["http://192.168.49.2:31560/auth/realms/pmsrealm/fab53fd0-3315-4e2f-bd17-6984fb7745f2"]
      - source:
          requestPrincipals: ["http://keycloak.default:8080/auth/realms/pmsrealm/fab53fd0-3315-4e2f-bd17-6984fb7745f2"]
        to:
          - operation:
              methods: ["GET", "POST", "PUT", "DELETE"]
              paths: ["/a1-policy*"]
            when:
              - key: request.auth.claims[role]
                values: ["pms_admin"]
    - from:
      - source:
          requestPrincipals: ["http://192.168.49.2:31560/auth/realms/pmsrealm/f96255ec-d553-4c2e-b106-0ed586ccab70"]
      - source:
          requestPrincipals: ["http://keycloak.default:8080/auth/realms/pmsrealm/f96255ec-d553-4c2e-b106-0ed586ccab70"]
        to:
          - operation:
              methods: ["GET"]
              paths: ["/a1-policy*"]
            when:
              - key: request.auth.claims[role]
                values: ["pms_viewer"]
```

pms_admin role:

Test 1: Testing GET /a1-policy

Received get request for a1-policy, params: nil

Test 2: Testing GET /a1-policy/1001

Received get request for a1-policy, params: id=1001

Test 3: Testing PUT /a1-policy/1002/xyz

Received put request for a1-policy, params: id=1002, data=xyz

Test 4: Testing DELETE /a1-policy/1001

Received delete request for a1-policy, params: id=1001

Test 5: Testing POST /a1-policy

Received post request for a1-policy, params: id=1003, data=abc

pms_viewer role:

Test 1: Testing GET /a1-policy

Received get request for a1-policy, params: nil

Test 2: Testing GET /a1-policy/1001

Received get request for a1-policy, params: id=1001

Test 3: Testing PUT /a1-policy/1002/xyz

RBAC: access denied

Test 4: Testing DELETE /a1-policy/1001
RBAC: access denied

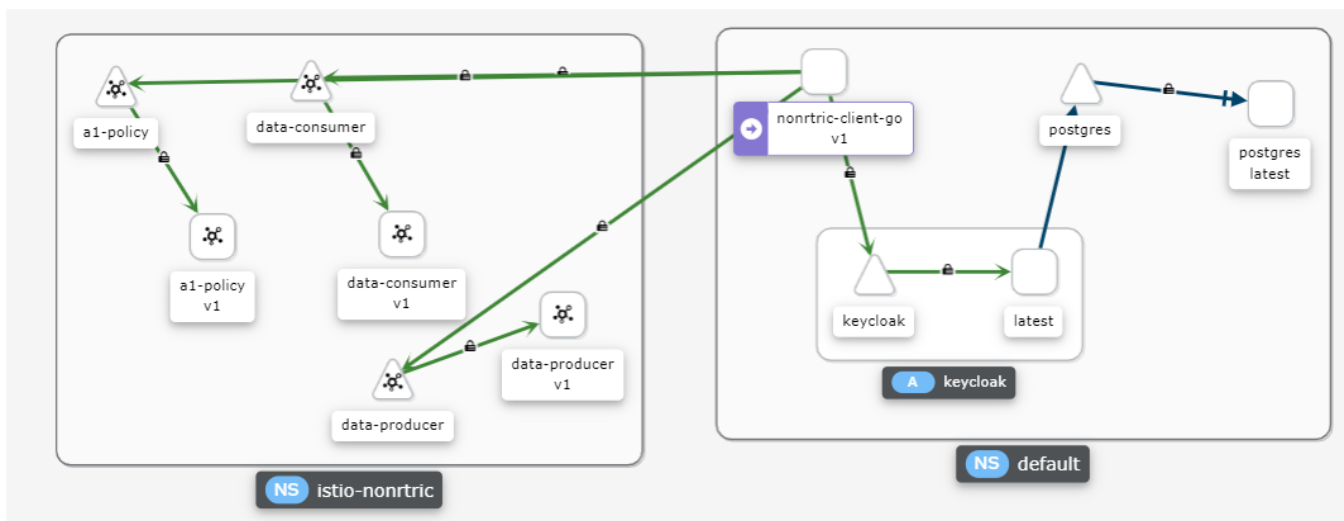
Test 5: Testing POST /a1-policy
RBAC: access denied

You can also leave out the from clause and just use to and when in the rules:

Rules

```
rules:
- to:
  - operation:
      methods: ["GET", "POST", "PUT", "DELETE"]
      paths: ["/a1-policy*"]
  when:
  - key: request.auth.claims[role]
    values: ["pms_admin"]
- to:
  - operation:
      methods: ["GET"]
      paths: ["/a1-policy*"]
  when:
  - key: request.auth.claims[role]
    values: ["pms_viewer"]
```

Further details on authorization policies are available [here](#)



Istio network policy is enforced at the pod level (in the Envoy proxy), in user-space, (layer 7), as opposed to Kubernetes network policy, which is in kernel-space (layer 4), and is enforced on the host. By operating at application layer, Istio has a richer set of attributes to express and enforce policy in the protocols it understands (e.g. HTTP headers).

[Istio Network Policy](#)

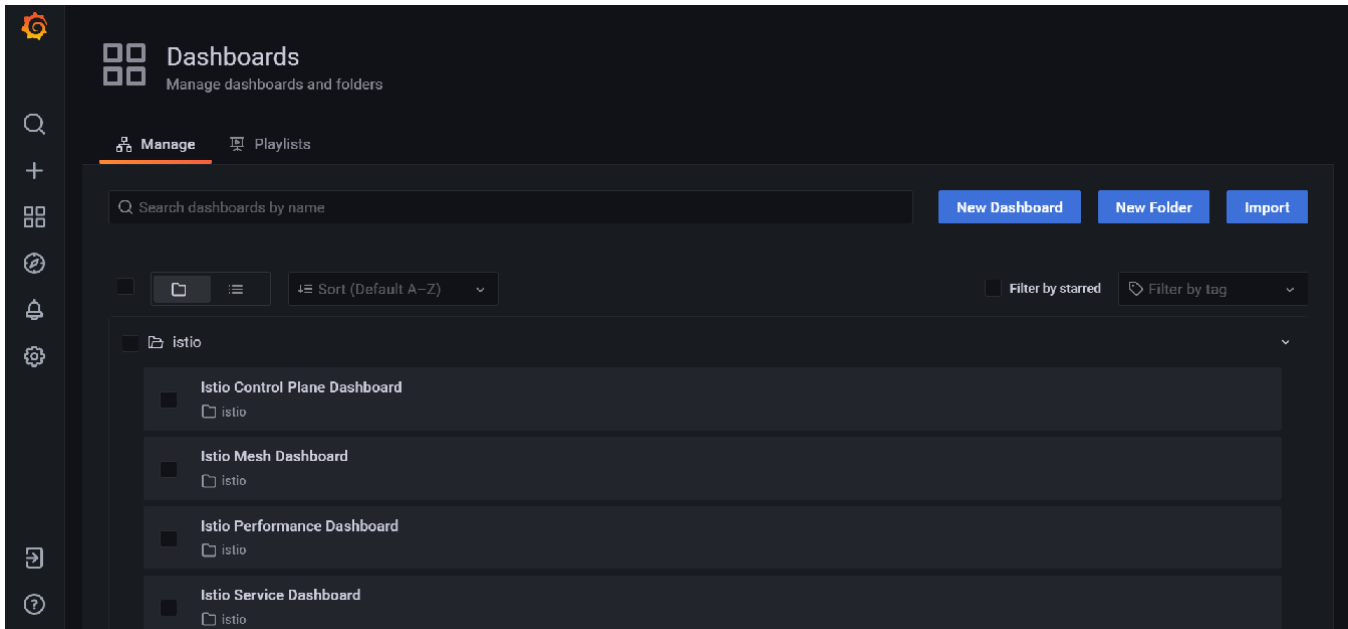
Grafana

Istio also comes with grafana, to start it run : `istioctl dashboard grafana`

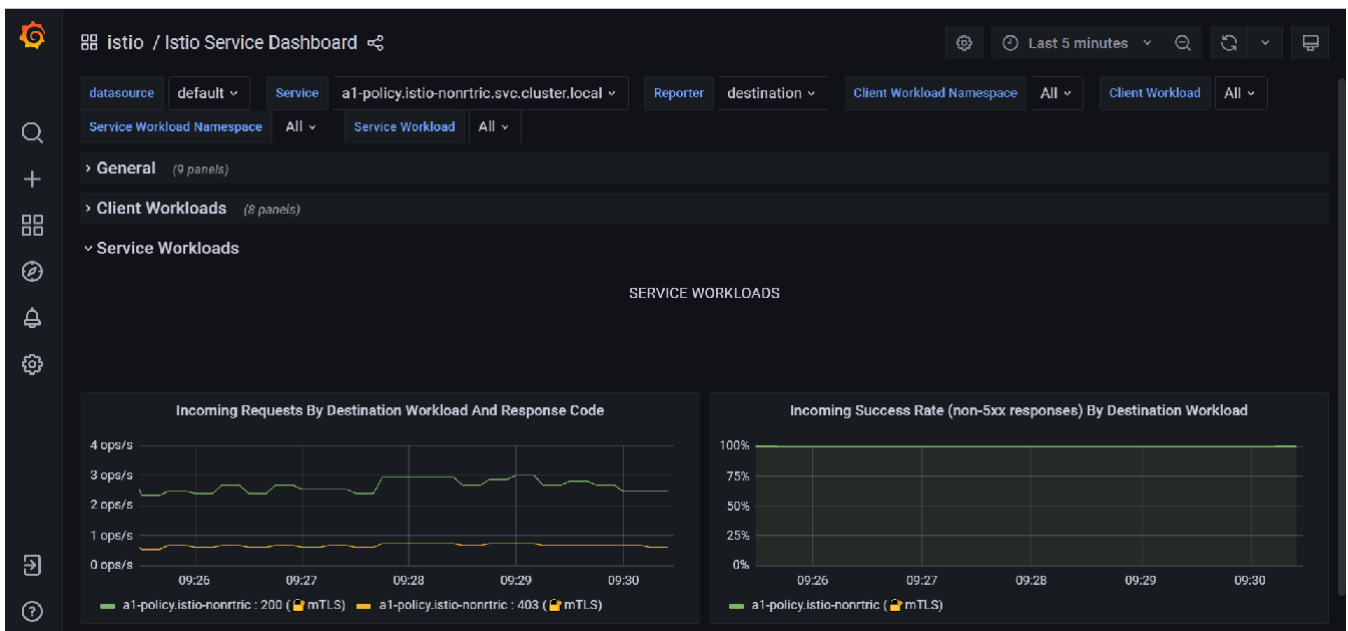
This will bring up the grafana home page

From the side menu select dashboards Manage

The istio dashboards are installed by default



Select the Istio Service dashboard service workloads to see the incoming requests



You can elasticsearch as a datasource to grafana.

Add the URL for your elasticsearch instance.

Set basic auth to on.

Add your elasticsearch username and password.

Add your index name (e.g. logstash-*)

Set the version to 7.10+

Set Max concurrent shard requests to 1

Save and test.

You data source is now setup.

To view the data being collected, download the grafana elasticseach dashboard and import it.

This does not really work for a single shard instance like the one we are using.

See also: [Grafana playground](#)

Prometheus

Start the prometheus dashboard by running: `istioctl dashboard prometheus`

See the following link on [Querying Metrics from Prometheus](#) for more information.

You can setup your own dashboard in grafana to view these metrics if the default dashboards don't meet your needs.

You can also insert your own customer metrics into your code: [INSTRUMENTING A GO APPLICATION FOR PROMETHEUS](#)

Code Snippet

```
import (
    "github.com/prometheus/client_golang/prometheus"
    "github.com/prometheus/client_golang/prometheus/promhttp"
)
var (
    reqDuration = prometheus.NewHistogramVec(prometheus.HistogramOpts{
        Name:    "rapp_http_request_duration_seconds",
        Help:    "Duration of the last request call.",
        Buckets: []float64{0.05, 0.1, 0.25, 0.5, 1, 2.5, 5, 10},
    }, []string{"app", "func", "handler", "method", "code"})
    reqBytes = prometheus.NewSummaryVec(prometheus.SummaryOpts{
        Name:    "rapp_bytes_summary",
        Help:    "Summary of bytes transferred over http",
    }, []string{"app", "func", "handler", "method", "code"})
)

func getToken() string {
    resp := &http.Response{}
    ...
    timer := prometheus.NewTimer(prometheus.ObserverFunc(func(v float64) {
        reqDuration.WithLabelValues("rapp-jwt-invoker", "getToken", resp.Request.URL.Path, resp.
Request.Method,
                                resp.Status).Observe(v)
    }))
    defer timer.ObserveDuration()
    resp, err = http.PostForm(keycloakUrl, url.Values{"client_assertion_type":
{client_assertion_type},
                                                    "client_assertion": {client_assertion},
"grant_type": {"client_credentials"},
                                                    "client_id": {clientId}, "scope": {scope}}})

    if err != nil {
        fmt.Println(err)
        panic("Something wrong with the credentials or url ")
    }

    defer resp.Body.Close()
    body, err := ioutil.ReadAll(resp.Body)
    json.Unmarshal([]byte(body), &jwt)
    reqBytes.WithLabelValues("rapp-jwt-invoker", "getToken", resp.Request.URL.Path, resp.Request.
Method,
                                resp.Status).Observe(float64(resp.ContentLength))
    ....
}
....
func main() {
    prometheus.Register(reqDuration)
    prometheus.Register(reqBytes)
    http.Handle("/metrics", promhttp.Handler())
    go func() {
        http.ListenAndServe(":9000", nil)
    }()
    ....
}
```

Lastly you need to update the `scrape_configs` section in `prometheus.yml`

```
scrape_configs:
- job_name: rapp
  scrape_interval: 10s
  metrics_path: /metrics
static_configs:
- targets:
- rapp-jwt-invoker.istio-nontrac:80
```

You can then create your own dashboard in grafana using these metrics: [rapps-requests.json](#)

OAuth2 Proxy

Welcome to OAuth2 Proxy | [OAuth2 Proxy \(oauth2-proxy.github.io\)](https://oauth2-proxy.github.io)

Calico network policy

<https://docs.projectcalico.org/security/calico-network-policy>

Calico can be used with Istio to enforce network policies : [Enforce Calico network policy using Istio](#)

For example we can limit connections to the keycloak database to only pods using the keycloak service account

GlobalNetworkPolicy

```
apiVersion: projectcalico.org/v3
kind: GlobalNetworkPolicy
metadata:
  name: postgres
spec:
  selector: app == 'postgres'
  ingress:
    - action: Allow
      source:
        serviceAccounts:
          names: ["keycloak"]
  egress:
    - action: Allow
```

Following the example in the link above I installed the test application in a separate namespace (calico-test). Using curl I was able to access the database prior to applying the GlobalNetworkPolicy. After applying the policy the request timed out rather than return a 403 forbidden message.

Logging

Elasticsearch

We can use elasticsearch, kibana and fluentd to aggregate and visualize the kubernetes logs.

You can use the following files to setup a single node ELK stack on minikube

[elastic.yaml](#)

[kibana.yaml](#)

[fluentd-rbac.yaml](#)

[fluentd-daemonset.yaml](#)

Latest version of files (8.1.2)

[elastic-8.1.2.yaml](#)

[kibana-8.1.2.yaml](#)

[fluentd.yaml](#)

- elastic.yaml includes a persistence volume that mounts the /usr/share/elasticsearch/data directory to a host path. This prevents loss of data when the pod is restarted. (You may need to change the hostPath path value to a directory on your own host)
- Both elastic.yaml and kibana.yaml contain a config map for configuring the component on start up.
- xpack.security.enabled is set to true to enable security.
- This is a single-node minikube setup, you may want to alter this for your own installation.
- elastic-8.1.2.yaml and kibana-8.1.2.yaml use the most up to date images.
- fluentd.yaml combines fluentd-rbac.yaml and fluentd-daemonset.yaml into 1 file and includes certificate configuration for version 8.1.2.

- They all add additional persistent volumes for storing the keys/certificates - please modify these values to suit your own requirements.

Please ensure to create the logging namespace before applying these files.

Once elasticsearch is up and running, log into kibana and create a new index for the logstash-* pipeline.

Once this is done use the discover tab to create a query against your logs:

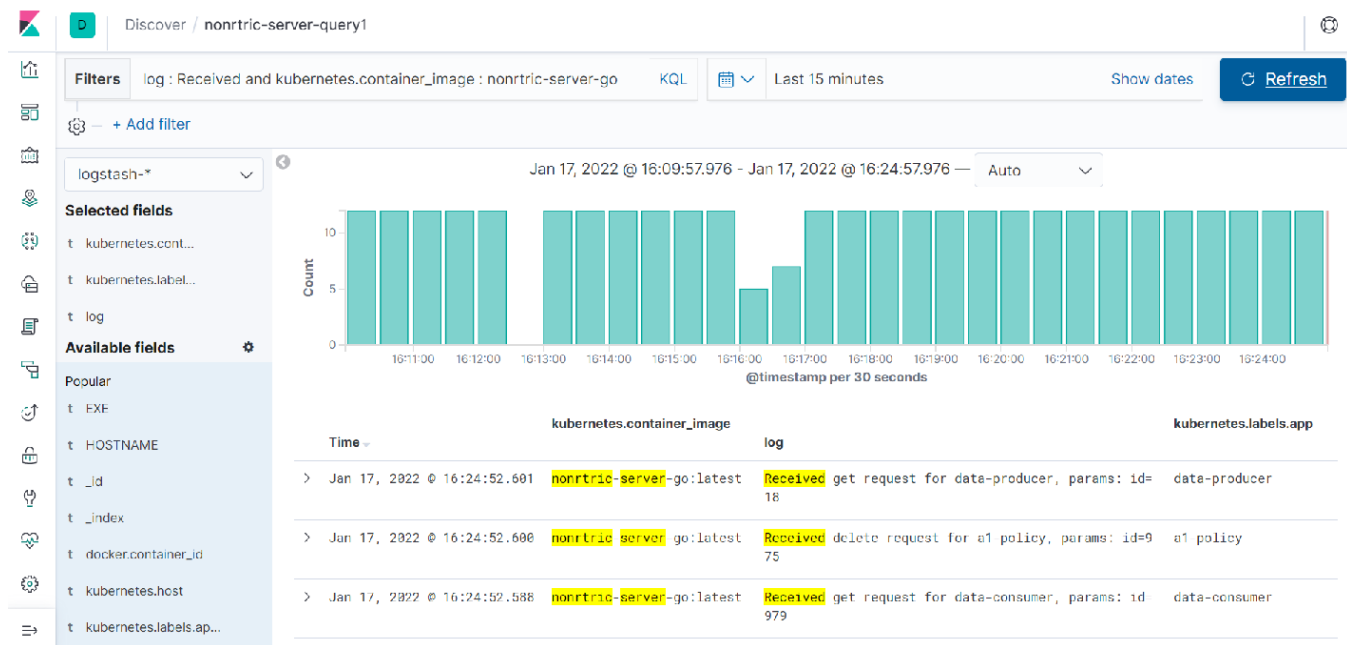
Select the timeStamp, kubernetes.container_image, log and kuberentes.label.app for you fields

Use the filters input textbox to only show the logs you want log : Received and kubernetes.container_image : nonrtic-server-go

Change the date field to the last 15 minutes.

Save your query.

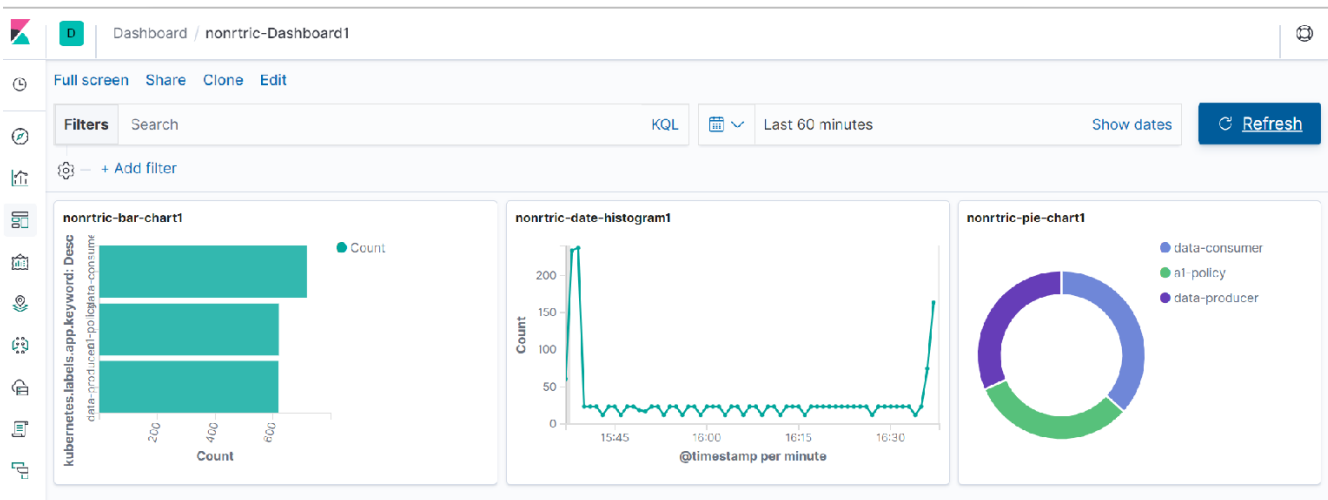
This will produce a report like the following:



This shows the number of requests made to the nonrtic-server-go.

Go to the visualize tab.

Here you can create different charts to display your data and then add them to a dashboard.



Here you can see 3 graphs, the first one shows the number of requests received by each NONRTIC component in the last 60 minutes.

The second one is a histogram showing the total number of requests broken down by time stamp.

The last one is a pie chart showing the distribution of requests across components.

Click the Dev tools tab to use the Elasticsearch console

Run `GET /_cat/indices?v` to see the list of indices currently in use

Console

Search Profiler

Grok Debugger

```

1 GET _search
2 {
3   "query": {
4     "match_all": {}
5   }
6 }
7
8 GET /_cat/indices?v

```

	health	status	index	uuid	pri	rep	docs.count	docs
1			health status index					
2	yellow	open	logstash-2022.01.19	fCY9TeIBTC-1vPw1gMi60w	1	1	79713	
3	green	open	.security-7	EMFHcywtT1G1BwBSF13mjQ	1	0	38	
4	yellow	open	logstash-2022.01.18	v_cir1E3SvuMgSPUjT0j2Q	1	1	720024	
5	green	open	.kibana_task_manager	DIw7qCwyQ9WYHQ8901utGg	1	0	2	
6	green	open	.kibana_1	ZQLYe44kSouyN55glz4m6A	1	0	17	
7								

You can delete indices that are no longer required by running the following command:

`DELETE /<index name>` e.g. `DELETE /logstash-2022.01.18`

You can create a policy to remove logstash indices older than 1 day

Delete logstash indices policy

```
PUT /_ilm/policy/cleanup_policy
{
  "policy": {
    "phases": {
      "hot": {
        "actions": {}
      },
      "delete": {
        "min_age": "1d",
        "actions": { "delete": {} }
      }
    }
  }
}

PUT /logstash-*/_settings
{ "lifecycle.name": "cleanup_policy" }

PUT /_template/logging_policy_template
{
  "index_patterns": ["logstash-*"],
  "settings": { "index.lifecycle.name": "cleanup_policy" }
}
```

Elasticsearch SDK

SDK Example

```
package main

import (
    "bytes"
    "context"
    "encoding/json"
    "fmt"
    "github.com/elastic/go-elasticsearch/esapi"
    "github.com/elastic/go-elasticsearch/v8"
    "io/ioutil"
    "log"
    "os/exec"
    "strings"
)

func main() {
    cmd := exec.Command("minikube", "ip")
    stdout, err := cmd.Output()
    ingressHost := strings.TrimSpace(string(stdout))

    cmd = exec.Command("minikube", "ssh-key")
    stdout, err = cmd.Output()
    ingressKey := strings.TrimSpace(string(stdout))

    // copy ca cert
    cmd = exec.Command("scp", "-i", ingressKey, "docker@"+ingressHost+":/var/elasticsearch/config/certs/ca/ca.crt", "/mnt/c/Users/ktimoney/go/elastic/")
    stdout, err = cmd.Output()

    // get the elasticsearch service nodePort
    cmd = exec.Command("kubectl", "get", "service", "elasticsearch", "-n", "logging",
        "-o", "jsonpath={.spec.ports[?(@.port==9200)].nodePort}")
    stdout, err = cmd.Output()
    secureIngressPort := strings.TrimSpace(string(stdout))
```

```

clusterURLs := []string{"https://" + ingressHost + ":" + secureIngressPort}
username := "elastic"
password := "secret"
cert, _ := ioutil.ReadFile("./ca.crt")

// client configuration
cfg := elasticsearch.Config{
    Addresses: clusterURLs,
    Username:  username,
    Password:  password,
    CACert:    cert,
}
ctx := context.Background()

es, err := elasticsearch.NewClient(cfg)
if err != nil {
    log.Fatalf("Error creating the client: %s", err)
}
log.Println(elasticsearch.Version)

resp, err := es.Info()
if err != nil {
    log.Fatalf("Error getting response: %s", err)
}
defer resp.Body.Close()
log.Println(resp)

// Index Query
indexResp, err := esapi.CatIndicesRequest{Format: "json", Pretty: true}.Do(ctx, es)
if err != nil {
    return
}
indexBody := &indexResp.Body
defer indexResp.Body.Close()

fmt.Println(indexResp.String())

body, err := ioutil.ReadAll(*indexBody)

var results []map[string]interface{}
json.Unmarshal(body, &results)
fmt.Printf("Index: %v\n", results)
indexName := fmt.Sprintf("%v", results[len(results)-1]["index"])
query := `{"query": {"match": {"log": "token"}}, "size": 3}`
runQuery(es, ctx, indexName, query)
query = `
{
  "query": {
    "bool": {
      "must": [
        { "match": { "kubernetes.container_name": "istio-proxy" }},
        { "match": { "log": "token" }},
        { "match": { "kubernetes.labels.app_kubernetes_io/name": "rapp-jwt-invoker" }},
        { "range": { "@timestamp": { "gte": "now-60m" }}}
      ]
    }
  }, "size": 1
}
`
runQuery(es, ctx, indexName, query)
query = `
{
  "query": {
    "bool": {
      "must": [
        { "match": { "kubernetes.container_name": "istio-proxy" }},
        { "match": { "log": "GET /rapp-jwt-provider" }},
        { "match": { "kubernetes.labels.app_kubernetes_io/name": "rapp-jwt-provider" }},
        { "match_phrase": { "tag": "jwt-provider" }},
        { "range": { "@timestamp": { "gte": "now-60m" }}}
      ]
    }
  }
}
`

```

```

        }
        }, "size": 1
    }
}

runQuery(es, ctx, indexName, query)
}

func runQuery(es *elasticsearch.Client, ctx context.Context, indexName string, query string) {
    // Query indexName
    var mapResp map[string]interface{}
    var buf bytes.Buffer
    var b strings.Builder
    b.WriteString(query)
    read := strings.NewReader(b.String())

    // Attempt to encode the JSON query and look for errors
    if err := json.NewEncoder(&buf).Encode(read); err != nil {
        log.Fatalf("Error encoding query: %s", err)

        // Query is a valid JSON object
    } else {
        fmt.Println("\njson.NewEncoder encoded query:", read, "\n")
    }

    // Pass the JSON query to client's Search() method
    searchResp, err := es.Search(
        es.Search.WithContext(ctx),
        es.Search.WithIndex(indexName),
        es.Search.WithBody(read),
        es.Search.WithTrackTotalHits(true),
        es.Search.WithPretty(),
    )

    if err != nil {
        log.Fatalf("Elasticsearch Search() API ERROR:", err)
    }
    defer searchResp.Body.Close()

    // Decode the JSON response and using a pointer
    if err := json.NewDecoder(searchResp.Body).Decode(&mapResp); err != nil {
        log.Fatalf("Error parsing the response body: %s", err)
    }

    // Iterate the document "hits" returned by API call
    for _, hit := range mapResp["hits"].(map[string]interface{})["hits"].([]interface{}) {

        // Parse the attributes/fields of the document
        doc := hit.(map[string]interface{})

        // The "_source" data is another map interface nested inside of doc
        source := doc["_source"]

        // Get the document's _id and print it out along with _source data
        docID := doc["_id"]
        fmt.Println("docID:", docID)
        fmt.Println("_source:", source, "\n")
        // extract the @timestamp field
        timeStamps := fmt.Sprintf("%v", source.(map[string]interface{})["@timestamp"])
        fmt.Println("timeStamps:", timeStamps)
        // extract the tag field
        tag := fmt.Sprintf("%v", source.(map[string]interface{})["tag"])
        fmt.Println("tag:", tag)
        // extract the log field
        k8slog := fmt.Sprintf("%v", source.(map[string]interface{})["log"])
        fmt.Println("log:", k8slog)
    }
    hits := int(mapResp["hits"].(map[string]interface{})["total"].(map[string]interface{})["value"]).
(float64))
    fmt.Println("Matches:", hits)
}

```



```
}
```

You can run the same query in elasticsearch dev-tools:

ConsoleSearch ProfilerGrok DebuggerPainless LabBETA

HistorySettingsHelp200 - OK

```
1 GET _search
2 {
3   "query": {
4     "match_all": {}
5   }
6 }
7
8 GET /_search
9 {
10  "query": {
11    "bool": {
12      "must": [
13        { "match": { "kubernetes.container_name": "istio-proxy" } },
14        { "match": { "log": "GET /rapp-jwt-provider" } },
15        { "match_phrase": { "tag": "jwt-provider" } },
16        { "match": { "kubernetes.labels.app_kubernetes_io/name": "rapp-jwt-provider" } },
17        { "range": { "@timestamp": { "gte": "now-60m" } } }
18      ]
19    }
20  }
21 }
```

```
1 {
2   "took" : 451,
3   "timed_out" : false,
4   "_shards" : {
5     "total" : 1,
6     "successful" : 1,
7     "skipped" : 0,
8     "failed" : 0
9   },
10  "hits" : {
11    "total" : {
12      "value" : 359,
13      "relation" : "eq"
14    },
15    "max_score" : 11.158988,
16    "hits" : [
17      {
18        "_index" : "logstash-2022.04.27",
19        "_id" : "e2wqa4ABJkcr8HCM725Z",
20        "_score" : 11.158988,
21        "_ignored" : [
22          "log.keyword"
23        ],
24        "source" : {
```

Quick Installation Guide

1. Download and install istio: `istioctl install --set profile=demo`
2. cd to the samples/addons/ directory and install the dashboards e.g. `kubectl create -f kiali.yaml`
3. Install postgres: `istioctl kube-inject -f postgres.yaml | kubectl apply -f -` (change the hostPath path value to a path on your host)
4. Install keycloak: `istioctl kube-inject -f keycloak.yaml | kubectl apply -f -`
5. Open the [keycloak](#) admin console and setup the required realms, users and clients
6. Setup the "pms_admin" and "pms_viewer" [roles](#) for pmsuser and pmsuser2 respectively.
7. Install [nonrtric-server-go](#): `docker build -t nonrtric-server-go:latest`
8. Create the istio-nonrtric namespace: `kubectl create namespace istio-nonrtric`
9. Enable istio for the istio-nonrtric namespace: `kubectl label namespace istio-nonrtric istio-injection=enabled`
10. Edit the [istio-test.yaml](#) so the host ip specified matches yours.
11. Also change the userid in the requestPrincipals field to match yours
12. Install [istio-test.yaml](#) : `kubectl create -f istio-test.yaml`
13. Install [nonrtric-client-go](#): `docker build -t nonrtric-client-go:latest`
14. Install the test client: `istioctl kube-inject -f client.yaml | kubectl apply -f -`
15. Open the [kiali](#) dashboard to check your services are up and running
16. Open the [grafana](#) to view the istio dashboard
17. Optionally install [elasticsearch](#)

ONAP

[ONAP Next Generation Security & Logging Architecture](#)

GO Client

[Create kubernetes jobs in golang](#)

[Building stuff with the Kubernetes API](#)

There is also a helm sdk you can use:

HELM SDK

Helm Deploy

package main

```

import (
    "fmt"
    "os"
    "log"
    "k8s.io/cli-runtime/pkg/genericclioptions"
    "k8s.io/client-go/rest"
    "helm.sh/helm/v3/pkg/action"
    "helm.sh/helm/v3/pkg/chart/loader"
)

func main() {
    chartPath := "/tmp/wordpress-12.3.3.tgz"
    chart, err := loader.Load(chartPath)

    releaseName := "wordpress"
    releaseNamespace := "default"

    actionConfig, err := getActionConfig(releaseNamespace)
    if err != nil {
        panic(err)
    }

    listAction := action.NewList(actionConfig)
    releases, err := listAction.Run()
    if err != nil {
        log.Println(err)
    }
    for _, release := range releases {
        log.Println("Release: " + release.Name + " Status: " + release.Info.Status.String())
    }

    iCli := action.NewInstall(actionConfig)
    iCli.Namespace = releaseNamespace
    iCli.ReleaseName = releaseName
    rel, err := iCli.Run(chart, nil)
    if err != nil {
        fmt.Println(err)
    }
    fmt.Println("Successfully installed release: ", rel.Name)
}

func getActionConfig(namespace string) (*action.Configuration, error) {
    actionConfig := new(action.Configuration)
    // Create the rest config instance with ServiceAccount values loaded in them
    config, err := rest.InClusterConfig()
    if err != nil {
        // fallback to kubeconfig
        home, exists := os.LookupEnv("HOME")
        if !exists {
            home = "/root"
        }
        kubeconfigPath := filepath.Join(home, ".kube", "config")
        if envvar := os.Getenv("KUBECONFIG"); len(envvar) > 0 {
            kubeconfigPath = envvar
        }
        if err := actionConfig.Init(kube.GetConfig(kubeconfigPath, "", namespace), namespace, os.Getenv("HELM_DRIVER"),
            func(format string, v ...interface{}) {
                fmt.Sprintf(format, v)
            }); err != nil {
                panic(err)
            }
    } else {
        // Create the ConfigFlags struct instance with initialized values from ServiceAccount
        var kubeConfig *genericclioptions.ConfigFlags
        kubeConfig = genericclioptions.NewConfigFlags(false)
        kubeConfig.APIServer = &config.Host
        kubeConfig.BearerToken = &config.BearerToken
        kubeConfig.CAFile = &config.CAFile
        kubeConfig.Namespace = &namespace
    }
}

```

```

        if err := actionConfig.Init(kubeConfig, namespace, os.Getenv("HELM_DRIVER"), func(format string, v
...interface{}) {
            fmt.Sprintf(format, v)
        }); err != nil {
            panic(err)
        }
    }
    return actionConfig, nil
}

```

The method `getActionConfig` works for both in-cluster deployments and from the localhost. It determines which one to use by calling the `rest.InClusterConfig()` function.

GO CLIENT SDK

Here are another couple of programs that demonstrate how to use the go client:

[hello-world.go](#)

[hello-world-del.go](#)

You can also use the client with YAML : [job.go](#)

There is also support for istio in client go [Istio client-go](#)

ISTIO SDK

AuthorizationPolicy

```

package main

import (
    "context"
    "bytes"
    "fmt"
    "os"
    "log"
    "path/filepath"
    k8sYaml "k8s.io/apimachinery/pkg/util/yaml"
    metav1 "k8s.io/apimachinery/pkg/apis/meta/v1"
    clientcmd "k8s.io/client-go/tools/clientcmd"
    versioned "istio.io/client-go/pkg/clientset/versioned"
    v1beta1 "istio.io/client-go/pkg/apis/security/v1beta1"
    securityv1beta1 "istio.io/api/security/v1beta1"
    typev1beta1 "istio.io/api/type/v1beta1"
)

const (
    NAMESPACE = "default"
)

const authorizationPolicyManifest = `
apiVersion: "security.istio.io/v1beta1"
kind: "AuthorizationPolicy"
metadata:
  name: "pms-policy"
  namespace: default
spec:
  selector:
    matchLabels:
      apptype: nonrtric-pms
  action: ALLOW
  rules:
  - from:
    - source:
      principals: ["cluster.local/ns/default/sa/goclient"]

```

```

to:
- operation:
  methods: ["GET", "POST", "PUT", "DELETE"]
  paths: ["/a1-policy*"]
  hosts: ["a1-policy*"]
  ports: ["8080"]
when:
- key: request.auth.claims[role]
  values: ["pms_admin"]
,

func connectToK8s() *versioned.Clientset {
  home, exists := os.LookupEnv("HOME")
  if !exists {
    home = "/root"
  }

  configPath := filepath.Join(home, ".kube", "config")

  config, err := clientcmd.BuildConfigFromFlags("", configPath)
  if err != nil {
    log.Fatalln("failed to create K8s config")
  }

  ic, err := versioned.NewForConfig(config)
  if err != nil {
    log.Fatalf("Failed to create istio client: %s", err)
  }

  return ic
}

func createAuthorizationPolicy(clientset *versioned.Clientset) {
  authClient := clientset.SecurityV1beta1().AuthorizationPolicies(NAMESPACE)

  auth := &v1beta1.AuthorizationPolicy{}
  dec := k8yaml.NewYAMLOrJSONDecoder(bytes.NewReader([]byte(authorizationPolicyManifest)), 1000)

  if err := dec.Decode(&auth); err != nil {
    fmt.Println(err)
  }

  result, err := authClient.Create(context.TODO(), auth, metav1.CreateOptions{})

  if err != nil {
    panic(err.Error())
  }

  fmt.Printf("Create Authorization Policy %s \n", result.GetName())
}

func createAuthorizationPolicy2(clientset *versioned.Clientset) {
  authClient := clientset.SecurityV1beta1().AuthorizationPolicies(NAMESPACE)

  auth := &v1beta1.AuthorizationPolicy{
    ObjectMeta: metav1.ObjectMeta{
      Name: "ics-policy",
    },
    Spec: securityv1beta1.AuthorizationPolicy {
      Selector: &typev1beta1.WorkloadSelector{
        MatchLabels: map[string]string{
          "apptype" : "nonrtric-ics",
        },
      },
      Action: securityv1beta1.AuthorizationPolicy_ALLOW,
      Rules: []*securityv1beta1.Rule{{
        From: []*securityv1beta1.Rule_From{{
          Source: &securityv1beta1.Source{
            Namespaces : []string{
              "default",
            },
          },
        }},
      }},
    },
  }
}

```

```

    },},
    To: []*securityv1beta1.Rule_To{
        Operation: &securityv1beta1.Operation{
            Methods : []string{
                "GET", "POST", "PUT", "DELETE",
            },
            Paths : []string{
                "/data-*",
            },
            Hosts : []string{
                "data-consumer*", "data-producer*",
            },
            Ports : []string{
                "8080",
            },
        },
    },
},},
},},
}

result, err := authClient.Create(context.TODO(), auth, metav1.CreateOptions{})

if err!=nil {
    panic(err.Error())
}

fmt.Printf("Create Authorization Policy %s \n", result.GetName())
}

func main() {
    clientset := connectToK8s()
    createAuthorizationPolicy(clientset)
    createAuthorizationPolicy2(clientset)
}

```

keycloak aslo has a client called [gocloak](#)

GOCLOAK SDK

gocloak

```

package main

import (
    "github.com/Nerzal/gocloak/v10"
    "context"
    "fmt"
)

func main(){
    client := gocloak.NewClient("http://192.168.49.2:31560")
    ctx := context.Background()
    token, err := client.LoginAdmin(ctx, "admin", "admin", "master")
    if err != nil {
        fmt.Println(err)
        panic("Something wrong with the credentials or url")
    }

    realmRepresentation := gocloak.RealmRepresentation{
        ID: gocloak.StringP("testRealm"),
        Realm: gocloak.StringP("testRealm"),
        DisplayName: gocloak.StringP("testRealm"),
        Enabled:    gocloak.BoolP(true),
    }
}

```

```

realm, err := client.CreateRealm(ctx, token.AccessToken, realmRepresentation)
if err != nil {
    fmt.Println(err)
    panic("Oh no!, failed to create realm :(")
} else {
    fmt.Println("Created new realm", realm)
}

newClient := gocloak.Client{
    ClientID: gocloak.StringP("testClient"),
    Enabled:  gocloak.BoolP(true),
    DirectAccessGrantsEnabled: gocloak.BoolP(true),
    BearerOnly: gocloak.BoolP(false),
    PublicClient: gocloak.BoolP(true),
}
clientId, err := client.CreateClient(ctx, token.AccessToken, realm, newClient)
if err != nil {
    fmt.Println(err)
    panic("Oh no!, failed to create client :(")
} else {
    fmt.Println("Created new client", clientId)
}

newUser := gocloak.User{
    FirstName: gocloak.StringP("Bob"),
    LastName:  gocloak.StringP("Uncle"),
    Email:     gocloak.StringP("something@really.wrong"),
    Enabled:   gocloak.BoolP(true),
    Username:  gocloak.StringP("testUser"),
}

userId, err := client.CreateUser(ctx, token.AccessToken, realm, newUser)
if err != nil {
    fmt.Println(err)
    panic("Oh no!, failed to create user :(")
} else {
    fmt.Println("Created new user", userId)
}

err = client.SetPassword(ctx, token.AccessToken, userId, realm, "secret", false)
if err != nil {
    fmt.Println(err)
    panic("Oh no!, failed to set password :(")
} else {
    fmt.Println("Set password for user")
}

removeRoles := []gocloak.Role{}
origRoles, err := client.GetRealmRoles(ctx, token.AccessToken, realm, gocloak.GetRoleParams{})
if err != nil {
    fmt.Println(err)
    panic("Oh no!, failed to retrieve roles :(")
} else {
    fmt.Println("Retrieved roles")
}
for _, r := range origRoles {
    removeRoles = append(removeRoles, *r)
}

newRole := gocloak.Role{
    Name: gocloak.StringP("testRole"),
}
roleName, err := client.CreateRealmRole(ctx, token.AccessToken, realm, newRole)
if err != nil {
    fmt.Println(err)
    panic("Oh no!, failed to create role :(")
} else {
    fmt.Println("Created new role", roleName)
}

```

```

role, err := client.GetRealmRole(ctx, token.AccessToken, realm, roleName)
if err != nil {
    fmt.Println(err)
    panic("Oh no!, failed to retrieve role :(")
} else {
    fmt.Println("Retrieved role")
}

roles := []gocloak.Role{}
roles = append(roles, *role)
err = client.AddRealmRoleToUser(ctx, token.AccessToken, realm, userId, roles)
if err != nil {
    fmt.Println(err)
    panic("Oh no!, failed to add role to user :(")
} else {
    fmt.Println("Role added to user")
}

err = client.DeleteRealmRoleFromUser(ctx, token.AccessToken, realm, userId, removeRoles)
if err != nil {
    fmt.Println(err)
    panic("Oh no!, failed to remove roles from user :(")
} else {
    fmt.Println("Roles removed from user")
}

newMapper := gocloak.ProtocolMapperRepresentation{
    ID:          gocloak.StringP("testMapper"),
    Name:        gocloak.StringP("testMapper"),
    Protocol:    gocloak.StringP("openid-connect"),
    ProtocolMapper: gocloak.StringP("oidc-usermodel-realm-role-mapper"),
    Config: &map[string]string{
        "access.token.claim": "true",
        "aggregate.attrs":    "",
        "claim.name":         "role",
        "id.token.claim":     "true",
        "jsonType.label":     "String",
        "multivalued":        "",
        "userinfo.token.claim": "true",
    },
}

_, err = client.CreateClientProtocolMapper(ctx, token.AccessToken, realm, clientId, newMapper)
if err != nil {
    fmt.Println(err)
    panic("Oh no!, failed to add roleampper to client :(")
} else {
    fmt.Println("Rolemapper added to client")
}
}

```

If you want to create a confidential client you can use these settings instead:

```

newClient := gocloak.Client{
    ClientID: gocloak.StringP("testClient"),
    Enabled:  gocloak.BoolP(true),
    DirectAccessGrantsEnabled: gocloak.BoolP(true),
    BearerOnly: gocloak.BoolP(false),
    PublicClient: gocloak.BoolP(false),
    ServiceAccountsEnabled: gocloak.BoolP(true),
    ClientAuthenticatorType: gocloak.StringP("client-secret"),
    Secret: gocloak.StringP("secret"),
}

```

You can then access the token with the following URL: `curl -X POST http://<keycloak host ip>:<keycloak port>/auth/realms/testRealm/protocol/openid-connect/token "Content-Type: application/x-www-form-urlencoded" -d client_id=testClient -d client_secret=secret -d grant_type=client_credentials'`

using client credentials instead of user credentials

You will also need to create a client role and use the "Hardcoded role" mapper to include the client role in the JWT.

This can be done in gocloak like this:

goclock client role

```
clientRole := gocloak.Role{
    Name: gocloak.StringP("icsClientRole"),
}
clientRoleName, err := client.CreateClientRole(ctx, token.AccessToken, realm, clientId, clientRole)
if err != nil {
    fmt.Println(err)
    panic("Oh no!, failed to create client role :(")
} else {
    fmt.Println("Created new client role", clientRoleName)
}

clientRole := *newClient.ClientID + "." + clientRoleName
fmt.Println("clientRole", clientRole)

hardcodedMapper := gocloak.ProtocolMapperRepresentation{
    ID:          gocloak.StringP("testMapper2"),
    Name:        gocloak.StringP("testMapper2"),
    Protocol:    gocloak.StringP("openid-connect"),
    ProtocolMapper: gocloak.StringP("oidc-hardcoded-role-mapper"),
    Config: &map[string]string{
        "role": clientRole,
    },
}

_, err = client.CreateClientProtocolMapper(ctx, token.AccessToken, realm, clientId, hardcodedMapper)
if err != nil {
    fmt.Println(err)
    panic("Oh no!, failed to add hardcoded roleampper to client :(")
} else {
    fmt.Println("Hardcoded rolemapper added to client")
}
```

This will produce a JWT token with the client role nested inside "resource_access"

JWT snippet

```
{
  "exp": 1645458971,
  "iat": 1645458671,
  "jti": "54fd719a-bf5b-4638-afd5-828ff10b7537",
  "iss": "http://192.168.49.2:31560/auth/realms/icsrealm",
  "aud": "account",
  "sub": "e9ebe72f-3729-4cd5-88da-79f9bfb23cfb",
  "typ": "Bearer",
  "azp": "icsclient",
  "acr": "1",
  "realm_access": {
    "roles": [
      "offline_access",
      "uma_authorization",
      "default-roles-icsrealm"
    ]
  },
  "resource_access": {
    "icsclient": {
      "roles": [
        "icsclientrole"
      ]
    }
  },
}
```


You can then setup your AuthorizationPolicy like this:

AuthorizationPolicy

```
apiVersion: "security.istio.io/v1beta1"
kind: "AuthorizationPolicy"
metadata:
  name: "ics-policy"
  namespace: istio-nonrtric
spec:
  selector:
    matchLabels:
      apptype: nonrtric-ics
  action: ALLOW
  rules:
    - from:
      - source:
          requestPrincipals: ["http://192.168.49.2:31560/auth/realms/icsrealm/"]
      - source:
          requestPrincipals: ["http://keycloak.default:8080/auth/realms/icsrealm/"]
    - to:
      - operation:
          methods: ["GET", "POST", "PUT", "DELETE"]
          paths: ["/data-*"]
  when:
    - key: request.auth.claims[resource_access][icsclient][roles]
      values: ["icsclientrole"]
```

You don't need to include the userId with the requestPrincipals.

keycloak secrets can be (re)generated and retrieved using the following code:

keycloak client secret

```
_, err = client.RegenerateClientSecret(ctx, token.AccessToken, realm, clientId)
if err != nil {
    fmt.Println(err)
    panic("Oh no!, failed to regenerate client secret :(")
} else {
    fmt.Println("Regenerated Secret")
}

cred, err := client.GetClientSecret(ctx, token.AccessToken, realm, clientId)
if err != nil {
    fmt.Println(err)
    panic("Oh no!, failed to get client secret :(")
} else {
    fmt.Println("Client Secret", *cred.Value)
}
```

Instead of using the hardcoded mapper you can call the GetClientServiceAccount method to get the service a/c user.

You can then add the client role to the service account user with the AddClientRoleToUser method.

Instead of using the hardcoded mapper you can use a client role mapper to include the client role in the JWT.

Finally you can set the default client scope to "email" to minimize the size of your token.

JWT

```
"iat": 1646152642,
"jti": "e55fd625-d3e5-476f-aeb7-5a0189380151",
"iss": "http://192.168.49.2:31560/auth/realms/hwrealm",
"sub": "d2f705d1-ca27-437d-979f-4d0b80d500d7",
"typ": "Bearer",
"azp": "hwclient",
"acr": "1",
"scope": "email",
"email_verified": false,
"clientHost": "127.0.0.6",
"clientId": "hwclient",
"clientRole": [
  "hwclientrole"
],
"clientAddress": "127.0.0.6"
}
```

In your Istio AuthorizationPolicy use the following when clause :

Istio

```
when:
- key: request.auth.claims[clientRole]
  values: ["hwclientrole"]
```

Keycloak Client Authenticator

Using X509 certificates

Create the server side certificates using the following script

server_certs.sh

```
#!/bin/sh
```

```
CA_SUBJECT="/C=IE/ST=/L=/O=/OU=EST/CN=est.tech/emailAddress=ca@mail.com"
SERVER_SUBJECT="/C=IE/ST=/L=/O=/OU=EST/CN=est.tech/emailAddress=server@mail.com"
PW=changeit
IP=$(minikube ip)
```

```
echo $PW > secretfile.txt
```

```
openssl req -x509 -sha256 -days 3650 -newkey rsa:4096 -keyout rootCA.key -subj "$CA_SUBJECT" -passout file:secretfile.txt -out rootCA.crt
```

```
openssl req -new -newkey rsa:4096 -keyout tls.key -subj "$SERVER_SUBJECT" -out tls.csr -nodes
```

```
echo "subjectKeyIdentifier    = hash" > x509.ext
echo "authorityKeyIdentifier  = keyid:always,issuer:always" >> x509.ext
echo "basicConstraints        = CA:TRUE" >> x509.ext
echo "keyUsage                 = digitalSignature, nonRepudiation, keyEncipherment, dataEncipherment, keyAgreement, keyCertSign" >> x509.ext
echo "subjectAltName           = DNS.1:localhost, IP.1:127.0.0.1, DNS.2:minikube, IP.2:${IP}, DNS.3:keycloak.default, DNS.4:keycloak.est.tech" >> x509.ext
echo "issuerAltName            = issuer:copy" >> x509.ext
echo "[ ca ]" >> x509.ext
echo "# X509 extensions for a ca" >> x509.ext
echo "keyUsage                 = critical, cRLSign, keyCertSign" >> x509.ext
echo "basicConstraints          = CA:TRUE, pathlen:0" >> x509.ext
echo "subjectKeyIdentifier      = hash" >> x509.ext
echo "authorityKeyIdentifier    = keyid:always,issuer:always" >> x509.ext
echo "" >> x509.ext
echo "[ server ]" >> x509.ext
echo "# X509 extensions for a server" >> x509.ext
echo "keyUsage                 = critical,digitalSignature,keyEncipherment" >> x509.ext
echo "extendedKeyUsage           = serverAuth,clientAuth" >> x509.ext
echo "basicConstraints           = critical,CA:FALSE" >> x509.ext
echo "subjectKeyIdentifier       = hash" >> x509.ext
echo "authorityKeyIdentifier     = keyid,issuer:always" >> x509.ext

openssl x509 -req -CA rootCA.crt -CAkey rootCA.key -in tls.csr -passin file:secretfile.txt -out tls.crt -days 365 -CAcreateserial -extfile x509.ext

rm secretfile.txt x509.ext 2>/dev/null
```

This will produce the following files: tls.key, tls.crt and rootCA.crt.

These need to be copied to a location where keycloak can pick them up when starting.

Add a PersistentVolume and PersistentVolumeClaim to map the hostPath on your localhost to the /etc/x509/https directory on the keycloak server.

This will automatically pick up the tls.key, tls.crt files and convert them into https-keystore files in the /opt/jboss/keycloak/standalone/configuration/keystores directory.

You will need to map the rootCA.crt file using an environment variable like this:

```
env:
- name: X509_CA_BUNDLE
value: /etc/x509/https/rootCA.crt
```

You'll also need to create a port mapping for the keycloak https port in your deployment:

```
env:
- name: KEYCLOAK_HTTPS_PORT
value: "8443"
```

ports:
- name: http
containerPort: 8080
- name: https
containerPort: 8443

and include the https port in your service:

ports:
- name: https
port: 8443
targetPort: 8443
nodePort: 31561

keycloak is now ready to accept https connections.

You can generate your client certificates using the following code:

client_certs

```
#!/bin/sh

CLIENT_SUBJECT="/C=IE/ST=/L=/O=/OU=EST/CN=est.tech/emailAddress=client@mail.com"
PW=changeit
CERTNAME=client
IP=$(minikube ip)

echo $PW > secretfile.txt

echo "subjectKeyIdentifier    = hash" > x509.ext
echo "authorityKeyIdentifier  = keyid:always,issuer:always" >> x509.ext
echo "basicConstraints        = CA:TRUE" >> x509.ext
echo "keyUsage                 = digitalSignature, nonRepudiation, keyEncipherment, dataEncipherment, keyAgreement, keyCertSign" >> x509.ext
echo "subjectAltName           = DNS.1:localhost, IP.1:127.0.0.1, DNS.2:minikube, IP.2:${IP}, DNS.3:keycloak.default, DNS.4:keycloak.est.tech" >> x509.ext
echo "issuerAltName            = issuer:copy" >> x509.ext

openssl req -new -newkey rsa:4096 -nodes -keyout ${CERTNAME}.key -subj "$CLIENT_SUBJECT" -out ${CERTNAME}.csr

openssl x509 -req -CA rootCA.crt -CAkey rootCA.key -in ${CERTNAME}.csr -passin file:secretfile.txt -out ${CERTNAME}.crt -days 365 -CAcreateserial -extfile x509.ext

openssl pkcs12 -export -clcerts -in ${CERTNAME}.crt -inkey ${CERTNAME}.key -passout file:secretfile.txt -out ${CERTNAME}.p12

openssl pkcs12 -in ${CERTNAME}.p12 -password pass:$PW -passout file:secretfile.txt -out ${CERTNAME}.pem -clcerts -nodes

rm secretfile.txt x509.ext 2>/dev/null
```

This will generate a client.crt and a client.key which you can use separately, it also generates client.pem which combined the certificate and key into 1 file.

If you use this as your cert file then you don't need to specify a key file parameter.

You now need to setup your realm and add an X.509 Direct Grant Flow.

See this link on how to do that https://wjlw465150.gitbooks.io/keycloak-documentation/content/server_admin/topics/authentication/x509.html

Next setup a client with access type of public.

Change Direct Grant Flow in the "Authentication Flow Overrides" section of your client settings to "x509 direct grant".

Last add a new user with an email address which is the same as the one given in the certificate subject i.e. client@mail.com

Note: The subjectAltName contains a list of DNS and IP entries, you must use one of these in your URL when using the cert.

Note: The CN will be used later on when specifying an SNI host name.

You can test your setup using the following script:

test_cert

```
#!/bin/sh
HOST=$(minikube ip)
KEYCLOAK_PORT=$(kubectl -n default get service keycloak -o jsonpath='{.spec.ports[?(@.name=="https")].nodePort}')
REALM="x509"
CLIENT="x509client"
curl -k -X POST https://$HOST:$KEYCLOAK_PORT/auth/realms/$REALM/protocol/openid-connect/token \
  --data "grant_type=password&scope=openid profile&username=&password=&client_id=$CLIENT" \
  --cert client.crt --key client.key

echo ""
```

This will retrieve a JWT token without the need to use a password.

If you are using a confidential client, include the client_secret:

```
curl -k -X POST https://$HOST:$KEYCLOAK_PORT/auth/realms/$REALM/protocol/openid-connect/token \
  --data "grant_type=password&scope=openid profile&client_id=$CLIENT" \
  -d client_secret=<client secret> \
  --cert client.crt --key client.key
```

For confidential clients you can also set the Client Authenticator to "X509 certificate" in the credentials tab.

You can then set your subject DN to something like: *.client@mail.com.* and turn on "Allow Regex Pattern Comparison"

The JWT can then be retrieved using a call like the following:

```
curl -k -X POST https://$HOST:$KEYCLOAK_PORT/auth/realms/$REALM/protocol/openid-connect/token \
  --data "grant_type=password&scope=openid profile&client_id=$CLIENT" \
  --cert client.pem
```

Alternatively you can use the -E option to encrypt the pem file

```
curl -k -X POST https://$HOST:$KEYCLOAK_PORT/auth/realms/$REALM/protocol/openid-connect/token \
  --data "grant_type=password&scope=openid profile&client_id=$CLIENT" \
  -E client.pem
```

For more information see: [X.509 Client Certificate User Authentication](#)

It is not possible to connect to a TLS server with curl using only a client certificate, without the client private key. <https://stackoverflow.com/questions/36431179/using-curl-with-cert>

Token can also be retrieved using go:

Go X509 Token

```
package main

import (
    "crypto/tls"
    "crypto/x509"
    "fmt"
    "io/ioutil"
    "net/http"
    "net/url"
)

func main() {
    caCert, _ := ioutil.ReadFile("/mnt/c/Users/ktimoney/keycloak-certs/rootCA.crt")
    caCertPool := x509.NewCertPool()
    caCertPool.AppendCertsFromPEM(caCert)

    cert, _ := tls.LoadX509KeyPair("/mnt/c/Users/ktimoney/keycloak-certs/client.crt", "/mnt/c/Users/ktimoney/keycloak-certs/client.key")

    client := &http.Client{
        Transport: &http.Transport{
            TLSClientConfig: &tls.Config{
                RootCAs:      caCertPool,
                Certificates: []tls.Certificate{cert},
            },
        },
    }

    keycloakHost := "192.168.49.2"
    keycloakPort := "31561"
    realmName := "x509"
    keycloakUrl := "https://" + keycloakHost + ":" + keycloakPort + "/auth/realms/" + realmName + "/protocol/openid-connect/token"

    clientId := "x509client"
    scope := "openid profile"
    resp, err := client.PostForm(keycloakUrl,
        url.Values{"username": {""}, "password": {""}, "grant_type": {"password"}, "client_id": {clientId}, "scope": {scope}})
    if err != nil {
        panic(err)
    }
    defer resp.Body.Close()

    fmt.Println("response Status:", resp.Status)
    fmt.Println("response Headers:", resp.Header)
    body, _ := ioutil.ReadAll(resp.Body)
    fmt.Println("response Body:", string(body))
}
```

Java example available here: [X.509 Authentication in Spring Security](#)

Istio CA Certs

To allow istio to work with keycloak you must add your certificate to the istio certs when you're installing.

An istio operator file is used for this: [istio.yaml](#)

```
istioctl install --set profile=demo -f istio.yaml
```

Further instruction are available here: [Custom CA Integration using Kubernetes CSR](#)

Using istio-gateway to obtain JWT tokens.

You may want to avoid connecting directly to the keycloak server for security reasons.

You can connect to it through the istio ingress gateway instead if you wish.

You will need to setup a gateway in PASSTROUGH mode and virtual service that maps the keycloak host to the keycloak SNI host.

The following file can be used to do this for the CN used when creating certificates above: [keycloak-gateway.yaml](#)

You can test this using curl:

Test Gateway

```
#!/bin/sh
INGRESS_HOST=$(minikube ip)
SECURE_INGRESS_PORT=$(kubectl -n default get service istio-ingressgateway -n istio-system -o jsonpath='{.spec.ports[?(@.name=="https")].nodePort}')

curl -v --resolve "keycloak.est.tech:$SECURE_INGRESS_PORT:$INGRESS_HOST" --cacert rootCA.crt "https://keycloak.est.tech:$SECURE_INGRESS_PORT"

CLIENT="myclient"
REALM="x509"
curl --resolve "keycloak.est.tech:$SECURE_INGRESS_PORT:$INGRESS_HOST" --cacert rootCA.crt \
      -X POST https://keycloak.est.tech:$SECURE_INGRESS_PORT/auth/realms/$REALM/protocol/openid-connect
/token \
      --data "grant_type=password&scope=openid profile&client_id=$CLIENT" \
      -E client.pem
echo ""
```

The following go code can be used to achieve the same result:

go

```
package main

import (
    "context"
    "crypto/tls"
    "crypto/x509"
    "fmt"
    "io/ioutil"
    "net"
    "net/http"
    "net/url"
    "os/exec"
    "strings"
    "time"
)

func main() {
    caCert, _ := ioutil.ReadFile("/mnt/c/Users/ktimoney/keycloak-certs/rootCA.crt")
    caCertPool := x509.NewCertPool()
    caCertPool.AppendCertsFromPEM(caCert)

    cert, _ := tls.LoadX509KeyPair("/mnt/c/Users/ktimoney/keycloak-certs/client.crt",
                                   "/mnt/c/Users/ktimoney/keycloak-certs/client.key")

    dialer := &net.Dialer{
        Timeout:   30 * time.Second,
        KeepAlive: 30 * time.Second,
        DualStack: true,
    }

    keycloakAlias := "keycloak.est.tech"
    cmd := exec.Command("minikube", "ip")
    stdout, err := cmd.Output()
    ingressHost := strings.TrimSpace(string(stdout))
```

```

cmd = exec.Command("kubectl", "get", "service", "istio-ingressgateway", "-n", "istio-system",
    "-o", "jsonpath={.spec.ports[?(@.name==\"https\")].nodePort}")
stdout, err = cmd.Output()
secureIngressPort := strings.TrimSpace(string(stdout))
fmt.Println("secureIngressPort = " + secureIngressPort)

client := &http.Client{
    Transport: &http.Transport{
        DialContext: func(ctx context.Context, network, addr string) (net.Conn, error) {
            fmt.Println("address original =", addr)
            if addr == keycloakAlias+": "+secureIngressPort {
                addr = ingressHost + ":" + secureIngressPort
                fmt.Println("address modified =", addr)
            }
            return dialer.DialContext(ctx, network, addr)
        },
        TLSClientConfig: &tls.Config{
            RootCAs:      caCertPool,
            Certificates: []tls.Certificate{cert},
        },
    },
}

realmName := "x509provider"
keycloakUrl := "https://" + keycloakAlias + ":" + secureIngressPort + "/auth/realms/" +
    realmName + "/protocol/openid-connect/token"

clientId := "x509provider-cli"
clientId = "myclient"
scope := "email openid"
resp, err := client.PostForm(keycloakUrl,
    url.Values{"grant_type": {"password"}, "client_id": {clientId}, "scope": {scope}})
if err != nil {
    panic(err)
}
defer resp.Body.Close()

fmt.Println("response Status:", resp.Status)
fmt.Println("response Headers:", resp.Header)
body, _ := ioutil.ReadAll(resp.Body)
fmt.Println("response Body:", string(body))
}

```

Note: If run outside the cluster the ISS will be ["https://keycloak.est.tech:30338/auth/realms/<realm>"](https://keycloak.est.tech:30338/auth/realms/<realm>) (the port number will differ depending on your setup).

Inside the cluster it will be: ["https://keycloak.est.tech:443/auth/realms/<realm>"](https://keycloak.est.tech:443/auth/realms/<realm>)

Note: Your istio `jwtksUri` won't be able to resolve the host alias so you should use the normal values for this e.g. ["https://keycloak.default:8443/auth/realms/<realm>/protocol/openid-connect/certs"](https://keycloak.default:8443/auth/realms/<realm>/protocol/openid-connect/certs)

Note: The file above also allows for http calls to keycloak through the gateway, the ISS in this case is: ["http://istio-ingressgateway.istio-system:80/auth/realms/<realm>"](http://istio-ingressgateway.istio-system:80/auth/realms/<realm>). In this case the `jwtksUri` should be set to the default URI for in-cluster keycloak calls i.e. ["http://keycloak.default:8080/auth/realms/<realm>/protocol/openid-connect/certs"](http://keycloak.default:8080/auth/realms/<realm>/protocol/openid-connect/certs)

Client authentication with signed JWT

Another option for retrieving JWT tokens for confidential clients is using client authentication with signed JWT.

Create a new confidential client and call it `jwtclient`.

In the credentials section choose "Signed JWT" from the Client Authenticator dropdown and choose RS256 as the Signature Algorithm.

Then in the Keys tab import the `client.crt` we generated earlier.

We need to create a self-signed JWT assertion to use this.

Create a public key from your private key with the following command: `openssl rsa -in client.key -outform PEM -pubout -out client_pub.key`

See the following link on how to do this: [Creating and validating a JWT RSA token in Golang](#)

We need to make some modifications to the token.go code to enable it to work for us.

The following fields need to be added to the claims map:

```
claims["jti"] = "myJWTId" + fmt.Sprint(now.UnixNano())
claims["sub"] = "jwtclient"
claims["iss"] = "jwtclient"
claims["aud"] = "http://192.168.49.2:31560/auth/realms/x509"
```

Also modify main.go so it uses you public and private keys and only outputs the token value.

Compile and run the code to produce the self-signed JWT assertion.

This can then be used to obtain a JWT access token with the following curl command:

JWT Assertion

```
#!/bin/sh
HOST=$(minikube ip)
KEYCLOAK_PORT=$(kubectrl -n default get service keycloak -o jsonpath='{.spec.ports[?(@.name=="http")].nodePort}')
REALM="x509"
CLIENT="jwtclient"

JWT=$(./main)

curl -k -X POST http://$HOST:$KEYCLOAK_PORT/auth/realms/$REALM/protocol/openid-connect/token \
  -d "grant_type=client_credentials" -d "scope=openid profile" -d client_id=$CLIENT \
  -d "client_assertion_type=urn:ietf:params:oauth:client-assertion-type:jwt-bearer" \
  -d client_assertion=$JWT
echo ""
```

No client secret is required for this authentication.

These self-signed JWT assertions are for one time use only, the jti claim value must have a unique id for every call.

Note: we can also call this using https with some small modifications.

Client authentication with signed JWT with client secret

This is similar to the option above except we sign with the client secret instead of the private key.

We also use a different algorithm.

The following code demonstrates this:

Signed JWT with client secret

```
secret := "NKTh1bfR9HNwllMhdWrDMKhVJHTvwreC"

token, err := jwt.NewWithClaims(jwt.SigningMethodHS256, claims).SignedString([]byte(secret))
if err != nil {
    return "", fmt.Errorf("create: sign token: %w", err)
}
```

Client keys tab

The client offer many different ways of configuring the authentication keys.

To use the JWKS option we need to create a jwks from our private key or public key.

The following code performs this operation:

PEM to JWKS

```
package main

import (
    "crypto/rsa"
    "crypto/sha1"
    "crypto/x509"
    "encoding/base64"
    "encoding/json"
    "encoding/pem"
    "flag"
    "fmt"
    "golang.org/x/crypto/ssh"
    "io/ioutil"
    "math/big"
)

type Jwks struct {
    Keys []Key `json:"keys"`
}

type Key struct {
    Kid string `json:"kid,omitempty"`
    Kty string `json:"kty"`
    Use string `json:"use"`
    N    string `json:"n"`
    E    string `json:"e"`
    X5c []string `json:"x5c"`
    X5t string `json:"x5t"`
}

var keyFile string
var keyType string
var certFile string

func getKeyFromPrivate(key []byte) (*rsa.PublicKey){
    parsed, err := ssh.ParseRawPrivateKey(key)
    if err != nil {
        fmt.Println(err)
    }

    // Convert back to an *rsa.PrivateKey
    privateKey := parsed.(*rsa.PrivateKey)

    publicKey := &privateKey.PublicKey
    return publicKey
}

func getKeyFromPublic(key []byte) (*rsa.PublicKey){
    pubPem, _ := pem.Decode(key)

    parsed, err := x509.ParsePKIXPublicKey(pubPem.Bytes)
    if err != nil {
        fmt.Println("Unable to parse RSA public key", err)
    }

    // Convert back to an *rsa.PublicKey
    publicKey := parsed.(*rsa.PublicKey)

    return publicKey
}

func getCert(cert []byte) *x509.Certificate {
    certPem, _ := pem.Decode(cert)
    if certPem == nil {
        panic("Failed to parse pem file")
    }
}
```

```

    }

    // pass cert bytes
    certificate, err := x509.ParseCertificate(certPem.Bytes)
    if err != nil {
        fmt.Println("Unable to parse Certificate", err)
    }

    return certificate
}

func main() {
    flag.StringVar(&keyFile, "keyFile", "/mnt/c/Users/ktimoney/keycloak-certs/client_pub.key", "Location of
key file")
    flag.StringVar(&keyType, "keyType", "public", "Type of key file")
    flag.StringVar(&certFile, "certFile", "/mnt/c/Users/ktimoney/keycloak-certs/client.crt", "Location of
cert file")
    flag.Parse()

    key, err := ioutil.ReadFile(keyFile)
    if err != nil {
        fmt.Println(err)
    }

    var publicKey *rsa.PublicKey

    if keyType == "public" {
        publicKey = getKeyFromPublic(key)
    } else {
        publicKey = getKeyFromPrivate(key)
    }

    cert, err := ioutil.ReadFile(certFile)
    if err != nil {
        fmt.Println(err)
    }

    certificate := getCert(cert)
    // generate fingerprint with sha1
    // you can also use md5, sha256, etc.
    fingerprint := sha1.Sum(certificate.Raw)

    jwksKey := Key{
        Kid: "SIGNING_KEY",
        Kty: "RSA",
        Use: "sig",
        N: base64.RawStdEncoding.EncodeToString(publicKey.N.Bytes()),
        E: base64.RawStdEncoding.EncodeToString(big.NewInt(int64(publicKey.E)).Bytes()),
        X5c: []string{base64.RawStdEncoding.EncodeToString(certificate.Raw)},
        X5t: base64.RawStdEncoding.EncodeToString(fingerprint[:])},
    }
    jwksKeys := []Key{jwksKey}
    jwks := Jwks{jwksKeys}

    jwksJson, err := json.Marshal(jwks)
    if err != nil {
        fmt.Println(err)
        return
    }
    fmt.Println(string(jwksJson))
}

```

The output will look like this:

For this to work with you JWT code you'll need to copy the "kid" value and update you code so this is included in the header: This is necessary when the JWKS has multiple keys.

JWT snippet

```
claims["iss"] = "jwtclient3"
claims["aud"] = "https://192.168.49.2:31561/auth/realms/x509"

token := jwt.NewWithClaims(jwt.SigningMethodRS256, claims)
token.Header["kid"] = "AKAwbsKtqu90mIwIsPOUf5zTJkIC73hzY9Myv4srjTs"
tokenString, err := token.SignedString(key)
if err != nil {
    return "", fmt.Errorf("create: sign token: %w", err)
}

return tokenString, nil
}
```

Keycloak Authorization code grant

The OAuth Authorization Code Grant flow is recommended if your application support redirects.
e.g. your application is a Web application or a mobile application.

See this link to see how to setup your client - [Keycloak: Authorization Code Grant Example](#)

Here is a sample shell script to retrieve an authorization code:

Authorization Code

```
#!/bin/sh
HOST=$(minikube ip)
KEYCLOAK_PORT=$(kubectl -n default get service keycloak -o jsonpath='{.spec.ports[?(@.name=="http")].nodePort}')
REALM="jwtrealm"
CLIENT="jwtsecret"
AUTH_USERNAME="jwtuser"
AUTH_PASSWORD="secret"
STATE=$(uuidgen)

URL="http://$HOST:$KEYCLOAK_PORT/auth/realms/$REALM/protocol/openid-connect/auth?
client_id=$CLIENT&response_type=code&state=$STATE"
STDOUT=$(curl -s -X GET $URL --insecure -D headers.out)
COOKIES=$(cat headers.out | grep set-cookie | cut -f2 -d' ' | tr -d '\n')
LOGIN_URL=$(echo $STDOUT | sed s'/. * action=//g' | cut -f1 -d' ' | sed s' /\\"/>

```

To set this up so it retrieves the JWT access token once logged in we must configure the keycloak client with a "Valid Redirect URI", in this case it will be "<https://192.168.49.2:31233/callback>"

The following go sever is running at this URI:

Authorization server callback

```

package main

import (
    "encoding/json"
    "fmt"
    "io/ioutil"
    "net/http"
    "net/url"
)

type Jwttoken struct {
    Access_token      string
    Expires_in        int
    Refresh_expires_in int
    Refresh_token      string
    Token_type         string
    Not_before_policy  int
    Session_state      string
    Scope              string
}

var jwt Jwttoken

func getToken(auth_code string) string {
    clientSecret := "Ctz6aBahmjQvAt7Lwgg8qDNSniuPkNCC"
    clientId := "jwtsecret"
    realmName := "jwtrealm"
    keycloakHost := "keycloak"
    keycloakPort := "8080"
    keycloakUrl := "http://" + keycloakHost + ":" + keycloakPort + "/auth/realms/" + realmName + "/protocol
/openid-connect/token"
    resp, err := http.PostForm(keycloakUrl,
        url.Values{"code": {auth_code}, "grant_type": {"authorization_code"},
            "client_id": {clientId}, "client_secret": {clientSecret}})

    if err != nil {
        fmt.Println(err)
        panic("Something wrong with the credentials or url ")
    }
    defer resp.Body.Close()
    body, err := ioutil.ReadAll(resp.Body)
    fmt.Println(string(body))
    json.Unmarshal([]byte(body), &jwt)
    return jwt.Access_token
}

func noprefix(res http.ResponseWriter, req *http.Request) {
    // create response binary data
    data := []byte("Authorization code default") // slice of bytes
    // write `data` to response
    res.Write(data)
}

func callback(res http.ResponseWriter, req *http.Request) {
    query := req.URL.Query()
    code := query.Get("code")
    token := getToken(code)
    res.WriteHeader(http.StatusOK)
    res.Write([]byte(token))
}

func main() {
    // create a new handler
    callbackHandler := http.HandlerFunc(callback)
    http.Handle("/callback", callbackHandler)
    noPrefixHandler := http.HandlerFunc(noprefix)
    http.Handle("/", noPrefixHandler)
    http.ListenAndServe(":9000", nil)
}

```

Login will trigger a call to the /callback endpoint which in turn gets the JWT token and returns it to the user.

PKCE

PKCE stands for Proof Key for Code Exchange and the PKCE-enhanced Authorization Code Flow builds upon the standard Authorization Code Flow and it provides an additional level of security for OAuth clients.

For setting up the keycloak realm, client and user please see : [PKCE Verification in Authorization Code Grant](#)

In this example I will use a confidential client called oauth2-pkce in the OAuth2Realm.

I have also added an audience mapper to map the client to the token.

You will need to copy the client secret into the code for this to work.

Download the go code: [oauth2.go](#)

Update the code to match your keycloak setup.

Once the code has compiled create your docker image using: [Dockerfile_oauth2](#)

Start the service using: [oauth2.yaml](#)

This program uses PKCE code_challenge and code_challenge_method parameters when making the authorization code request and the PKCE code_verifier parameter when exchanging the authorization code for a token.

If running on windows you may need to start a tunnel so your services are accessible from your windows browser (see [Accessing apps](#))

You may also need to update your hosts file to add an alias of keycloak for your local ip. (e.g. 127.0.0.1 keycloak)

This is important because the iss of the token needs to match the keycloak url you provide.

If everything has been setup correctly when you hit the endpoint <http://localhost:9000/> you should be redirected to the keycloak login screen.

Enter a username and password for your realm.

The authorization code will be sent to your call back URL (redirect_uri) where it can be exchanged for a token.

The token will be printed on the screen.

It should look something like this:

[illegible]

```
curl -H "Authorization: Bearer $TOKEN" localhost:9000
Hello World OAuth2!
```

Keycloak Rest API

Below is some sample code that calls the clients rest api to create a new client:

Keycloak Client Rest API

```
export ADMIN_TKN=$(curl -s -X POST --insecure https://$HOST:$KEYCLOAK_PORT/auth/realms/master/protocol/openid-connect/token \
-H "Content-Type: application/x-www-form-urlencoded" \
-d "username=admin" \
-d 'password=admin' \
-d 'grant_type=password' \
-d 'client_id=admin-cli' | jq -r '.access_token')
echo "ADMIN CLIENT TOKEN = $ADMIN_TKN"

curl -X POST --insecure https://$HOST:$KEYCLOAK_PORT/auth/admin/realms/x509provider/clients \
-H "authorization: Bearer $ADMIN_TKN" \
-H "Content-Type: application/json" \
--data \
{
  "id": "x509Client",
  "name": "x509Client",
  "enabled": "true",
  "defaultClientScopes": ["email"],
  "redirectUris": ["*"],
  "attributes": {"use.refresh.tokens": "true", "client_credentials.use_refresh_token": "true"}
}
```

Keycloak SSO & User management

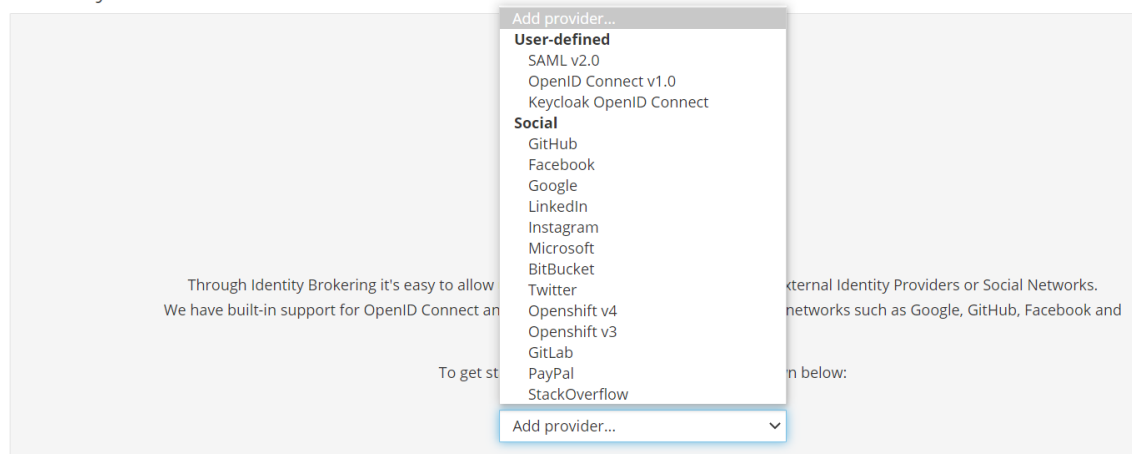
Identity Providers

You can use keycloak for single-sign so users don't have to login to each application individually.

You can also use external identity providers such as google or github if required.

See the "Identity Providers" menu in the keycloak UI.

Identity Providers



User Federation

You can also use existing LDAP, active directory servers or relational databases for user management if this is required.

[Open Source Identity and Access Management](#)

See the "User Federation" menu in the keycloak UI.

Keycloak Authorization services

[Authorization Services Guide](#)

[Keycloak Quickstarts Code Repository](#)

[REST Service Protected Using Keycloak Authorization Services](#)

[Easily secure your Spring Boot applications with Keycloak](#)

[A Quick Guide to Using Keycloak with Spring Boot](#)

[Istio External Authorization](#)

[Redhat AUTHORIZATION SERVICES](#)

[Sample External Authorization Server with Istio](#)

Working example

1. To use keycloak authorization services start by creating a confidential client.
2. Set "Authorization Enabled" to on.
3. Create 2 roles rapp_admin and rapp_user and assigned them to the service account.
4. Click on the authorization tab for the client to setup your authorization policies.
5. Start by creating 4 scopes (create,edit, delete and view) in the "Authorization scopes" section
6. Next create a resource "Rapp resource", set the URI to /api/resources/* and set the scopes to create,edit, delete and view.
7. Next create a policy "View Policy", select the "rapp_user" role and set required to on.
8. Create an "Admin policy", select the "rapp_admin" role and set required to on.
9. In the permission section, create a "Scope Based" permission - for resource choose the "Rapp resource" created earlier, scope should be set to view and select the "View Policy" for policy.
10. Create another "Scope Based" permission - for resource choose the "Rapp resource" created earlier, scope should be set to create, edit and delete and select the "Admin Policy" for policy.

Create a spring-boot application to work with this "resource server"

The following 4 files are all that is required:

[pom.xml](#)

[application.properties](#)

[MyApplication.java](#)

[ApplicationController.java](#)

Use mvn clean package spring-boot:repackage to create the jar file

Use mvn spring-boot:run to run the application from the comand line.

Alternatively you can package the jar into a docker file and run the app as part of your cluster

[Dockerfile](#)

[rapp-resource-server.yaml](#)

To test use the following script:

[test.sh](#)

You should see the following output:

GET request using service account access token
GET resources 1

PUT request using service account access token
PUT resources 1

POST request using service account access token
POST resources id=1

GET request using service account requesting party token
GET resources 1

POST request using service account requesting party token
POST resources id=1

PUT request using service account requesting party token
PUT resources 1

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 you specify policy as code and simple APIs to offload policy decision-making from your software.

OPA policies are expressed in a high-level declarative language called Rego. Rego is purpose-built for expressing policies over complex hierarchical data structures.

It even has a VSCode plugin that lets you highlight and evaluate rules and query policies right within the IDE.

[Policy-based control for cloud native environments](#)

[Introducing Policy As Code: The Open Policy Agent \(OPA\)](#)

[Istio External Authorization with OPA](#)

[Rego playground](#)

[OPA and Istio Tutorial](#)

[Dynamic Policy Composition for OPA](#)

[Open Policy Agent: Authorization in a Cloud Native World](#)

[OPA On Kubernetes](#)

[Kubernetes Admission Control](#)

[Microservices Authorization using Open Policy Agent and Traefik \(API Gateway\)](#)

[A Study in Serverless Authorization with Open Policy Agent](#)

[OpenFaaS OPA](#)

[Godaddy Opa Lambda Extension Plugin](#)

[Extending OPA](#)

[OPA Ecosystem](#)

GO

Go provides a library for opa.

GO OPA

```
package main

import (
    "context"
    "encoding/json"
    "fmt"
    "github.com/open-policy-agent/opa/rego"
    "io/ioutil"
    "net/http"
    "net/url"
    "os"
)

type Jwttoken struct {
    Access_token      string
    Expires_in        int
    Refresh_expires_in int
    Refresh_token     string
}
```

```

        Token_type      string
        Not_before_policy int
        Session_state   string
        Scope            string
    }

    var token JwtToken

    var opaPolicy string = `
package authz

import future.keywords.in

default allow = false

jwks := jwks_request("http://keycloak:8080/auth/realms/opa/protocol/openid-connect/certs").body
filtered_jwks := [ key |
    some key in jwks.keys
    key.use == "sig"
]
token_cert := json.marshal({"keys": filtered_jwks})

token = { "isValid": isValid, "header": header, "payload": payload } {
    [isValid, header, payload] := io.jwt.decode_verify(input, { "cert": token_cert, "aud": "account",
"iss": "http://keycloak:8080/auth/realms/opa"})
}

allow {
    is_token_valid
}

is_token_valid {
    token.isValid
    now := time.now_ns() / 1000000000
    token.payload.iat <= now
    now < token.payload.exp
    token.payload.clientRole == "[opa-client-role]"
}

jwks_request(url) = http.send({
    "url": url,
    "method": "GET",
    "force_cache": true,
    "force_json_decode": true,
    "force_cache_duration_seconds": 3600 # Cache response for an hour
})

func getToken() string {
    clientSecret := "63wkv0RUXkp01pbqtNTSwghhTxemW55I"
    clientId := "opacli"
    realmName := "opa"
    keycloakHost := "keycloak"
    keycloakPort := "8080"
    keycloakUrl := "http://" + keycloakHost + ":" + keycloakPort + "/auth/realms/" + realmName + "/protocol
/openid-connect/token"
    resp, err := http.PostForm(keycloakUrl,
        url.Values{"client_secret": {clientSecret}, "grant_type": {"client_credentials"}, "client_id":
{clientId}})
    if err != nil {
        fmt.Println(err)
        panic("Something wrong with the credentials or url ")
    }
    defer resp.Body.Close()
    body, err := ioutil.ReadAll(resp.Body)
    json.Unmarshal([]byte(body), &token)
    return token.Access_token
}

func traceOpa(input string) {
    ctx := context.TODO()

```

```

    test := rego.New(
        rego.Query("x = data.authz.allow"),
        rego.Trace(true),
        rego.Module("example.rego", opaPolicy),
        rego.Input(input),
    )

    test.Eval(ctx)
    rego.PrintTraceWithLocation(os.Stdout, test)
}

func evaluateOpa(input string) {
    ctx := context.TODO()

    query, err := rego.New(
        rego.Query("x = data.authz.allow"),
        rego.Module("example.rego", opaPolicy),
    ).PrepareForEval(ctx)
    if err != nil {
        // Handle error.
        fmt.Println(err.Error())
    }

    results, err := query.Eval(ctx, rego.EvalInput(input))
    // Inspect results.
    if err != nil {
        // Handle evaluation error.
        fmt.Println("Error: " + err.Error())
    } else if len(results) == 0 {
        // Handle undefined result.
        fmt.Println("Results are empty")
    } else {
        // Handle result/decision.
        fmt.Printf("Results = %v\n", results) //=> [{Expressions:[true] Bindings:map[x:true]}]
    }
}

func main() {
    tokenStr := getToken()
    traceOpa(tokenStr)
    evaluateOpa(tokenStr)
}

```

OPA bundles and dynamic composition

Method 1

We can combine OPA bundles with dynamic composition to provide different policies for different services.

In the root directory of your bundle create main.rego

main.rego

```
package main

import input.attributes.request.http as http_request

default allow = false

name := trim_prefix(replace(http_request.path, "-", ""), "/")

router[policy] = data.policies[name][policy].deny

deny[msg] {
    policy := router[_]
    msg := policy[_]
}

allow {
    count(deny) == 0
}
```

This main policy will use the request path to determine which policy to apply. (We remove the forward slash and and "-" characters)

Create a directory policies/<app name> off the main directory.

In here create a policy called policy.rego

policy.rego

```
package policies.rappopaprovider.policy

import input.attributes.request.http as http_request
import future.keywords.in

realm_name := "opa"
realm_url := sprintf("http://keycloak:8080/auth/realms/%v", [realm_name])
certs_url := sprintf("%v/protocol/openid-connect/certs", [realm_url])

jwks := jwks_request(certs_url).body
filtered_jwks := [ key |
    some key in jwks.keys
    key.use == "sig"
]
token_cert := json.marshal({"keys": filtered_jwks})

token = { "isValid": isValid, "header": header, "payload": payload } {
    [_, encoded] := split(http_request.headers.authorization, " ")
    [isValid, header, payload] := io.jwt.decode_verify(encoded, { "cert": token_cert, "aud": "account",
"iss": realm_url})
}

deny[msg] {
    not is_token_valid
    msg = "denied by rappopaprovider.policy: not a valid token"
}

is_token_valid {
    token.isValid
    now := time.now_ns() / 1000000000
    token.payload.iat <= now
    now < token.payload.exp
    token.payload.clientRole == "[opa-client-role]"
}

jwks_request(url) = http.send({
    "url": url,
    "method": "GET",
    "force_cache": true,
    "force_json_decode": true,
    "force_cache_duration_seconds": 3600 # Cache response for an hour
})
```

This policy will verify the jwt token, check the token issue time and expiration time against the current time and also ensure the token contains the correct role.

If all these condtions are met the user will be granted access to the resource.

NGINX can be used for the bundles server: [nginx.yaml](#)

OPA server: [opa.yaml](#)

rapp-opa-provider: [rapp-opa-provider.yaml](#)

To test retrieve the access token from keycloak and run the curl command for the rapp-opa-provider url

opa_test.sh

```
#!/bin/bash
INGRESS_HOST=$(minikube ip)
INGRESS_PORT=$(kubectl -n istio-system get service istio-ingressgateway -o jsonpath='{.spec.ports[?(@.name=="http2")].nodePort}')
TESTS=0
PASSED=0
FAILED=0
TEST_TS=$(date +%F-%T)
TOKEN=""
ACCESS_TOKEN=""
REFRESH_TOKEN=""

function get_token
{
    local prefix="${1}"
    url="http://${KEYCLOAK_HOST}:${KEYCLOAK_PORT}/auth/realms"
    TOKEN=$(curl -s -X POST $url/opa/protocol/openid-connect/token -H \
        "Content-Type: application/x-www-form-urlencoded" -d \
        client_secret=63wkv0RUXkp01pbqtNTSwghhTxEMW55I \
        -d 'grant_type=client_credentials' -d client_id=opacli)
    ACCESS_TOKEN=$(echo $TOKEN | jq -r '.access_token')
}

function run_test
{
    local prefix="${1}" type=${2} msg="${3}" data=${4}
    TESTS=$((TESTS+1))
    echo "Test ${TESTS}: Testing $type /${prefix}"
    get_token $prefix
    url=$INGRESS_HOST:$INGRESS_PORT/"$prefix
    result=$(curl -s -X ${type} -H "Content-type: application/json" -H "Authorization: Bearer $ACCESS_TOKEN" $url)
    echo $result
    if [ "$result" != "$msg" ]; then
        echo "FAIL"
        FAILED=$((FAILED+1))
    else
        echo "PASS"
        PASSED=$((PASSED+1))
    fi
    echo ""
}

run_test "rapp-opa-provider" "GET" "Hello OPA World!" ""

echo
echo "-----"
echo "Number of Tests: $TESTS, Tests Passed: $PASSED, Tests Failed: $FAILED"
echo "Date: $TEST_TS"
echo "-----"
```

Method 2

We can also organize the policies in the following way.

Create a new file in your bundle to do the common processing:

Common Rules

```
package policy.common.request

import input.attributes.request.http as http_request
import future.keywords.in

policy_realms := {
    "rappopaprovider": "opa"
}

method = http_request.method
path = input.parsed_path
policy = trim_prefix(replace(http_request.path, "-", ""), "/")

realm_name := policy_realms[policy]
realm_url := sprintf("http://keycloak:8080/auth/realms/%v", [realm_name])
certs_url := sprintf("%v/protocol/openid-connect/certs", [realm_url])

jwks := jwks_request(certs_url).body
filtered_jwks := [ key |
    some key in jwks.keys
    key.use == "sig"
]
token_cert := json.marshal({"keys": filtered_jwks})

token = { "isValid": isValid, "header": header, "payload": payload } {
    [_, encoded] := split(http_request.headers.authorization, " ")
    [isValid, header, payload] := io.jwt.decode_verify(encoded, { "cert": token_cert, "aud": "account",
"iss": realm_url})
}

jwks_request(url) = http.send({
    "url": url,
    "method": "GET",
    "force_cache": true,
    "force_json_decode": true,
    "force_cache_duration_seconds": 3600 # Cache response for an hour
})

user = token.payload.sub
clientRole = token.payload.clientRole
audience = token.payload.aud
exp = token.payload.exp
iat = token.payload.iat
```

Create another rules.rego file for you application e.g. policy/services/rappopaprovider/ingress/rules.rego

Application rules

```
package policy.services.rappopaprovider.ingress

import data.policy.common.request

allow = true {
    request.token.isValid
    request.method == "GET"
    request.path == [ "rapp-opa-provider" ]
    now := time.now_ns() / 1000000000
    request.iat <= now
    now < request.exp
    request.clientRole == "[opa-client-role]"
}
```

Lastly create the parent rules file that will call the appropriate policy based on the http request path

Main Rules

```
package policy.ingress

import data.policy.common.request
import data.policy.services

allow = true {
  services[request.policy].ingress.allow
}
```

To use this set of rules make sure opa is pointing to the parent rules file : `--set=plugins.envoy_ext_authz_grpc.query=data.policy.ingress.allow`

Note If you do not wish to validate the jet you can use this code instead:

```
token = { "isValid": isValid, "payload": payload } {
  authorization_header := input.attributes.request.http.headers.authorization
  encoded_token := trim_prefix(authorization_header, "Bearer ")
  payload := io.jwt.decode(encoded_token)[1]
  isValid := true
}
```

OPA with prometheus and grafana

Add the following job to your prometheus.yaml file in the scrape_configs section:

```
- job_name: opa
  scrape_interval: 10s
  metrics_path: /metrics
  static_configs:
  - targets:
    - opa.default:8181
```

This will enable metric collection from the opa /metrics endpoint:

The full list is available here: [Open Policy Agent Monitoring](#)

Download the OPA metrics dashboard from grafana and import it into your grafana instance [Open Policy Agent Metrics Dashboard](#)

In the instance dropdown, type opa.default:8181 (assuming opa is running in the default namespace and metrics are being served on port 8181)

You should see a dashboard similar to the following:


```

MTI3LjAuMCM4M2IiwiZW1hawxfdmVyawZpZWQiomZhbHNlLCJjbGllbnRSb2x1Ijoiw29wYS1jbGllbnQtcm9sZV0iLCJwcmVmZXXJyZWRFdXNlcm5h
bWUiOiJzZXJ2aWNLlWfjY291bnQtb3BhY2xpIiwiY2xpZW50QWRkcmlVZcyI6IjEyNy4wLjAuNiJ9.k_NtngXgwyTPB2z8IArnqxvx3iYP18xc-
1fwQoZ0Az2BOK3kfWrdSmIngn_ilwLXrTSdX-
n_Tx_o2NLlwQ13RMRXN5zoJaCnU2iSXvel7hjYA_PSDZbv3MW1boqOZmqzuTA5ugRXuVAGQ42k0PIPnwqSm6JujUGfVzB_mrc43I3jXNuHuqwx6m
iat4NmJo2MCxM_Y1s39ixxREfQIovqFz1ky69IKfz8QcxyFhSsCmydjK4T6HufC3_SJO0XaBKWAoJpdcgdom1kYcIeoGxWwn3lX5E0kQ3eL4TH0F
6IfCtjLZwFlzlhTdjItD6ddglJpEsc6rcuLw-06_VyjeqzSg",
  "content-type": "application/json",
  "user-agent": "curl/7.68.0",
},
{
  "host": "192.168.49.2:31000",
  "id": "15472195549358141958",
  "method": "GET",
  "path": "/rapp-opa-provider",
  "protocol": "HTTP/1.1",
  "scheme": "http"
},
{
  "time": "2022-06-28T07:07:47.099076Z"
},
{
  "source": {
    "address": {
      "socketAddress": {
        "address": "172.17.0.4",
        "portValue": 54862
      }
    },
    "principal": "spiffe://cluster.local/ns/istio-system/sa/istio-ingressgateway-service-account"
  }
},
{
  "parsed_body": null,
  "parsed_path": [
    "rapp-opa-provider"
  ],
  "parsed_query": {},
  "truncated_body": false,
  "version": {
    "encoding": "protojson",
    "ext_authz": "v3"
  }
}
}

default allow = false

allow = true {
  services[request.policy].ingress.allow
}

```

```

opa eval --data rbactest.rego --profile --count=100 --format=pretty 'data.rbactest.allow'
false

```

```

+-----+-----+-----+-----+-----+
| METRIC | MIN | MAX | MEAN | 90% | 99% |
+-----+-----+-----+-----+-----+
| timer_rego_external_resolve_ns | 300 | 2400 | 461 | 600 | 2382.9999999999914 |
| timer_rego_load_files_ns | 3069300 | 6160300 | 4.024052e+06 | 4.82397e+06 | 6.1526629999999996e+06 |
| timer_rego_module_compile_ns | 690400 | 2288700 | 983743 | 1.42366e+06 | 2.28638199999999986e+06 |
| timer_rego_module_parse_ns | 439300 | 1834400 | 613517 | 882270.0000000001 | 1.832610999999999e+06 |
| timer_rego_query_compile_ns | 49500 | 190100 | 68390 | 93410 | 189761.99999999983 |
| timer_rego_query_eval_ns | 25600 | 423300 | 40197 | 42630.00000000001 | 421415.99999999907 |
| timer_rego_query_parse_ns | 44700 | 674500 | 70035 | 81690 | 671625.9999999986 |
+-----+-----+-----+-----+-----+
| MIN | MAX | MEAN | 90% | 99% | NUM EVAL | NUM REDO | LOCATION |
+-----+-----+-----+-----+-----+
| 14.1µs | 404µs | 25.251µs | 28.82µs | 402.438µs | 1 | 1 | data.rbactest.allow |
| 9.8µs | 27.8µs | 12.843µs | 16.48µs | 27.756µs | 1 | 1 | rbactest.rego:62 |
+-----+-----+-----+-----+-----+

```

```

opa bench --data rbactest.rego 'data.rbactest.allow'
+-----+
| samples | 22605 |
| ns/op   | 47760 |
| B/op    | 6269  |
| allocs/op | 112  |
| histogram_timer_rego_external_resolve_ns_75% | 400 |
| histogram_timer_rego_external_resolve_ns_90% | 500 |
| histogram_timer_rego_external_resolve_ns_95% | 500 |
| histogram_timer_rego_external_resolve_ns_99% | 871 |
| histogram_timer_rego_external_resolve_ns_99.9% | 29394 |
| histogram_timer_rego_external_resolve_ns_99.99% | 29800 |
| histogram_timer_rego_external_resolve_ns_count | 22605 |
| histogram_timer_rego_external_resolve_ns_max | 29800 |
| histogram_timer_rego_external_resolve_ns_mean | 434 |
| histogram_timer_rego_external_resolve_ns_median | 400 |
| histogram_timer_rego_external_resolve_ns_min | 200 |
| histogram_timer_rego_external_resolve_ns_stddev | 1045 |
| histogram_timer_rego_query_eval_ns_75% | 31100 |
| histogram_timer_rego_query_eval_ns_90% | 37210 |
| histogram_timer_rego_query_eval_ns_95% | 47160 |
| histogram_timer_rego_query_eval_ns_99% | 91606 |
| histogram_timer_rego_query_eval_ns_99.9% | 630561 |
| histogram_timer_rego_query_eval_ns_99.99% | 631300 |
| histogram_timer_rego_query_eval_ns_count | 22605 |
| histogram_timer_rego_query_eval_ns_max | 631300 |
| histogram_timer_rego_query_eval_ns_mean | 29182 |
| histogram_timer_rego_query_eval_ns_median | 25300 |
| histogram_timer_rego_query_eval_ns_min | 15200 |
| histogram_timer_rego_query_eval_ns_stddev | 32411 |
+-----+

```

OPA & Minio

[OPA & MinIO's Access Management Plugin](#)

OPA Sidecar injection

First create a namespace for your apps and enable istio and opa

```

kubectl create ns opa
kubectl label namespace opa opa-istio-injection="enabled"
kubectl label namespace opa istio-injection="enabled"

```

Create the opa injection ojects using:

```

kubectl create -f opa\_inject.yaml

```

Ensure your istio mesh config has been setup to include grpc local authorizer

```

kubectl edit configmap istio -n istio-system

```

extensionProviders

```

extensionProviders:
- envoyExtAuthzGrpc:
    port: "9191"
    service: local-opa-grpc.local
    name: opa-local

```

Update your rapp-provider authorization policy to use this provider:

AuthorizationPolicy

```
apiVersion: security.istio.io/v1beta1
kind: AuthorizationPolicy
metadata:
  name: rapp-opa-provider-opa
  namespace: opa
spec:
  selector:
    matchLabels:
      app: rapp-opa-provider
  action: CUSTOM
  provider:
    name: "opa-local"
  rules:
  - to:
    - operation:
        paths: ["/rapp-opa-provider"]
        notPaths: ["/health"]
```

Run the `opa_test.sh` script above and you should see a message confirming your connection to the service.

Note: References to keycloak need to be updated to include the keycloak schema i.e `keycloak.default`

Basic Authentication

We can add basic authentication to our NGINX bubble server by following these steps:

Create a password file using the following command: `sudo htpasswd -c .htpasswd <user>`, you will be prompted to input the password.

This will produce a file called `.htpasswd` containing the username and encrypted password

e.g. `admin:$apr1$tPQCjrVW$okcSj4QVknCEDna0Fc2o/`

Add the following configmap definitions to your `nginx.yaml`

configMaps

```
apiVersion: v1
kind: ConfigMap
metadata:
  name: nginx-pwd-config
  namespace: default
data:
  .htpasswd: |
    admin:$apr1$tPQCjrVW$sokcSj4QVknCEDna0Fc2o/
---
apiVersion: v1
kind: ConfigMap
metadata:
  name: nginx-conf-config
  namespace: default
data:
  default.conf: |
    server {
      server_name localhost;

      location ~ ^/bundles/(.*)$ {
        root /usr/share/nginx/html/bundles;
        try_files $1 =404;
        auth_basic "Restricted";
        auth_basic_user_file /etc/nginx/conf.d/conf/.htpasswd;
      }
    }
---
```

Then update your volumes and volume mounts to include these files with your deployment

Volumes

```
volumeMounts:
- name: bundlesdir
  mountPath: /usr/share/nginx/html/bundles
  readOnly: true
- name: nginx-conf
  mountPath: /etc/nginx/conf.d/default.conf
  subPath: default.conf
- name: nginx-pwd
  mountPath: /etc/nginx/conf.d/conf/.htpasswd
  subPath: .htpasswd
volumes:
- name: bundlesdir
  hostPath:
    # Ensure the file directory is created.
    path: /var/opa/bundles
    type: DirectoryOrCreate
- name: nginx-conf
  configMap:
    name: nginx-conf-config
    defaultMode: 0644
- name: nginx-pwd
  configMap:
    name: nginx-pwd-config
    defaultMode: 0644
```

This will add basic authentication to your bundles directory.

Run `echo -n <username>:<password> | base64` to encrypt your username and password

e.g. `echo -n admin:admin | base64`
`YWRtaW46YWRtaW4=`

Update the opa-istio-config ConfigMap in the opa_inject.yaml file to include the encrypted string as a token in the credentials section:

opa-istio-config

```
apiVersion: v1
kind: ConfigMap
metadata:
  name: opa-istio-config
  namespace: opa
data:
  config.yaml: |
    plugins:
      envoy_ext_authz_grpc:
        addr: :9191
        path: policy/ingress/allow
    decision_logs:
      console: true
    services:
      - name: bundle-server
        url: http://bundle-server.default
        credentials:
          bearer:
            token: YWRtaW46YWRtaW4=
            scheme: Basic

    bundles:
      authz:
        service: bundle-server
        resource: bundles/opa-bundle.tar.gz
        persist: true
        polling:
          min_delay_seconds: 10
          max_delay_seconds: 20
---
```

Your bundle is now protected with basic authentication.

JWT Injection

To enable automatic include a jwt token in our rapp request we need to enable some k8s objects:

1) MutatingWebhookConfiguration to inject jwt retrieval pod as a sidecar. The MutatingWebhookConfiguration uses a pod mutating serive to alter our pod and add the new sidecar.

Mutating Webhook

```
package main

import (
    "encoding/json"
    "errors"
    "flag"
    "fmt"
    "io/ioutil"
    "k8s.io/api/admission/v1beta1"
    v1 "k8s.io/api/core/v1"
    "k8s.io/apimachinery/pkg/runtime"
    "k8s.io/apimachinery/pkg/runtime/serializer"
    "log"
    "net/http"
    "strconv"
)

type ServerParameters struct {
    port    int    // webhook server port
```



```

    certFile string // path to the x509 cert
    keyFile  string // path to the x509 private key
}

type patchOperation struct {
    Op    string    `json:"op"`
    Path  string    `json:"path"`
    Value interface{} `json:"value,omitempty"`
}

var parameters ServerParameters
var (
    universalDeserializer = serializer.NewCodecFactory(runtime.NewScheme()).UniversalDeserializer()
)

func main() {
    flag.IntVar(&parameters.port, "port", 8443, "Webhook server port.")
    flag.StringVar(&parameters.certFile, "tlsCertFile", "/certs/tls.crt", "File containing the x509 certificate")
    flag.StringVar(&parameters.keyFile, "tlsKeyFile", "/certs/tls.key", "File containing the x509 private key")
    flag.Parse()

    http.HandleFunc("/inject-sidecar", HandleSideCarInjection)
    log.Fatal(http.ListenAndServeTLS(":"+strconv.Itoa(parameters.port), parameters.certFile, parameters.keyFile, nil))
}

func HandleSideCarInjection(w http.ResponseWriter, r *http.Request) {

    body, err := ioutil.ReadAll(r.Body)
    err = ioutil.WriteFile("/tmp/request", body, 0644)
    if err != nil {
        panic(err.Error())
    }

    var admissionReviewReq v1beta1.AdmissionReview

    if _, _, err := universalDeserializer.Decode(body, nil, &admissionReviewReq); err != nil {
        w.WriteHeader(http.StatusBadRequest)
        fmt.Errorf("Could not deserialize request: %v", err)
    } else if admissionReviewReq.Request == nil {
        w.WriteHeader(http.StatusBadRequest)
        errors.New("Malformed admission review - request is empty")
    }

    fmt.Printf("Received Admission Review Request - Type: %v \t Event: %v \t Name: %v \n",
        admissionReviewReq.Request.Kind,
        admissionReviewReq.Request.Operation,
        admissionReviewReq.Request.Name,
    )

    var pod v1.Pod

    err = json.Unmarshal(admissionReviewReq.Request.Object.Raw, &pod)

    if err != nil {
        fmt.Errorf("Could not unmarshal pod from admission request: %v", err)
    }

    var patches []patchOperation

    labels := pod.ObjectMeta.Labels
    labels["sidecar-injection-webhook"] = "jwt-proxy"

    patches = append(patches, patchOperation{
        Op:    "add",
        Path:  "/metadata/labels",
        Value: labels,
    })
}

```

```

var containers []v1.Container
containers = append(containers, pod.Spec.Containers...)
container := v1.Container{
    Name:        "jwt-proxy",
    Image:       "ktimoney/rapps-jwt",
    ImagePullPolicy: v1.PullIfNotPresent,
    Ports: []v1.ContainerPort{
        {
            Name:        "http",
            Protocol:    v1.ProtocolTCP,
            ContainerPort: 8888,
        },
    },
    VolumeMounts: []v1.VolumeMount{
        {
            Name:        "certsdir",
            MountPath: "/certs",
            ReadOnly:    true,
        },
    },
}

containers = append(containers, container)
fmt.Println(containers)

patches = append(patches, patchOperation{
    Op:    "add",
    Path:  "/spec/containers",
    Value: containers,
})

pathType := v1.HostPathDirectoryOrCreate
pathTypePtr := &pathType
var volumes []v1.Volume
volumes = append(volumes, pod.Spec.Volumes...)
volume := v1.Volume{
    Name: "certsdir",
    VolumeSource: v1.VolumeSource{
        HostPath: &v1.HostPathVolumeSource{
            Path: "/var/rapps/certs",
            Type: pathTypePtr,
        },
    },
}

volumes = append(volumes, volume)
fmt.Println(volumes)

patches = append(patches, patchOperation{
    Op:    "add",
    Path:  "/spec/volumes",
    Value: volumes,
})
fmt.Println(patches)

patchBytes, err := json.Marshal(patches)

if err != nil {
    fmt.Errorf("Error occurred when trying to marshal JSON patch: %v", err)
}

admissionReviewResponse := v1beta1.AdmissionReview{
    Response: &v1beta1.AdmissionResponse{
        UID:    admissionReviewReq.Request.UID,
        Allowed: true,
    },
}

admissionReviewResponse.Response.Patch = patchBytes

bytes, err := json.Marshal(&admissionReviewResponse)
if err != nil {

```

```
        fmt.Errorf("Error occurred when trying to marshal Admission Review response: %v", err)
    }

    w.Write(bytes)
}
```

[rapps-webhook.yaml](#)

[MutatingWebhookConfiguration.yaml](#)

Note: You'll need to configure your deployment to include a `tls.crt` and `tls.key` secret. Your `MutatingWebhookConfiguration` will need to include the corresponding `ca bundle`.

2) Envoyfilter to update request header with jwt token.

Envoy Filter

```

apiVersion: networking.istio.io/v1alpha3
kind: EnvoyFilter
metadata:
  name: RAPP-NAME-outbound-filter
  namespace: RAPP-NS
spec:
  workloadSelector:
    labels:
      app.kubernetes.io/name: RAPP-NAME
  configPatches:
    # The first patch adds the lua filter to the listener/http connection manager
    - applyTo: HTTP_FILTER
      match:
        context: SIDECAR_OUTBOUND
        listener:
          filterChain:
            filter:
              name: "envoy.filters.network.http_connection_manager"
              subFilter:
                name: "envoy.filters.http.router"
      patch:
        operation: INSERT_BEFORE
        value: # lua filter specification
        name: envoy.lua
        typed_config:
          "@type": "type.googleapis.com/envoy.extensions.filters.http.lua.v3.Lua"
          inlineCode: |
            function envoy_on_request(request_handle)
              local uri = request_handle:headers():get(":path")
              local method = request_handle:headers():get(":method")
              if (method ~= "POST" and path ~= "/auth/realms/REALM-NAME/protocol/openid-connect/token")
              then
                -- Make an HTTP call to an upstream host with the following headers, body, and timeout.
                local headers, body = request_handle:httpCall(
                  "jwt_cluster",
                  {
                    [":method"] = "GET",
                    [":path"] = "/token",
                    [":authority"] = "jwt-proxy",
                    ["realm"] = "REALM-NAME",
                    ["client"] = "CLIENT-NAME"
                  },
                  "jwt call",
                  5000)
                if (headers["authorization"] ~= nil)
                then
                  request_handle:headers():add("authorization", headers["authorization"])
                end
              end
            end
          end
    - applyTo: CLUSTER
      match:
        context: SIDECAR_OUTBOUND
      patch:
        operation: ADD
        value: # cluster specification
        name: jwt_cluster
        type: STRICT_DNS
        connect_timeout: 60s
        lb_policy: ROUND_ROBIN
        load_assignment:
          cluster_name: jwt_cluster
          endpoints:
            - lb_endpoints:
                - endpoint:
                    address:
                      socket_address:
                        address: 0.0.0.0
                        port_value: 8888

```

CFSSL

CFSSL is CloudFlare's PKI/TLS tool. It is both a command line tool and an HTTP API server for signing, verifying, and bundling TLS certificates.

To run this you first need to create an image with cfssl installed:

cfssl

```
FROM debian:latest
RUN apt-get update && apt-get install -y curl && \
curl -L https://github.com/cloudflare/cfssl/releases/download/v1.5.0/cfssl_1.5.0_linux_amd64 -o /usr/local/bin/cfssl && \
curl -L https://github.com/cloudflare/cfssl/releases/download/v1.5.0/cfssljson_1.5.0_linux_amd64 -o /usr/local/bin/cfssljson && \
chmod +x /usr/local/bin/cfssl && \
chmod +x /usr/local/bin/cfssljson
RUN mkdir /config
RUN mkdir /config
RUN mkdir /certs
WORKDIR /certs
EXPOSE 8888
EXPOSE 8889
ENTRYPOINT ["cfssl version"]
```

This will install cfssl on a debian image.

You can then use this image to create a cfssl service in your k8s cluster.

kubectl create -f [rapps-cfssl.yaml](#)

Note: If you want to use this with a postgres db you'll need to setup a new database and username/password and then create the tables.

cfssl create db and user

```
SELECT 'CREATE DATABASE cfssl'
WHERE NOT EXISTS (SELECT FROM pg_database WHERE datname = 'cfssl')\gexec
DO $$
BEGIN
    IF NOT EXISTS (SELECT FROM pg_user WHERE username = 'cfssl') THEN
        CREATE USER cfssl WITH PASSWORD 'cfssl';
        GRANT ALL PRIVILEGES ON DATABASE cfssl TO cfssl;
    END IF;
END
$$;
```

Login as the cfssl user then create the tables:

cfssl create tables

```
CREATE TABLE IF NOT EXISTS certificates (
  serial_number          bytea NOT NULL,
  authority_key_identifier bytea NOT NULL,
  ca_label               bytea,
  status                 bytea NOT NULL,
  reason                 int,
  expiry                 timestampz,
  revoked_at             timestampz,
  pem                    bytea NOT NULL,
  issued_at              timestampz,
  not_before             timestampz,
  metadata               jsonb,
  sans                   jsonb,
  common_name            TEXT,
  PRIMARY KEY(serial_number, authority_key_identifier)
);

CREATE TABLE IF NOT EXISTS ocsp_responses (
  serial_number          bytea NOT NULL,
  authority_key_identifier bytea NOT NULL,
  body                   bytea NOT NULL,
  expiry                 timestampz,
  PRIMARY KEY(serial_number, authority_key_identifier),
  FOREIGN KEY(serial_number, authority_key_identifier) REFERENCES certificates(serial_number,
  authority_key_identifier)
);
```

Once the pod is up and running you can connect to it by using port forwarding:

```
kubectl port-forward service/rapps-cfssl 8888:8888
```

You can generate signed certificates using a post request like the following:

```
curl -s -X POST -H "Content-Type: application/json" -d @./rapp-helloworld-provider-server.json http://127.0.0.1:8888/api/v1/cfssl/newcert
```

The rapp-helloworld-provider-server.json looks like this:

rapp-helloworld-provider-server

```
{
  "request":{
    "hosts":[
      "rapp-helloworld-provider"
    ],
    "names":[
      {
        "C":"IE",
        "ST":"Ireland",
        "L":"Dublin",
        "O":"EST Rapp Provider",
        "OU":"EST Rapp Provider hosts"
      }
    ],
    "CN":"rapp-helloworld-provider",
    "key":{
      "algo":"rsa",
      "size":2048
    }
  },
  "profile":"server"
}
```

To parse the response contents you can use the following method:

```
NEWCERT=$(curl -s -X POST -H "Content-Type: application/json" -d @./rapp-helloworld-provider-server.json http://127.0.0.1:8888/api/v1/cfssl/newcert)
echo $NEWCERT | jq -r .result.certificate
echo $NEWCERT | jq -r .result.private_key
```

OCSP & CRL

OCSP and CRL are ways of checking a certificates validity.

The cfssl crl endpoint run on port 8888: 127.0.0.1:8888/api/v1/cfssl/crl

For ocsp to run you need to run the following commands in your container:

```
cfssl ocspprefetch -db-config /config/db-pg.json -ca /certs/ca-server.pem -responder /certs/server-ocsp.pem -responder-key /certs/server-ocsp-key.pem
cfssl ocsppdump -db-config /config/db-pg.json > ocsppdump.txt
cfssl ocspsolve -port=8889 -responses=/config/ocsppdump.txt -loglevel=0
```

These commands will need to be re-run every time a new revoke request is received.

To revoke a certificate use:

```
curl -d '{ "serial": "708853190752997406197199597002842275021840632879", "authority_key_id": "dd2cdb5b5b8abbe2fba81fd6c04393938f802b03",
"reason": "superseded" }' http://localhost:8888/api/v1/cfssl/revoke
```

You can obtain the serial and authority_key_id from your database using the following SQL:

```
select encode(authority_key_identifier,'escape') a_key, encode(serial_number,'escape') serial, encode(status,'escape') status from certificates;
```

You can also obtain the serial and authority_key_id from the certinfo endpoint

1. Convert your certificate into a variable: pem=\$(cat my.crt | sed -z 's/\n/\n/g')
2. curl -d '{"certificate": ""'\$pem'""}' <http://localhost:8888/api/v1/cfssl/certinfo>
3. The serial number will come back as is but the authority_key_id needs to be converted: echo "22:8B:FA:ED:8B:FF:66:E7:05:A3:08:3A:41:33:D8:01:20:CA:CC:F4" | tr '[:upper:]' '[:lower:]' | sed s'://g' =228bfaed8bff66e705a3083a4133d80120caccf4

You can check your certificate against ocsp and crl using the following code:

Verifyc Certificate

```
package main

import (
    "bytes"
    "context"
    "crypto"
    "crypto/x509"
    "crypto/x509/pkix"
    "encoding/json"
    "encoding/pem"
    "flag"
    "fmt"
    "golang.org/x/crypto/ocsp"
    "io/ioutil"
    "log"
    "net/http"
    "net/url"
    "os"
    "time"
)

type Cinfo struct {
    Success string `json:"success,omitempty"`
    Result struct {
        Certificate string `json:"certificate"`
        Usages      []string `json:"usages"`
        Expiry      string  `json:"expiry"`
    }
    Errors  []string `json:"errors"`
    Messages []string `json:"messages"`
}
```

```

var cfinfo Cfinfo

type Crlinfo struct {
    Success bool    `json:"success,omitempty"`
    Result  string    `json:"result,omitempty"`
    Errors  []string  `json:"errors"`
    Messages []string `json:"messages"`
}

var crlinfo Crlinfo

type ServerParameters struct {
    certFile string // path to the x509 cert
    issuerUrl string // webhook server port
    crlUrl    string // webhook server port
}

var parameters ServerParameters

func main() {
    flag.StringVar(&parameters.certFile, "certFile", "", "File containing the x509 certificate")
    flag.StringVar(&parameters.issuerUrl, "issuerUrl", "http://127.0.0.1:8888/api/v1/cfssl/info", "Url for
retrieving the issuer certificate")
    flag.StringVar(&parameters.crlUrl, "crlUrl", "http://127.0.0.1:8888/api/v1/cfssl/crl", "Url for retrieving
the crl")
    flag.Parse()
    if parameters.certFile == "" {
        flag.Usage()
        os.Exit(1)
    }
    // read x509 certificate from PEM encoded file
    cert_bytes := readFile(parameters.certFile)
    cert, err := decodeCert(cert_bytes)
    if err != nil {
        log.Fatal(err)
    }

    issuer_bytes, err := getIssuer(parameters.issuerUrl) //readCert(os.Args[2])
    if err != nil {
        log.Fatal(err)
    }

    issuer, err := decodeCert(issuer_bytes)
    if err != nil {
        log.Fatal(err)
    }

    // Perform OCSP Check
    fmt.Println("Checing OCSP")
    status, err := checkOCSPStatus(cert, issuer)
    if err != nil {
        fmt.Println(err)
    } else {
        switch status {
        case ocsp.Good:
            fmt.Printf("[+] Certificate status is Good\n")
        case ocsp.Revoked:
            fmt.Printf("[-] Certificate status is Revoked\n")
        case ocsp.Unknown:
            fmt.Printf("[-] Certificate status is Unknown\n")
        }
    }

    crl_bytes, err := getCrl(parameters.crlUrl) //readCert(os.Args[2])
    if err != nil {
        log.Fatal(err)
    }

    crl, err := decodeCrl(crl_bytes)
    if err != nil {
        log.Fatal(err)
    }
}

```



```

    }

    fmt.Println("\nChecing CRL")
    _, err = checkCRLStatus(cert, issuer, crl)
    if err != nil {
        log.Fatal(err)
    }else{
        fmt.Println("[+] Certificate status is not Revoked\n")
    }
}

func checkCRLStatus(cert *x509.Certificate, issuer *x509.Certificate, crl *pkix.CertificateList) (bool, error) {
    var revoked = false
    // Check CRL signature
    err := issuer.CheckCRLSignature(crl)
    if err != nil {
        return revoked, err
    }

    // Check CRL validity
    if crl.TBSCertList.NextUpdate.Before(time.Now()) {
        return revoked, fmt.Errorf("CRL is outdated")
    }

    // Searching for our certificate in CRL
    for _, revokedCertificate := range crl.TBSCertList.RevokedCertificates {
        if revokedCertificate.SerialNumber.Cmp(cert.SerialNumber) == 0 {
            //Found validated certificate in list of revoked ones
            revoked = true
            return revoked, fmt.Errorf("[-] Certificate status is Revoked\n")
        }
    }

    return revoked, nil
}

// CheckOCSPStatus will make an OCSP request for the provided certificate.
// If the status of the certificate is not good, then an error is returned.
func checkOCSPStatus(cert *x509.Certificate, issuer *x509.Certificate) (int, error) {
    var (
        ctx    = context.Background()
        ocspURL = cert.OCSPServer[0]
    )

    // Build OCSP request
    buffer, err := ocsp.CreateRequest(cert, issuer, &ocsp.RequestOptions{
        Hash: crypto.SHA256,
    })
    if err != nil {
        return ocsp.Unknown, fmt.Errorf("creating ocsp request body: %w", err)
    }

    req, err := http.NewRequest(http.MethodPost, ocspURL, bytes.NewBuffer(buffer))
    if err != nil {
        return ocsp.Unknown, fmt.Errorf("creating http request: %w", err)
    }

    ocspUrl, err := url.Parse(ocspURL)
    if err != nil {
        return ocsp.Unknown, fmt.Errorf("parsing ocsp url: %w", err)
    }

    req.Header.Add("Content-Type", "application/ocsp-request")
    req.Header.Add("Accept", "application/ocsp-response")
    req.Header.Add("host", ocspUrl.Host)
    req = req.WithContext(ctx)

    // Make OCSP request
    httpResponse, err := http.DefaultClient.Do(req)
    if err != nil {
        return ocsp.Unknown, fmt.Errorf("making ocsp request: %w", err)
    }
}

```

```

defer httpResponse.Body.Close()

output, err := ioutil.ReadAll(httpResponse.Body)
if err != nil {
    return ocsp.Unknown, fmt.Errorf("reading response body: %w", err)
}

// Parse response
ocspResponse, err := ocsp.ParseResponse(output, issuer)
if err != nil {
    return ocsp.Unknown, fmt.Errorf("parsing ocsp response: %w", err)
}
return ocspResponse.Status, nil
}

func readFile(file string) []byte {
    cert, err := ioutil.ReadFile(file)
    if err != nil {
        log.Fatalln(err)
    }
    return cert
}

func decodeCert(cert_bytes []byte) (*x509.Certificate, error) {
    b, _ := pem.Decode(cert_bytes)
    var cert *x509.Certificate

    cert, err := x509.ParseCertificate(b.Bytes)
    if err != nil {
        fmt.Println("Parse Error")
        return nil, fmt.Errorf("parsing certificate: %w", err)
    }

    return cert, err
}

func decodeCrl(cert_bytes []byte) (*pkix.CertificateList, error) {
    b, _ := pem.Decode(cert_bytes)

    crl, err := x509.ParseCRL(b.Bytes)
    if err != nil {
        return nil, fmt.Errorf("parsing crl: %w", err)
    }
    return crl, err
}

func getIssuer(issuerUrl string) ([]byte, error) {
    var resp = &http.Response{}
    values := map[string]string{"label": "intermediate"}
    jsonValue, _ := json.Marshal(values)
    resp, err := http.Post(issuerUrl, "application/json", bytes.NewBuffer(jsonValue))
    if err != nil {
        fmt.Println(err)
        panic("Something wrong with the post request")
    }

    defer resp.Body.Close()
    body, err := ioutil.ReadAll(resp.Body)
    json.Unmarshal([]byte(body), &cfinfo)
    return []byte(cfinfo.Result.Certificate), nil
}

func getCrl(crlUrl string) ([]byte, error) {
    resp, err := http.Get(crlUrl)
    if err != nil {
        return nil, err
    }
    defer resp.Body.Close()

    if resp.StatusCode >= 300 {
        return nil, fmt.Errorf("failed to retrieve CRL")
    }
}

```

```
}

body, err := ioutil.ReadAll(resp.Body)
json.Unmarshal([]byte(body), &crinfo)
crlString := "-----BEGIN X509 CRL-----\n" + crlinfo.Result + "\n-----END X509 CRL-----"

return []byte(crlString), err
}
```

Kafka

Strimzi

You can install strimzi kafka using the quick start guide: [Strimzi Quickstarts](#)

You'll need to overwrite the kafka cluster with your own definition: [my-cluster.yaml](#)

This file includes an authorization section:

opa

```
authorization:
  type: opa
  url: http://opa.default:8181/v1/data/policy/kafka/authz/allow
  allowOnError: false
  initialCacheCapacity: 1000
  maximumCacheSize: 10000
  expireAfterMs: 10 #60000
  superUsers:
    - CN=henri
    - anwar
    - CN=wesley
    - CN=my-user
```

This file includes an listeners section:

listeners

```
listeners:
- name: plain
  port: 9092
  tls: false
  type: internal
- name: tls
  port: 9093
  tls: true
  type: internal
- name: plain3
  port: 9097
  tls: false
  type: internal
  authentication:
    type: oauth
    checkIssuer: false
    checkAccessTokenType: true
    accessTokenIsJwt: true
    enableOAuthBearer: true
    introspectionEndpointUri: http://keycloak.default:8080/auth/realms/opa/protocol/openid-connect/token
/introspect
  clientId: opacli
  clientSecret:
    secretName: my-cluster-oauth
    key: clientSecret
  validIssuerUri: http://keycloak.default:8080/auth/realms/opa
  clientAudience: account
  customClaimCheck: "@.resource_access['opacli'].roles[0] == 'opa-client-role'"
```

Where opa and keycloak are configured.

If you are publishing or subscribing using this listener you will need to provide a JWT with your request.

The token will be verified using keycloak along with the audience field and the resource access['opacli'].roles field.

Kafka will then pass the authorization on to opa where other checks will take place.

Below is a sample opa policy you might use to check the kafka input:

opa rules

```
package policy.kafka.authz

default allow = false

allow = true {
  allowedActions := ["DESCRIBE", "DESCRIBE_CONFIGS", "READ"]
  input.action.operation == allowedActions[_]
  input.requestContext.header.name.clientId == "kowl"
}

allow = true {
  allowedActions := ["DESCRIBE", "DESCRIBE_CONFIGS"]
  allowedTopics := ["__consumer_offsets", "__strimzi_store_topic", "__strimzi-topic-operator-kstreams-topic-store-changelog",]
  input.action.resourcePattern.name == allowedTopics[_]
}

allow = true {
  allowedActions := ["DESCRIBE", "READ"]
  input.action.operation == allowedActions[_]
  allowedResourceTypes := ["GROUP"]
  input.action.resourcePattern.resourceType == allowedResourceTypes[_]
  input.requestContext.principal.name == "service-account-opacli"
}

allow = true {
  input.action.operation == "CREATE"
  input.action.resourcePattern.name == "kafka-cluster"
  input.action.resourcePattern.resourceType == "CLUSTER"
  input.requestContext.principal.name == "service-account-opacli"
  input.requestContext.header.name.clientId == "consumer-client"
}

allow = true {
  allowedActions := ["DESCRIBE", "READ"]
  input.action.operation == allowedActions[_]
  input.action.resourcePattern.name == "my-topic"
  input.action.resourcePattern.resourceType == "TOPIC"
  input.requestContext.principal.name == "service-account-opacli"
  input.requestContext.header.name.clientId == "consumer-client"
}

allow = true {
  allowedActions := ["DESCRIBE", "WRITE"]
  input.action.operation == allowedActions[_]
  input.action.resourcePattern.name == "my-topic"
  input.action.resourcePattern.resourceType == "TOPIC"
  input.requestContext.principal.name == "service-account-opacli"
  input.requestContext.header.name.clientId == "producer-client"
}
```

The default value of the sub field (principal name) in keycloak is the user id, this can be changed to the user name using a property mapper:

kube-mgmt

By default the entire policy and data cache are defined by the opa bundle.

If you need to add data from other sources you need to define the bundle root directories in the .manifest file

e.g.

manifest

```
{
  "revision" : "1",
  "roots": ["policy", "roles"]
}
```

You can then add the kube-mgmt sidecar to your opa deployment and this will pull data from configmaps in the namespace specified

```
- name: kube-mgmt
  image: openpolicyagent/kube-mgmt:latest
  args:
    - "--namespaces=opa"
```

```
hello-data.yaml
```

```
kind: ConfigMap
apiVersion: v1
metadata:
  name: hello-data
  namespace: opa
  labels:
    openpolicyagent.org/data: opa
data:
  x.json: |
    {"a": [1,2,3,4]}
```

token.json

[illegible]

You can also add extra data using curl e.g. `curl -X PUT $host:31182/v1/data/jwt -d @token.json`

You can view all the data available to opa using curl: `curl <opa host>:<port>/v1/data`

You should see something similar to the following output:

opa data

[illegible]

You can get individual values like this: `curl <opa host>:<port>/v1/data/jwt/access_token` or refer to them in your code like this: `data.opa["hello-data"]["x.json"].a[0]`

Strimzi Bridge

You can communicate with kafka over http by adding strimzi bridge:

Strimzi Bridge

```
apiVersion: kafka.strimzi.io/v1beta2
kind: KafkaBridge
metadata:
  name: strimzi-bridge
  namespace: kafka
spec:
  replicas: 1
  bootstrapServers: my-cluster-kafka-bootstrap:9092
  http:
    port: 8080
```

See also:

[Using Open Policy Agent with Strimzi and Apache Kafka](#)

[Using Strimzi](#)

[kube-mgmt](#)

[Styra opa-kafka-plugin](#)

[Secure Kafka with Keycloak: SASL OAuth Bearer](#)

[Enforce Custom Resource policies with Open Policy Agent Gatekeeper](#)

[How to integrate Kafka with Istio](#)

[Example with JWT payload passed from Envoy](#)

[Kafka Broker filter](#)

[Kafka mesh filter in Envoy](#)

[Kafka authentication using OAuth 2.0](#)

[A deep dive into Strimzi](#)

[Using HTTP Bridge as a Kubernetes sidecar](#)

[Kafka SSL : Setup with self signed certificate](#)

Kafka & Istio

Integration of Istio with Kafka is limited.

The Kafka Protocol is a TCP level protocol (Layer 4)

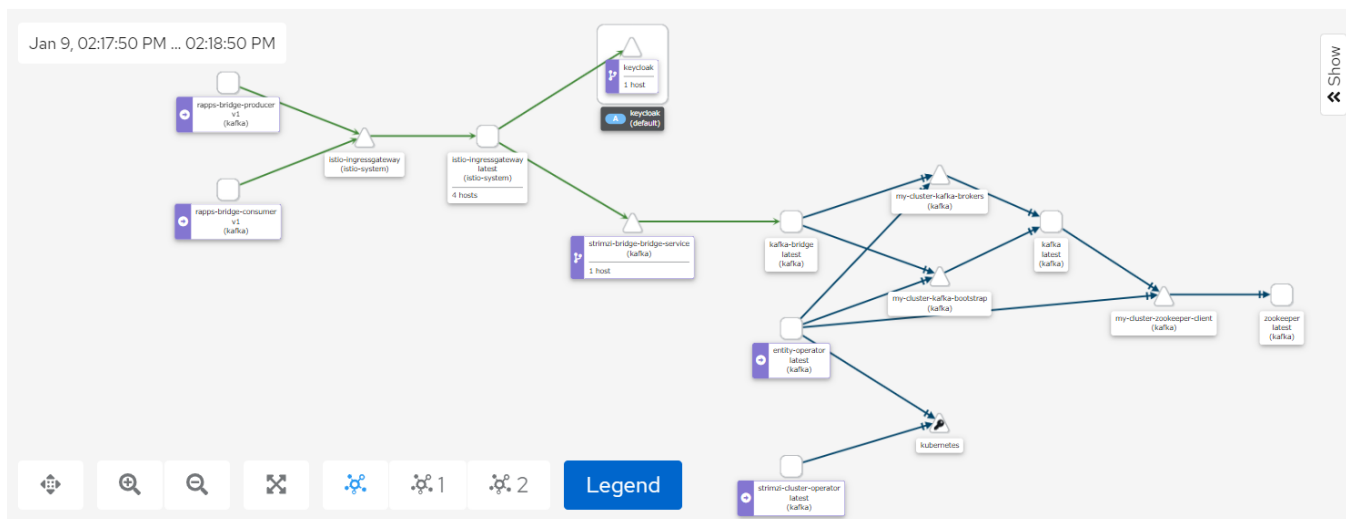
Kafka is a binary wrapper over TCP protocol.

Istio mainly supports HTTP/HTTPS on layer 7.

Higher level protocols such as HTTP have access to metadata so they can properly route requests, this is not the case with the Kafka protocol.

[Service Mesh and Proxies: Examples for Kafka](#)

Setting up Strimzi bridge with Istio Authorization and ACLs



The Kiali screenshot above represents both a producer and a consumer connecting to Kafka through the Strimzi bridge.

Access to the bridge is controlled using JWT which is checked using an Istio AuthorizationPolicy.

AuthorizationPolicy

```
apiVersion: "security.istio.io/v1beta1"
kind: "AuthorizationPolicy"
metadata:
  name: "kafka-bridge-policy"
  namespace: kafka
spec:
  selector:
    matchLabels:
      app.kubernetes.io/name: kafka-bridge
  action: ALLOW
  rules:
    - from:
        - source:
            requestPrincipals: ["http://keycloak.default:8080/auth/realms/opa", "http://istio-ingressgateway.istio-system:80/auth/realms/opa"]
      to:
        - operation:
            methods: ["POST", "GET"]
            paths: ["/topics", "/topics/*", "/consumers/*"]
      when:
        - key: request.auth.claims[clientRole]
          values: ["opa-client-role"]
```

By enabling tls on one of our bootstrap listeners user certificates are automatically created when we create a new KafkaUser

```
- name: tlsauth
  type: internal
  port: 9096
  tls: true
  authentication:
    type: tls
```

Setting the authentication type to tls also ensure secure communication between Kafka and zookeeper.

We also set authorization to simple for the Kafka cluster, this means ACLs will be used.

```
kafka:
  authorization:
    type: simple
  superUsers:
    - CN=kowl
```

Any users you want to by-pass ACL checks should be listed under superUsers.

We can then setup our bridge user and include the ACL permissions as part of the KafkaUser definition:

KafkaUser

```
apiVersion: kafka.strimzi.io/v1beta1
kind: KafkaUser
metadata:
  name: bridge
  namespace: kafka
  labels:
    strimzi.io/cluster: my-cluster
spec:
  authentication:
    type: tls
  authorization:
    type: simple
  acls:
    # access to the topic
    - resource:
        type: topic
        name: my-topic
      operations:
        - Create
        - Describe
        - Read
        - Write
        - AlterConfigs
      host: "*"
    # access to the group
    - resource:
        type: group
        name: my-group
      operations:
        - Describe
        - Read
      host: "*"
    # access to the cluster
    - resource:
        type: cluster
      operations:
        - Alter
        - AlterConfigs
      host: "*"

```

Authorization between the bridge and Kafka is done using user certificates.

KafkaBridge

```
apiVersion: kafka.strimzi.io/v1beta2
kind: KafkaBridge
metadata:
  name: strimzi-bridge
  namespace: kafka
spec:
  replicas: 1
  bootstrapServers: my-cluster-kafka-bootstrap:9096
  http:
    port: 8080
  logging:
    type: inline
    loggers:
      logger.bridge.level: "DEBUG"
      logger.send.name: "http.openapi.operation.send"
      logger.send.level: "DEBUG"
  tls:
    trustedCertificates:
      - secretName: my-cluster-cluster-ca-cert
        certificate: ca.crt
  authentication:
    type: tls
    certificateAndKey:
      secretName: bridge
      certificate: user.crt
      key: user.key
```

Records can then be posted to a topic with a call like this:

Endpoint:

<http://istio-ingressgateway.istio-system:80/topics/my-topic>

Payload: `{"records":[{"key":"key-366","value":"value-366"}]}`

and read from a topic using the following syntax:

i) Create a consumer group

Endpoint: <http://istio-ingressgateway.istio-system:80/consumers/my-group>

Payload: `{"name":"my-consumer","format":"json","auto.offset.reset":"earliest","enable.auto.commit":false}`

ii) subscribe to a topic

Endpoint: <http://istio-ingressgateway.istio-system:80/consumers/my-group/instances/my-consumer/subscription>

Payload: `{"topics":["my-topic"]}`

iii) Read records from a topic

Endpoint: <http://istio-ingressgateway.istio-system:80/consumers/my-group/instances/my-consumer/records>

These calls will be redirected to the bridge using a gateway and a virtual service

Gateway/VirtualService

```
apiVersion: networking.istio.io/v1beta1
kind: Gateway
metadata:
  name: strimzi-bridge-gateway
  namespace: kafka
spec:
  selector:
    istio: ingressgateway # use Istio gateway implementation
  servers:
    - port:
        number: 80
        name: http
        protocol: HTTP
      hosts:
        - "*"
---
apiVersion: networking.istio.io/v1beta1
kind: VirtualService
metadata:
  name: strimzi-bridge-vs
  namespace: kafka
spec:
  hosts:
    - "*"
  gateways:
    - strimzi-bridge-gateway
  http:
    - name: "strimzi-bridge-routes"
      match:
        - uri:
            prefix: "/topics"
        - uri:
            prefix: "/consumers"
      route:
        - destination:
            port:
              number: 8080
            host: strimzi-bridge-bridge-service.kafka.svc.cluster.local
```

Note: To use Kowl with this setup you'll need to create a kowl user and configure kowl to use tls

Kowl

```
apiVersion: kafka.strimzi.io/v1beta1
kind: KafkaUser
metadata:
  name: kowl
  namespace: kafka
  labels:
    strimzi.io/cluster: my-cluster
spec:
  authentication:
    type: tls
```

Kowl configmap

```
apiVersion: v1
kind: ConfigMap
metadata:
  name: kowl-config-cm
  namespace: kafka
data:
  config.yaml: |
    kafka:
      brokers:
        - my-cluster-kafka-0.my-cluster-kafka-brokers.kafka.svc:9093
      tls:
        enabled: true
        caFilepath: /etc/strimzi/ca/ca.crt
        certFilepath: /etc/strimzi/user-crt/crt/user.crt
        keyFilepath: /etc/strimzi/user-key/key/user.key
```

- ca.crt is obtained from the my-cluster-cluster-ca-cert secret, user.crt and user.key are obtained from the kowl secret.

Admission Controllers

An *admission controller* is a piece of code that intercepts requests to the Kubernetes API server prior to persistence of the object, but after the request is authenticated and authorized.

[Admission Controllers Reference](#)

Kyverno

<https://kyverno.io/>

Opa Gatekeeper

[Open-policy-agent Gatekeeper](#)

[OPA Gatekeeper: Policy and Governance for Kubernetes](#)

