Policy-as-Code: Across the Stack

Abhay Bhargav

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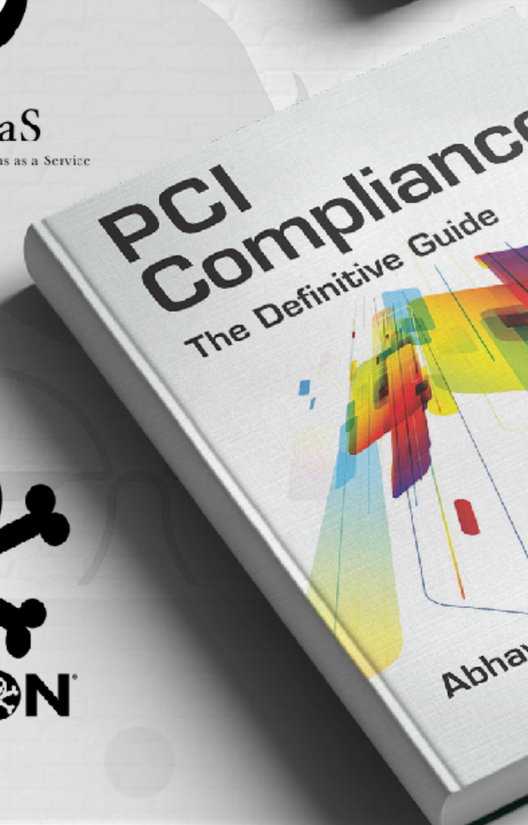
Yours Truly

- Founder @ we45
- Founder @ AppSecEngineer
- AppSec Automation Junkie
- Trainer/Speaker at DEF CON, BlackHat, OWASP Events, etc world-wide
- Co-author of Secure Java For Web Application Development
- Author of PCI Compliance: A Definitive Guide



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My talk...

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Agenda

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- The need for decoupled security controls

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- The need for “Policy-as-Code”

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- PaC across the StaCk

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- Application and API Gateway: Policy-as-Code

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- Cloud-Native Control Planes - Policy-as-Code

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- The need for decoupled security controls
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- PaC across the StaCk
- Application and API Gateway: Policy-as-Code
- Cloud-Native Control Planes - Policy-as-Code
- Workload Policy-as-Code

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- The need for decoupled security controls
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- PaC across the StaCk
- Application and API Gateway: Policy-as-Code
- Cloud-Native Control Planes - Policy-as-Code
- Workload Policy-as-Code
- Conclusions

Trends on the Application Delivery Front

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Some numbers...

- An Average of 15,564 APIs in use per Enterprise - Noname Security Report 2022
- Large Enterprises have 25,592 APIs (Noname Security Report 2022)
- 67% of Enterprises reported a slowed down deployment of security issues related to Kubernetes - Redhat State of Kubernetes Security Report 2023
- Kubernetes: Platform for moving workloads to public cloud. Grew 127+% in 2022 - Dynatrace Report

Dev-First Workflows!

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~~Dev-First Workflows!~~

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~~Dev–First Workflows!~~

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Workflows that support iterative and continuous delivery of apps

^

~~Dev–First Workflows!~~

This means...

- Dev has consumed Ops (Infrastructure-as-Code, Continuous Integration, Continuous Deployment)
- Dev has consumed QA (Test Automation)
- Dev is halfway through consuming security (Security-as-code)
- Dev is coming for policy, compliance, etc next

Why is this good?

- ⬆️ Automation!
- ⬇️ Human Intervention
- ⏭ Faster delivery of features
- 🌤 Highly Scalable

DevSecOps

Threat modeling, Training, Baselines	SAST Source Composition Analysis Secure Defaults Build Security Processes	DAST IAST, InfraSec, Sec Regression	Infrastructure Security, Cloud Hardening, Secrets Management	Security monitoring & attack detection, Threat Hunting, Attack Simulation/RedTeam

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DevSecOps

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SAST as Code

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SAST as Code

DAST/Regression as Code

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SAST as Code

DAST/Regression as Code

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DevSecOps

Threat modeling, Training, Baselines

SAST
Source Composition Analysis
Secure Defaults
Build Security Processes

DAST
IAST,
InfraSec,
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Infrastructure Security,
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Security monitoring
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SAST as Code

DAST/Regression as Code

Decoupled Security Controls
/Policy-As-Code

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DevSecOps

Plan	Code	Build	Test	Release	Deploy	Operate	Monitor
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Threat Models as Code

SAST as Code

DAST/Regression as Code

Decoupled Security Controls /Policy-As-Code

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Threat Models as Code

SAST as Code

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Decoupled Security Controls /Policy-As-Code

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DevSecOps

Threat modeling, Training, Baselines

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Source Composition Analysis
Secure Defaults
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Threat Models as Code

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Decoupled Security Controls
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Detection Engineering

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Threat Models as Code	SAST as Code	DAST/Regression as Code	Decoupled Security Controls /Policy-As-Code	Detection Engineering

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Decoupled Security Controls and Policy as Code

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Need and Motivation

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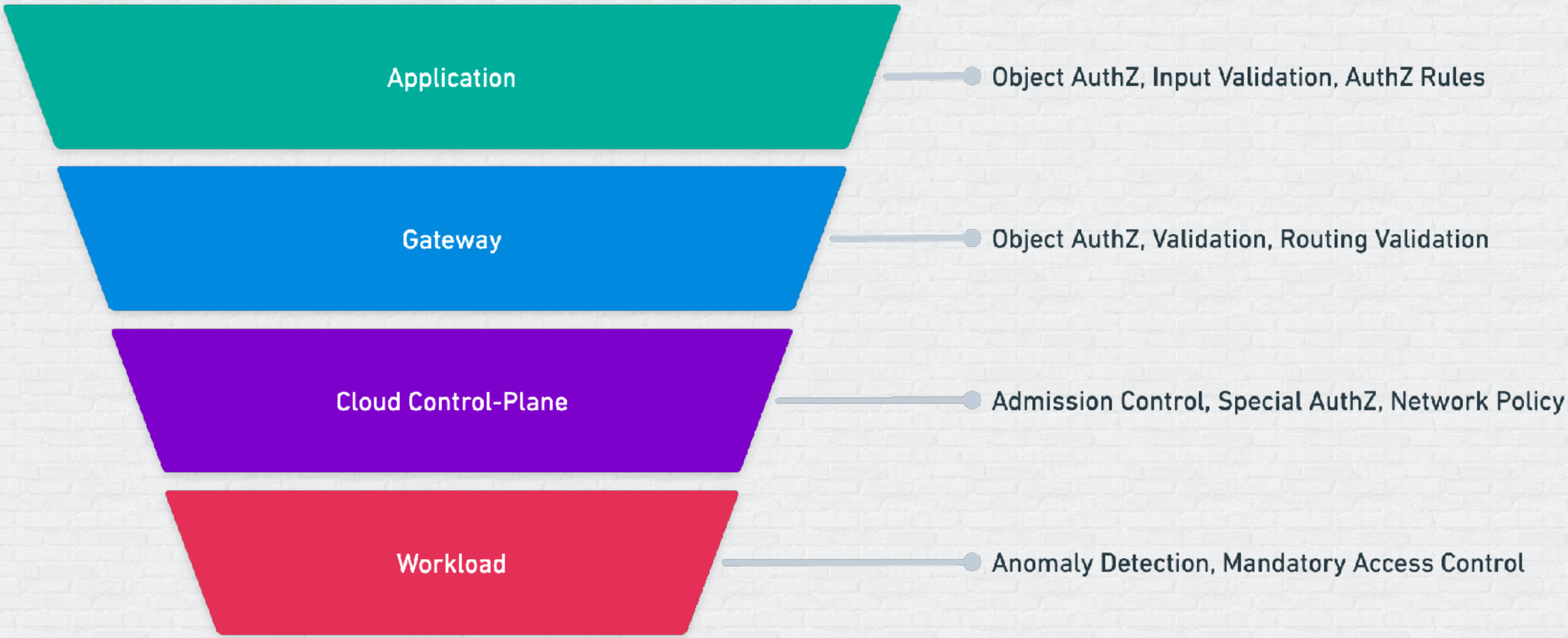
Need and Motivation

- The idea is to NOT hardcode security rules in app that have rapidly evolving and changing requirements
- Customisable and Purpose-Built
- Testable
- Scalable
- Create a “Paved Road” for Product Engineering Teams

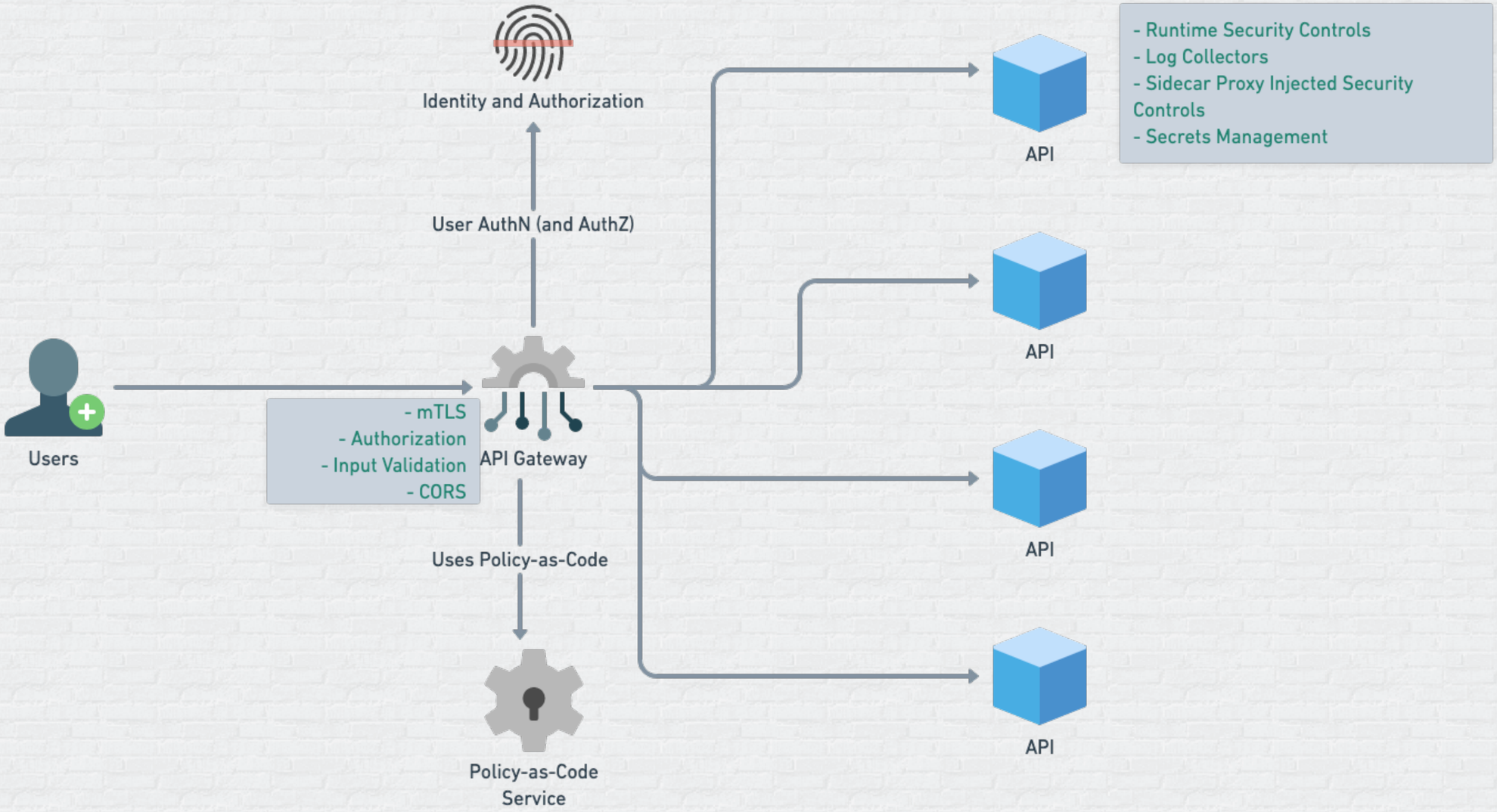
Typical Use-Cases

- Syscall Profiling, Seccomp, AppArmor and eBPF for Runtime Security enforcement
- Authorization, CORS, Rate-Limiting, mTLS and others on the API Gateway
- Log Collection and aggregation of services from Cloud-Native environments
- Input Validation, Access Control with Policy-as-Code Frameworks

Across the Stack



Security Model – An Example



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Application + Gateway

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BOLA

Broken Object Level AuthZ

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Broken Object Level AuthZ

BOLA

EDE

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Broken Object Level AuthZ

BOLA

Excessive Data Exposure

EDE

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Broken Object Level AuthZ

BOLA

BFLA

Excessive Data Exposure

EDE

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Broken Object Level AuthZ

BOLA

Broken Function Level AuthZ

BFLA

Excessive Data Exposure

EDE

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Broken Object Level AuthZ

BOLA

BA

Broken Function Level AuthZ

BFLA

Excessive Data Exposure

EDE

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Broken Object Level AuthZ

BOLA

Broken AuthN

BA

Broken Function Level AuthZ

BFLA

Excessive Data Exposure

EDE

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Imagine...

Imagine...

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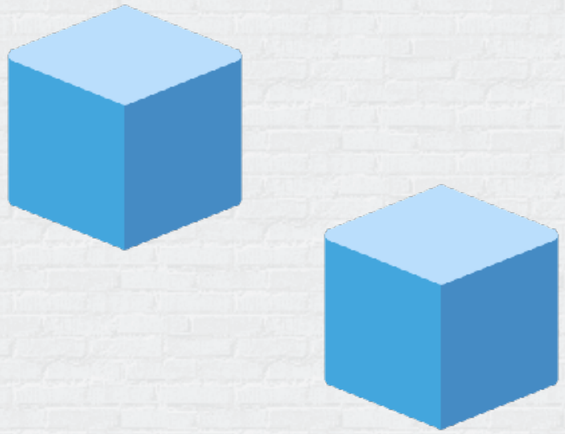

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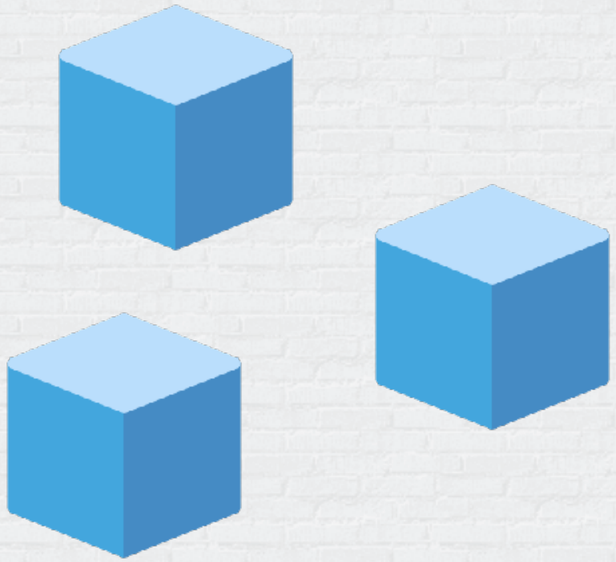

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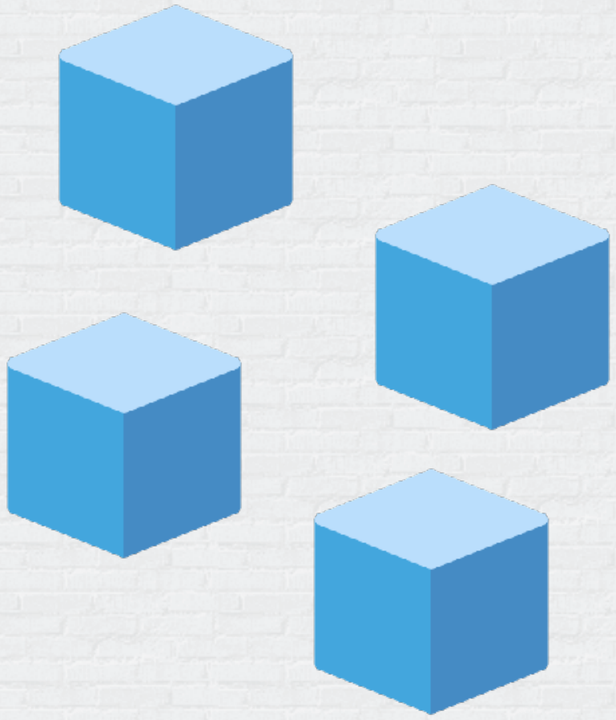

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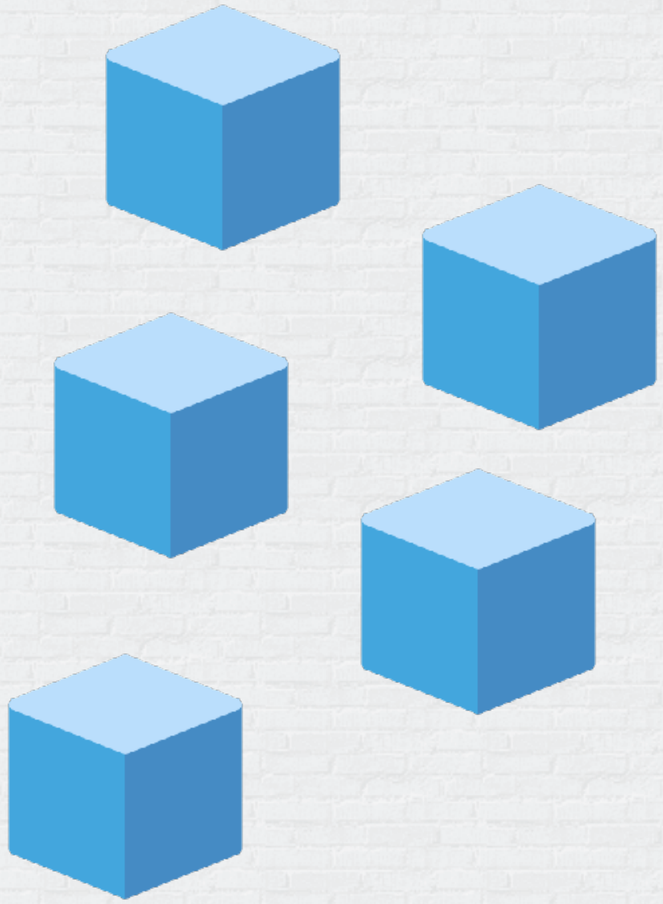

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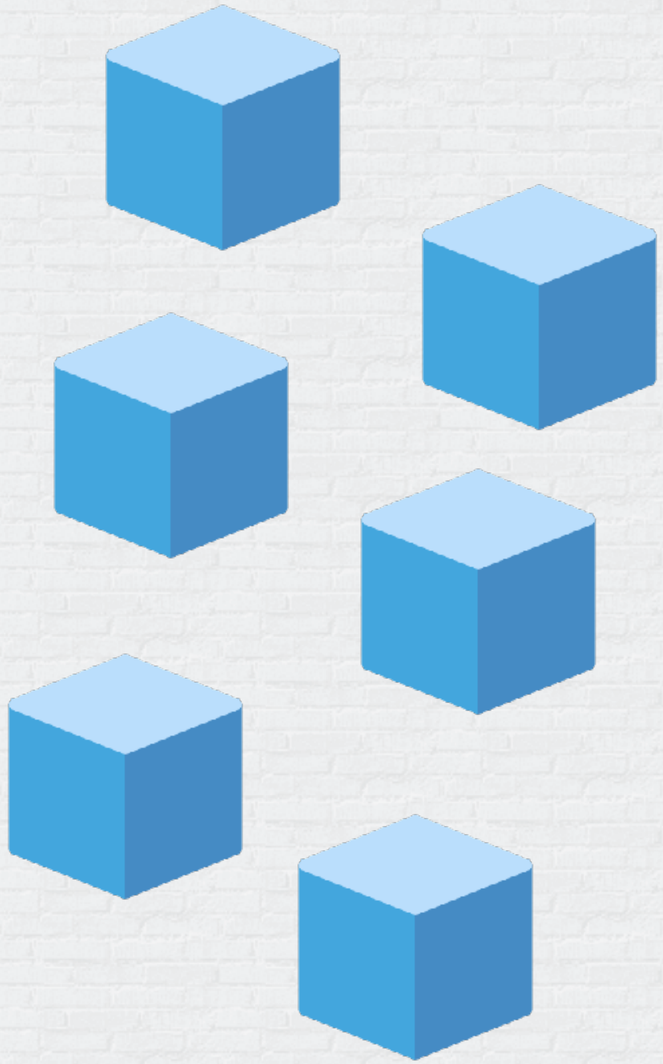

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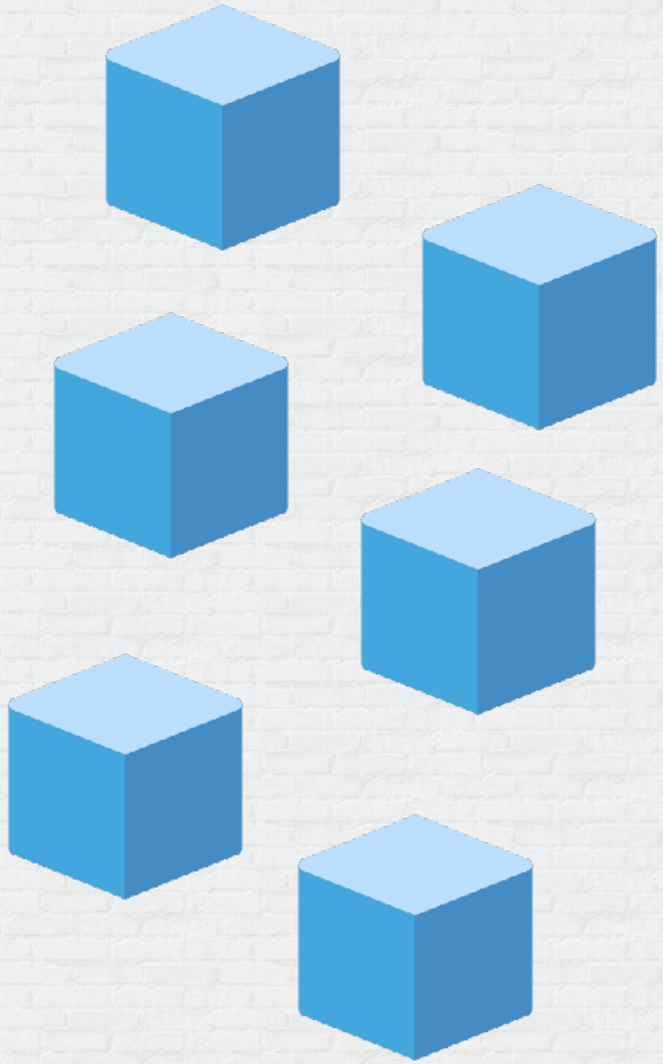
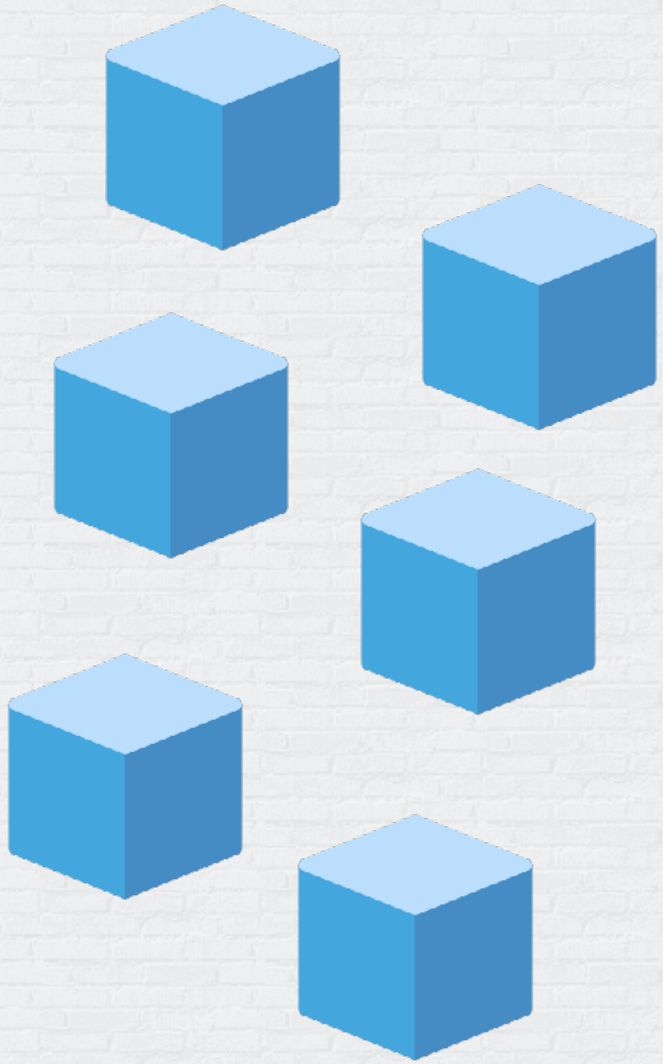


Your Service Business Logic

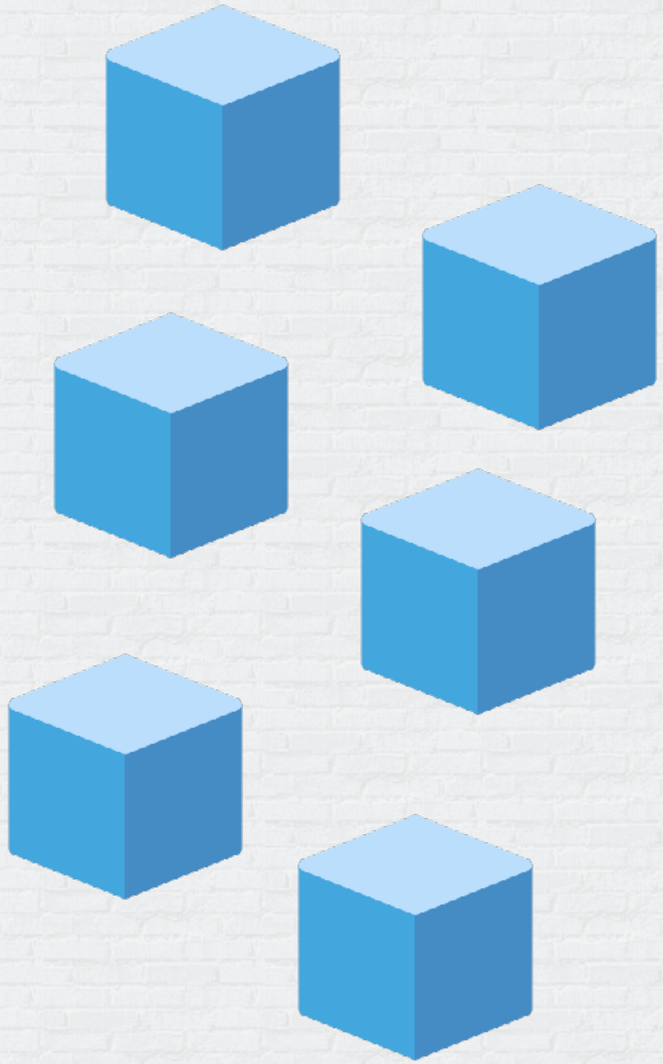
Imagine...



JWT Authorization

Your Service Business Logic

Imagine...



Input Validation

JWT Authorization

Your Service Business Logic

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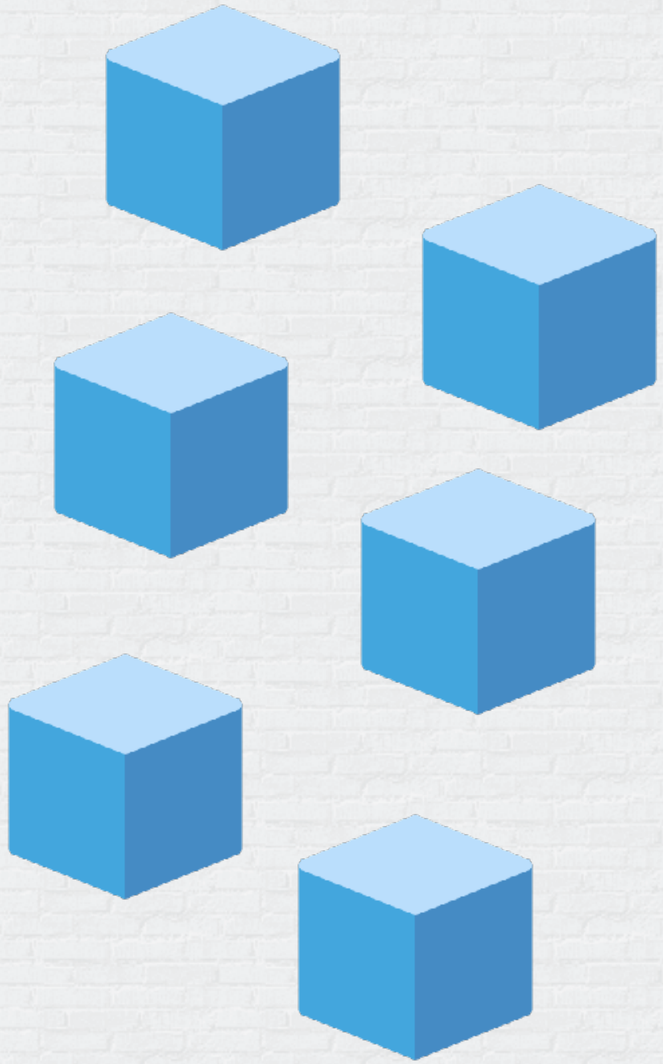
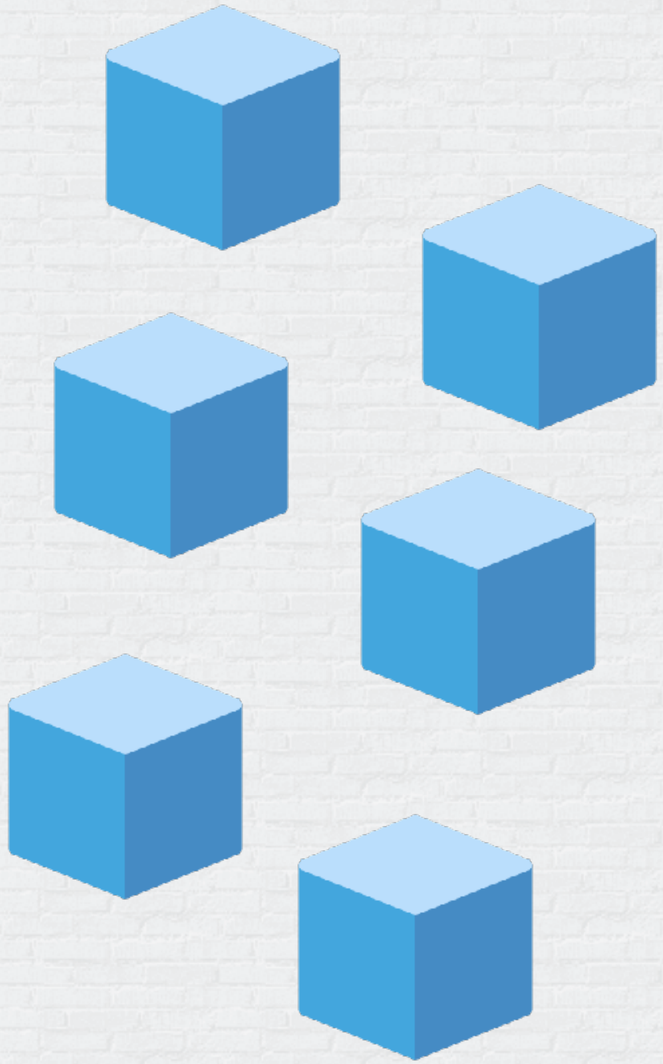
Imagine...



- Object Access Control
- Input Validation
- JWT Authorization
- Your Service Business Logic

Imagine...



- Authentication
- Object Access Control
- Input Validation
- JWT Authorization
- Your Service Business Logic

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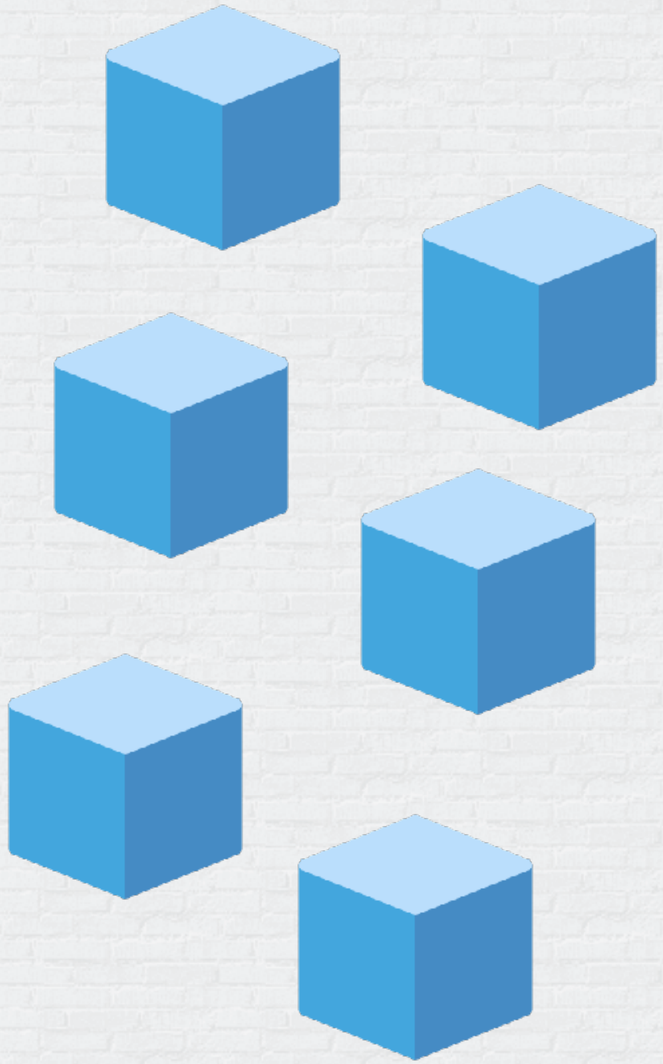

- Logging
- Authentication
- Object Access Control
- Input Validation
- JWT Authorization
- Your Service Business Logic

PaC – Applicability

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- Input Validation at Gateway

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- Input Validation at Gateway
- JWT Validation at Gateway + Claims

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- Function Level AuthZ at App + Gateway

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- Input Validation at Gateway
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- Object Level AuthZ at App + Gateway

Frameworks we'll use

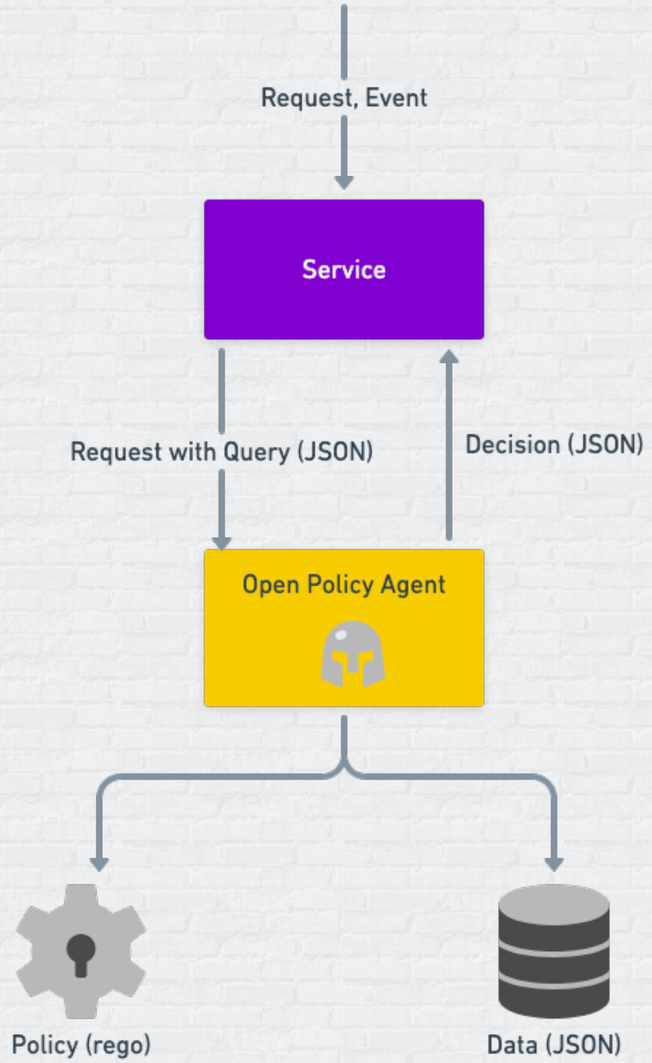
- Open Policy Agent and Rego
- Casbin/Oso/Permify, etc

Open-Policy-Agent

- Policy Management Framework for “any” environment
- Allows you to define policies that can be enforced based on generic json input and output parameters
- Uses a DSL (domain specific language) called “rego” that is used to define policies

Open Policy Agent

Open Policy Agent – Operation



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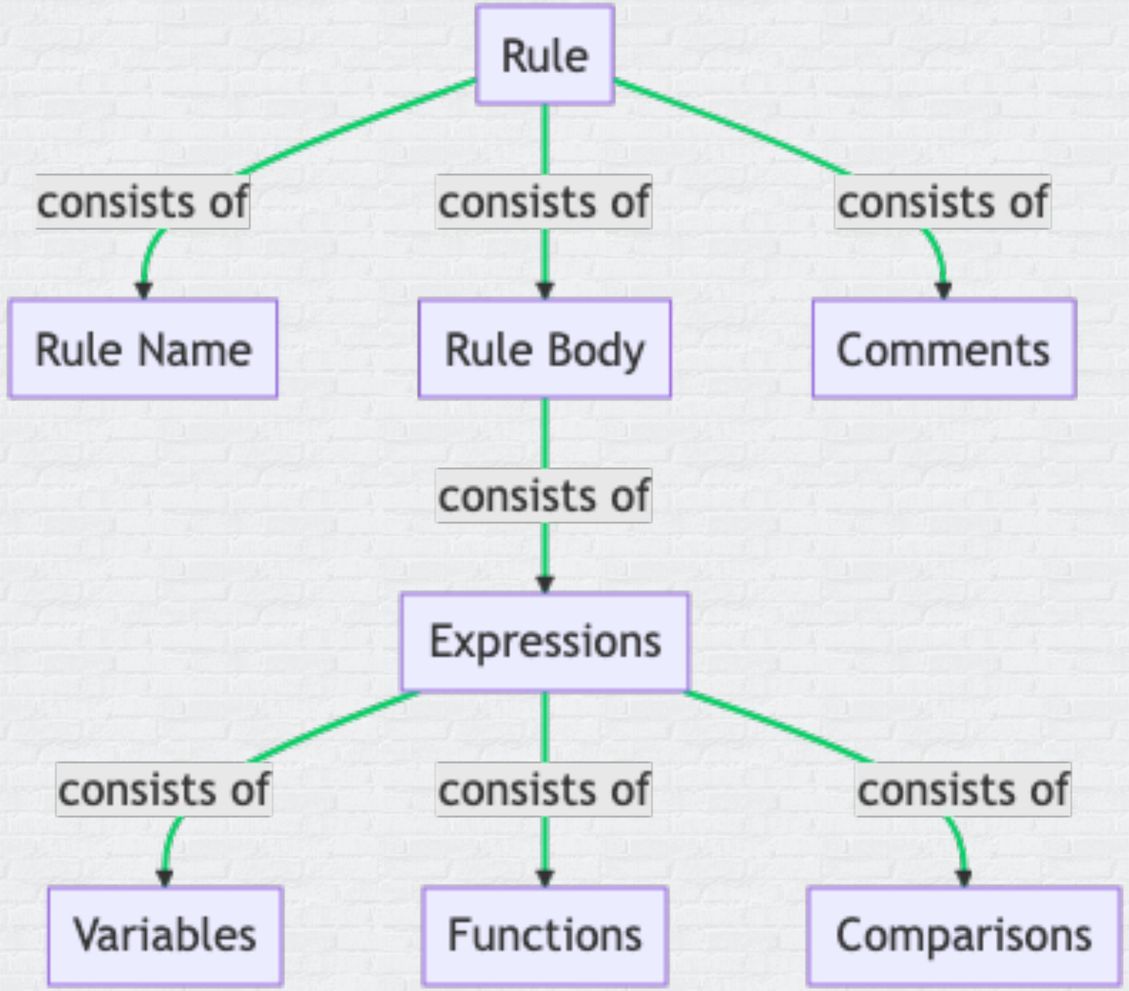
Rego Rule Syntax



Rego Rule Syntax

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Rego Rule Syntax

```
allow {
    "read" == input.method
    input.resource == "/protected"
}
```

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Rego Rule Syntax

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Rego Rule Syntax

```
default allow = false

allow {
    "read" == input.method
    input.resource == "/protected"
}
```

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Rego Rule Syntax

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Rego Rule Syntax

```
allow = true {
    "read" == input.method
    input.resource == "/protected"
}
```

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Rego Rule Syntax

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Rego Rule Syntax

```
is_admin(user) {
    user.role == "admin"
}
```

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Rego Rule Syntax

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Rego Rule Syntax

```
valid_email(email) {
    startswith(email, "user@")
    endswith(email, ".com")
}
```

Rego Rule Syntax

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Rego Rule Syntax

```
//function level access control

allow {
    split(input.path, "/")[2] == input.user.id
}
```

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Rego Rule Syntax

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Rego Rule Syntax

```
default allow = false

allow {
    input.path = ["users"]
    input.method = "POST"
    claims.user
}

claims := payload {
    io.jwt.verify_hs256(token, "password")
    [_,payload,_] := io.jwt.decode(token)
}

token := t {
    t := input.token
}
```

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Rego Rule Syntax

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OPA Use-Cases

- Kubernetes Policy Management
- API AuthZ and Policy Management
- OS Policy Management - SSH and Access Control
- Kafka Topic Authorization
- Many more...

OPA – API AuthZ

```
package authz

allow {
    input.path == ["users"]
    input.method == "POST"
}

allow {
    some profile_id
    input.path = ["users", profile_id]
    input.method == "GET"
    profile_id == input.user_id
}
```

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OPA Demos

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AuthZ-as-Code

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Let's look at most AuthZ flaws

- Inconsistent implementation of Object Level Authorization
- Access Control code strewn across multiple services
- Lack of standardization and expressive capability for AuthZ frameworks
- Heavily design dependent - which gets complex at scale


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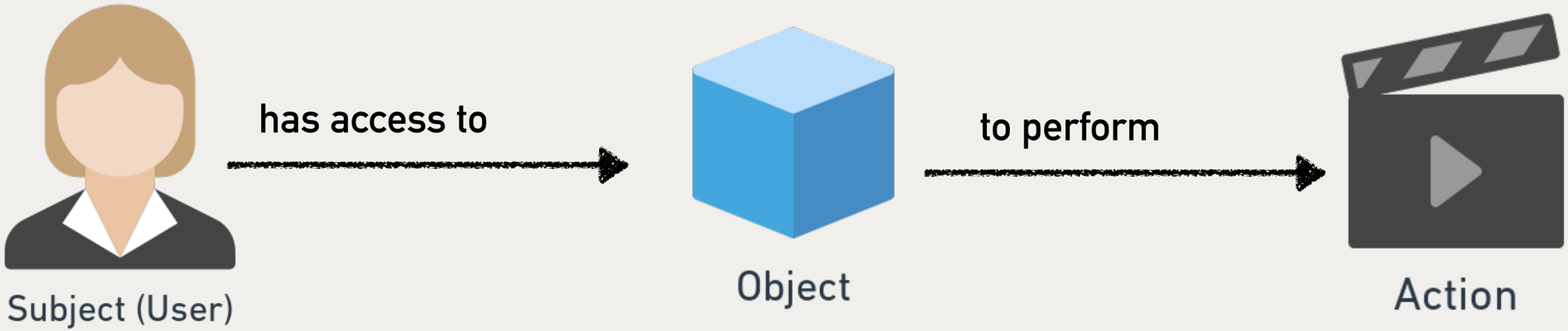
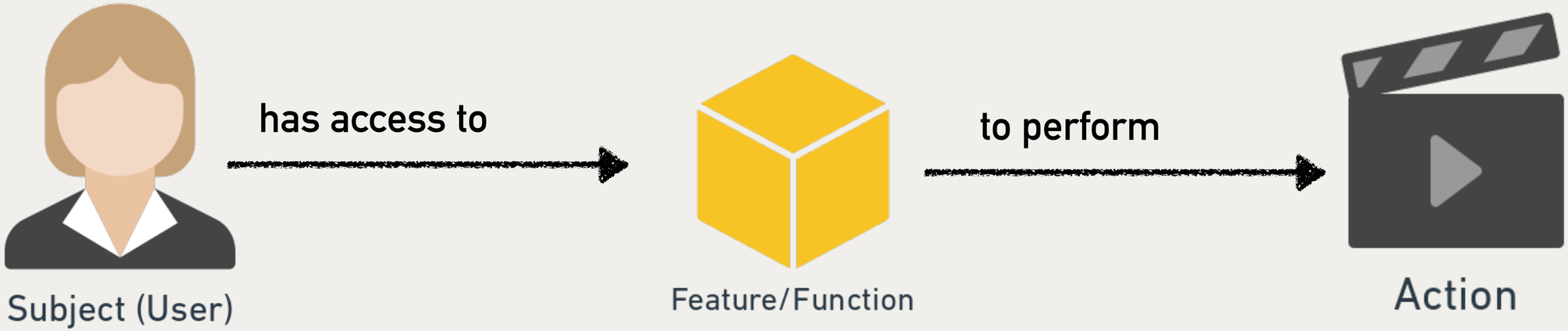
AuthZ-as-Code Frameworks

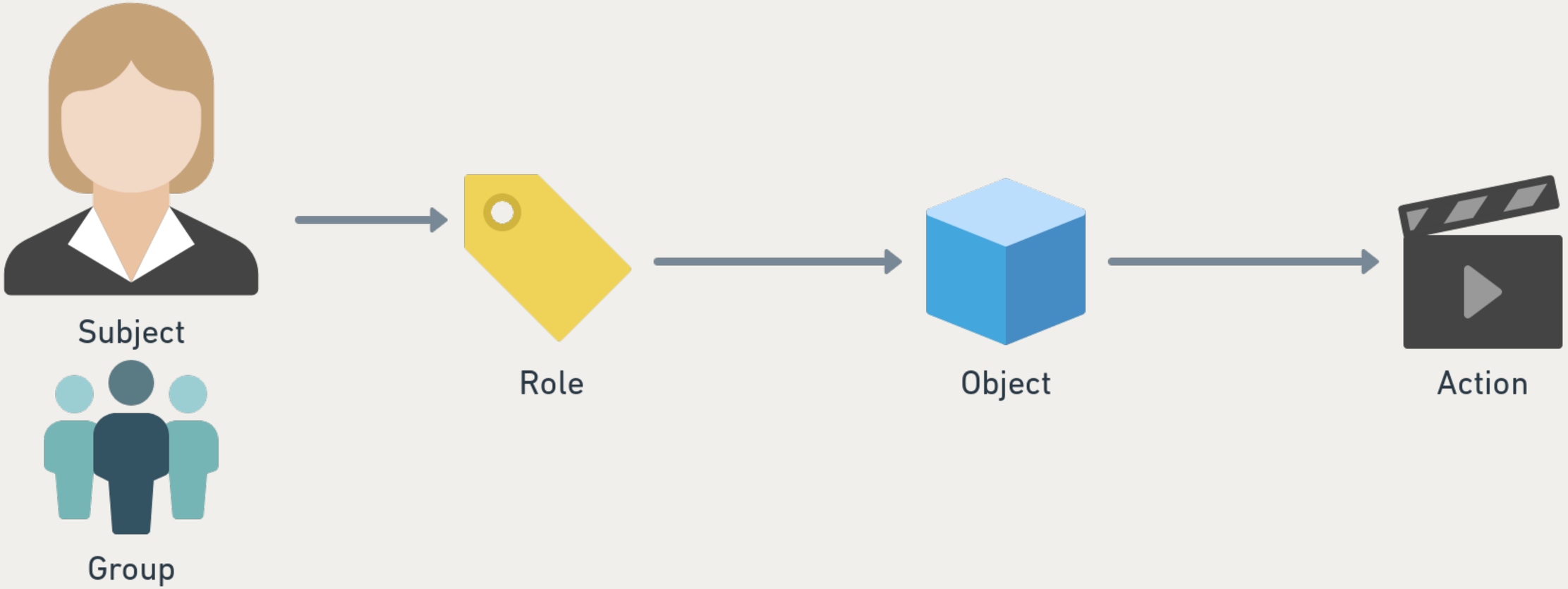
Object Level AuthZ



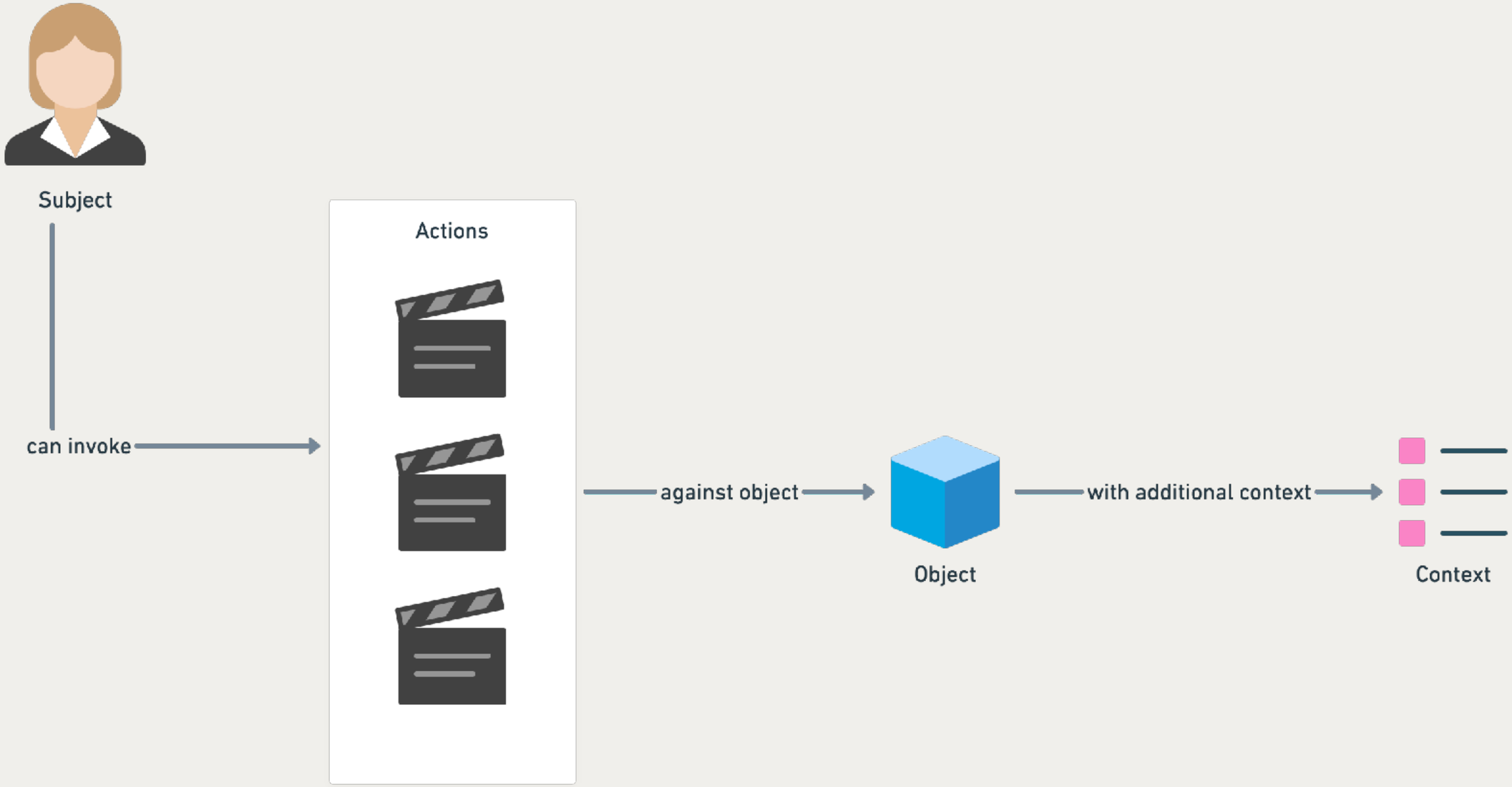
Functional AuthZ



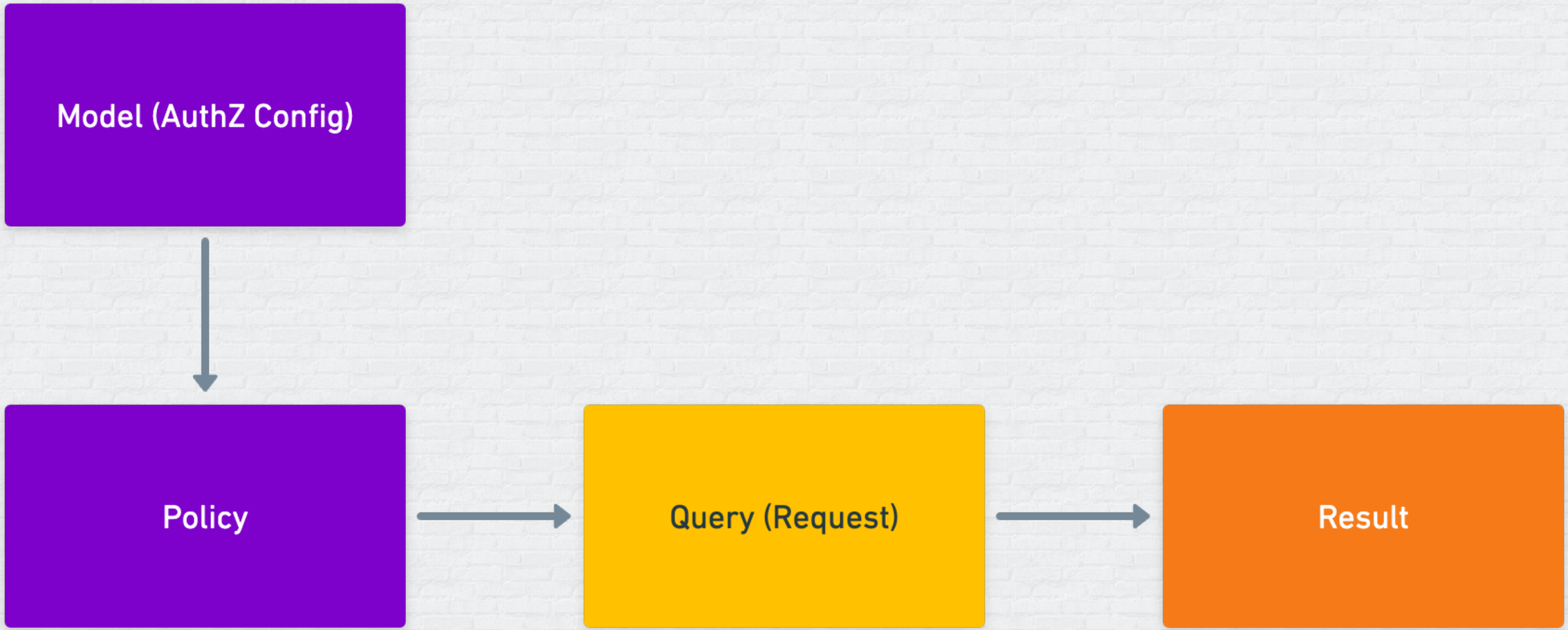
RBAC – Role Based Access Control



ABAC – Attribute Based Access Control



Google Zanzibar approach



Approach

Approach

```
definition user {}

/**
 * resource is an example resource.
 */
definition resource {
    relation writer: user
    relation viewer: user

    permission write = writer
    permission view = viewer + writer
}
```

Approach

Approach

```
// Some example relationships
resource:someresource#viewer@user:somegal
resource:someresource#writer@user:anotherguy
resource:anotherresource#writer@user:somegal
```

Approach

Casbin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Casbin

```
[request_definition]
r = sub, obj, act

[policy_definition]
p = sub, obj, act

[role_definition]
g = _, _

[policy_effect]
e = some(where (p.eft == allow))

[matchers]
m = g(r.sub, p.sub) && r.obj == p.obj && r.act == p.act
```

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Casbin


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Casbin

```
# Roles definition.
p, admin, data1, read
p, admin, data1, write
p, user, data2, read

# Assign roles to users.
g, alice, admin
g, bob, user
```

Casbin


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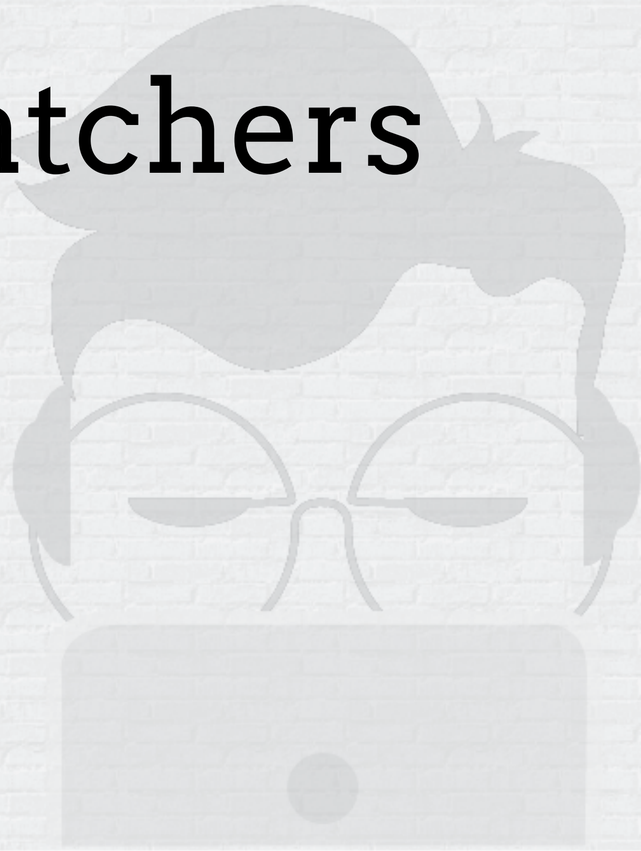
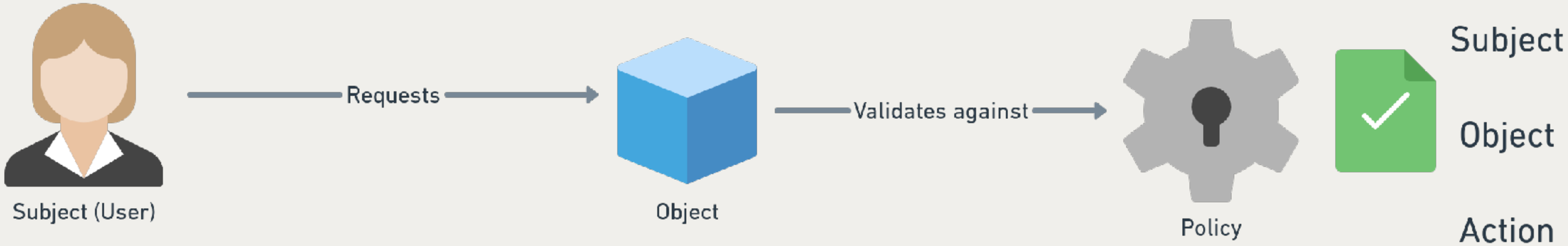
PERM

PERM

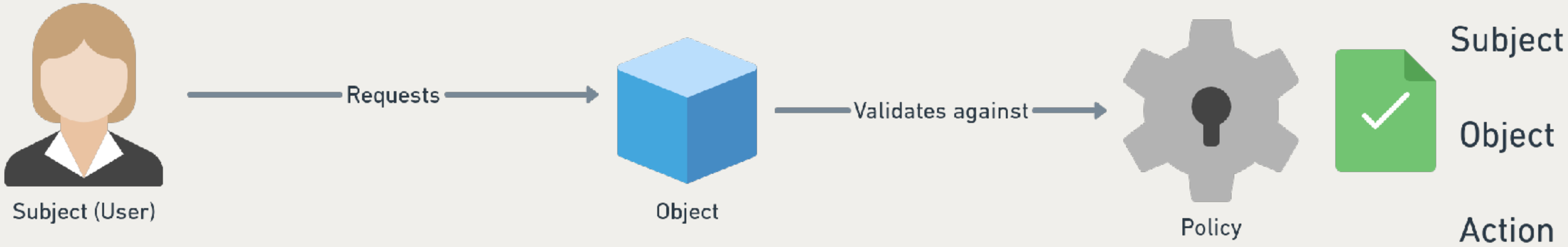
Policy, Effect, Request, Matchers



What is PERM?

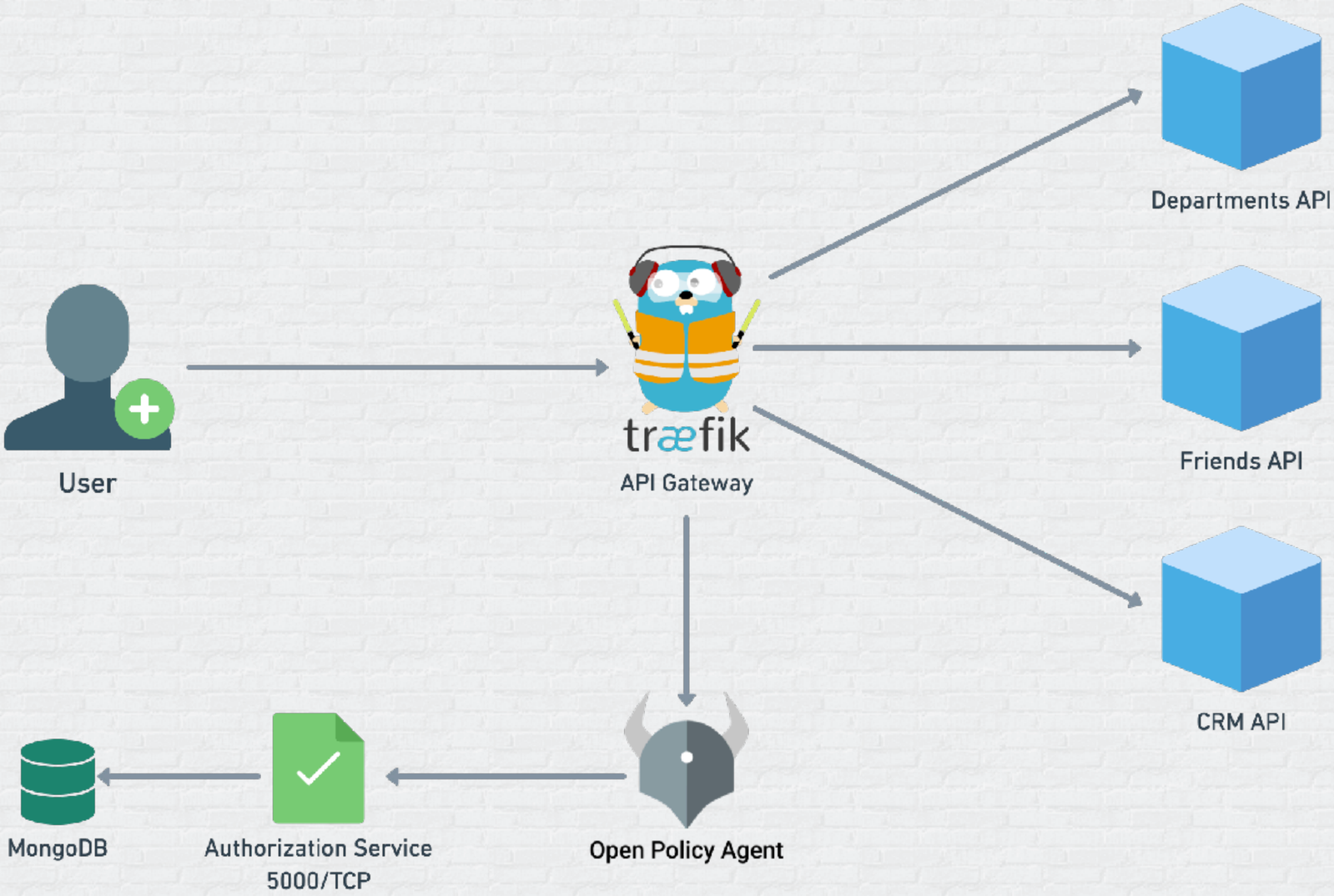

Subject (User)
Requests
Object
Validates against
Policy
Subject
Object
Action

What is PERM?



Request Attributes must MATCH Policy Attributes

Lab: OPA, Traefik and Decentralized security Controls



PaC on Cloud Control-Planes

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PaC Applicability

- PaC is already important for enforcing policies across Cloud and Cloud-Native Control-Planes
- Can be leveraged for Access Control, Admission Control
- Common Use-Cases: Network Policy, Service Policies, Admission Control Policies

PaC – Cloud Control–Planes

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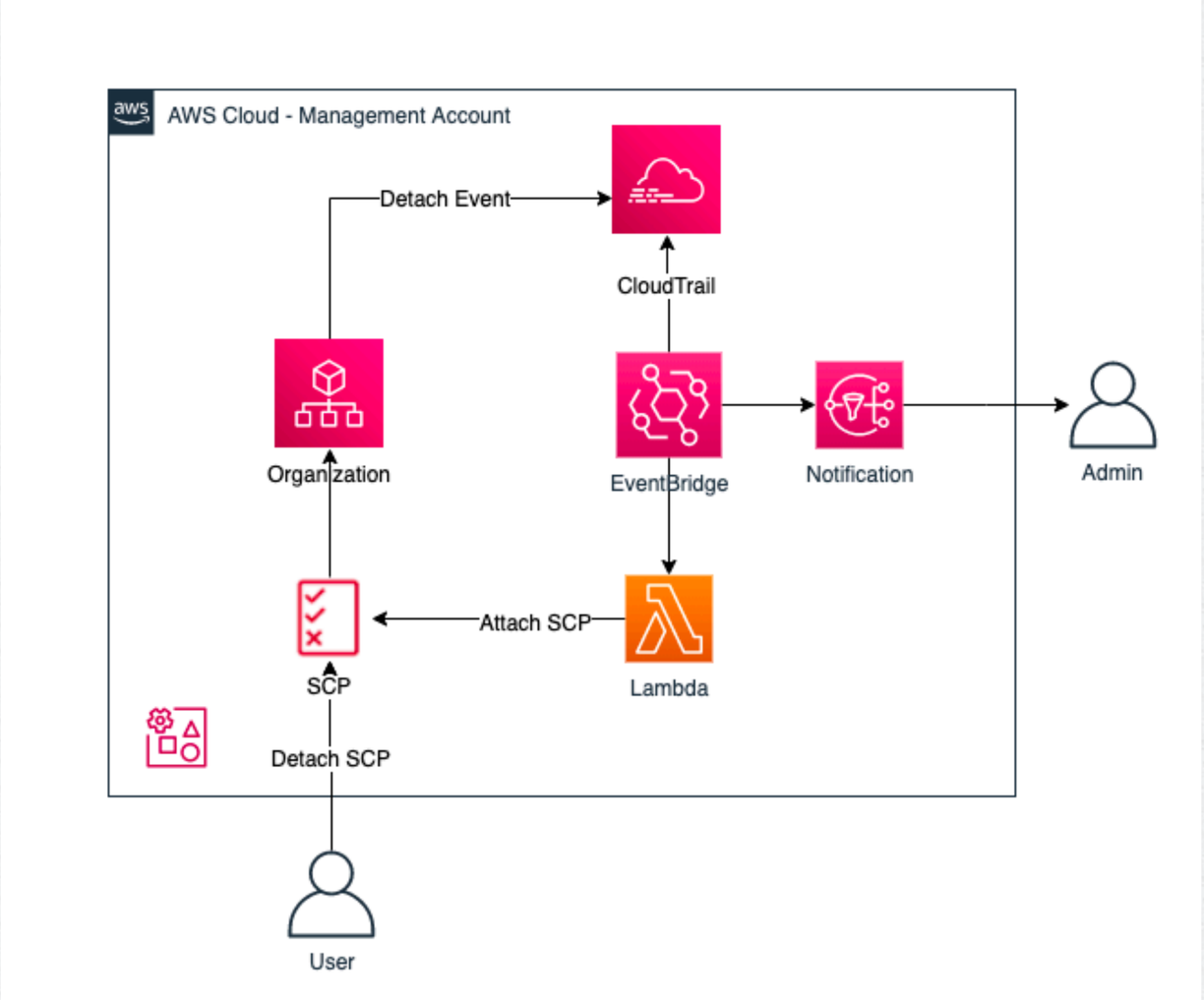
PaC – Cloud Control–Planes



PaC – Cloud Control–Planes

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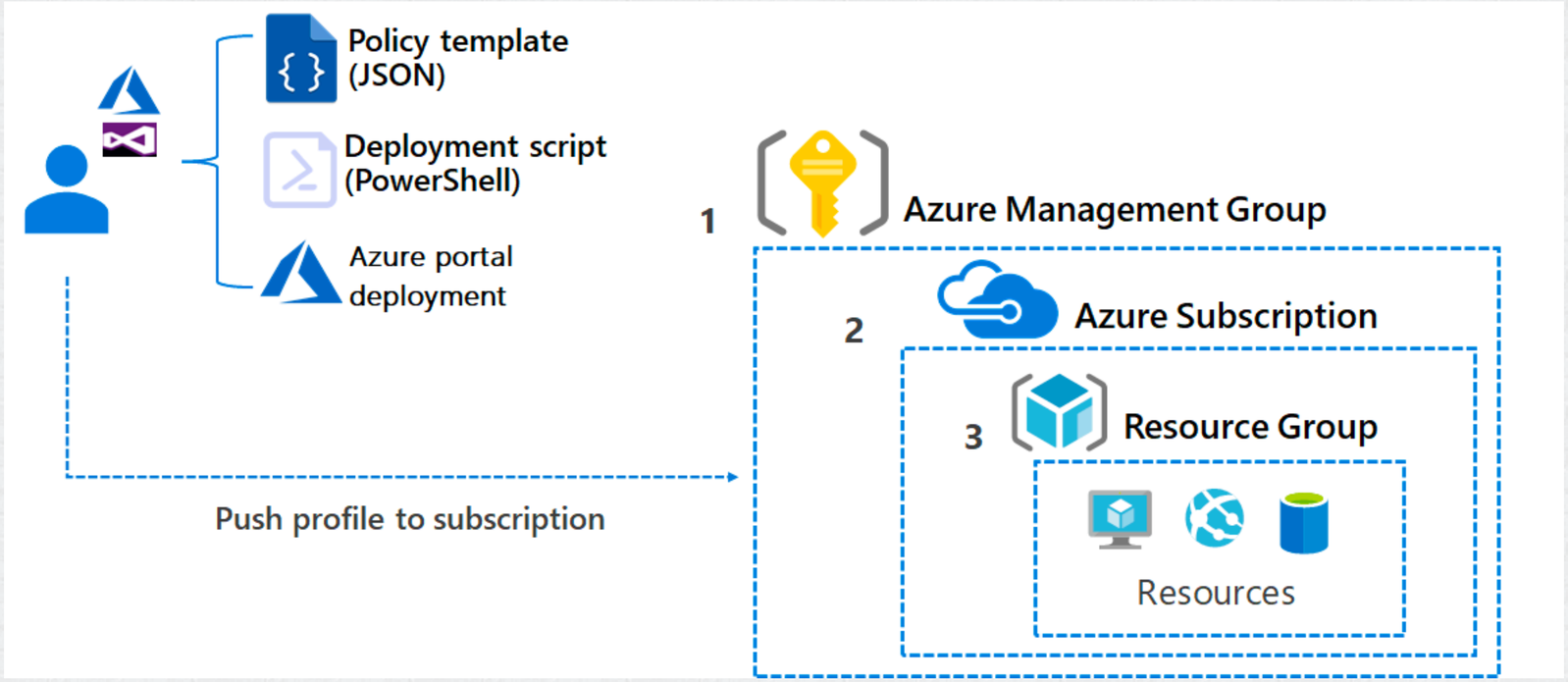

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PaC – Cloud Control–Planes

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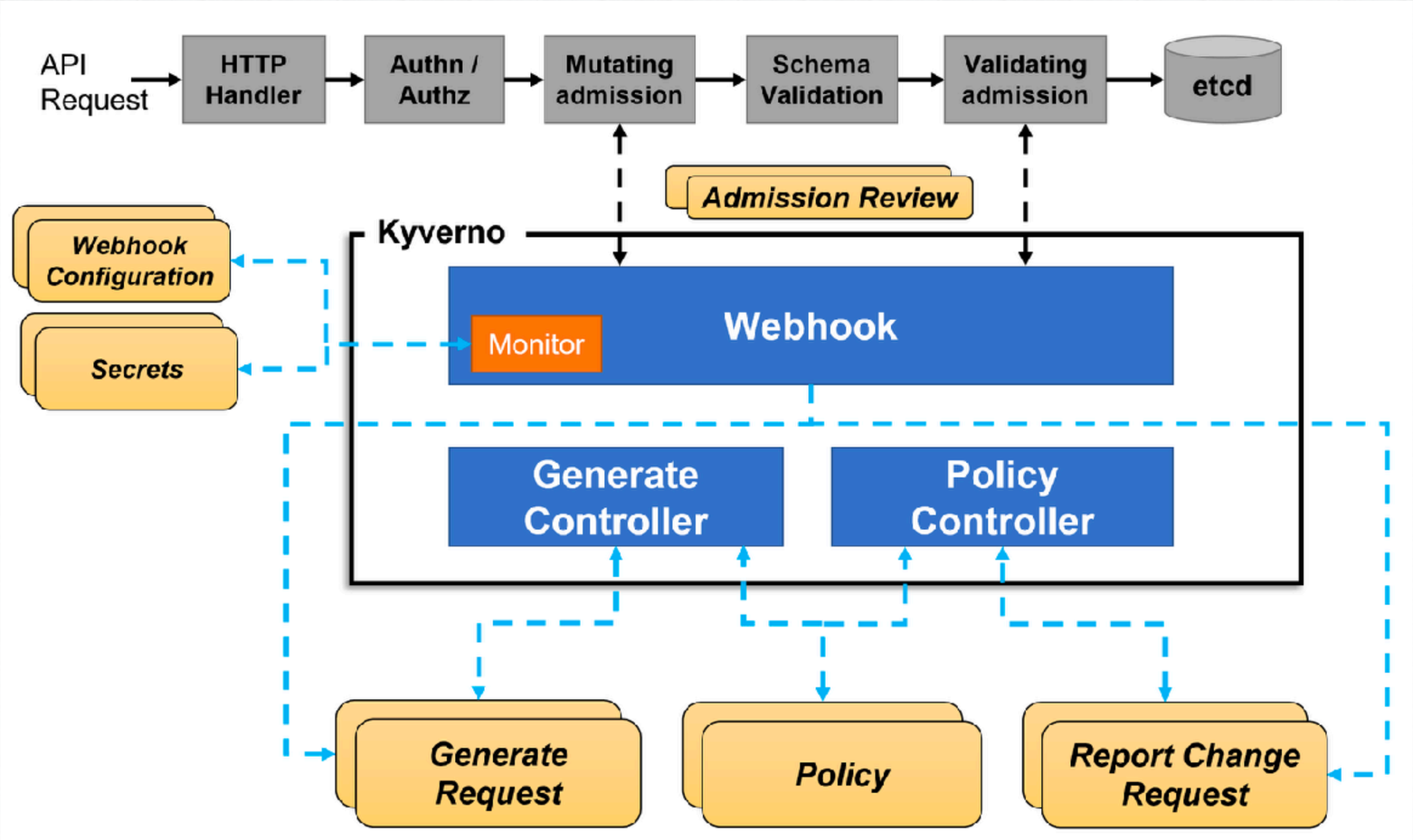
PaC – Cloud Control–Planes



PaC – Cloud Control–Planes

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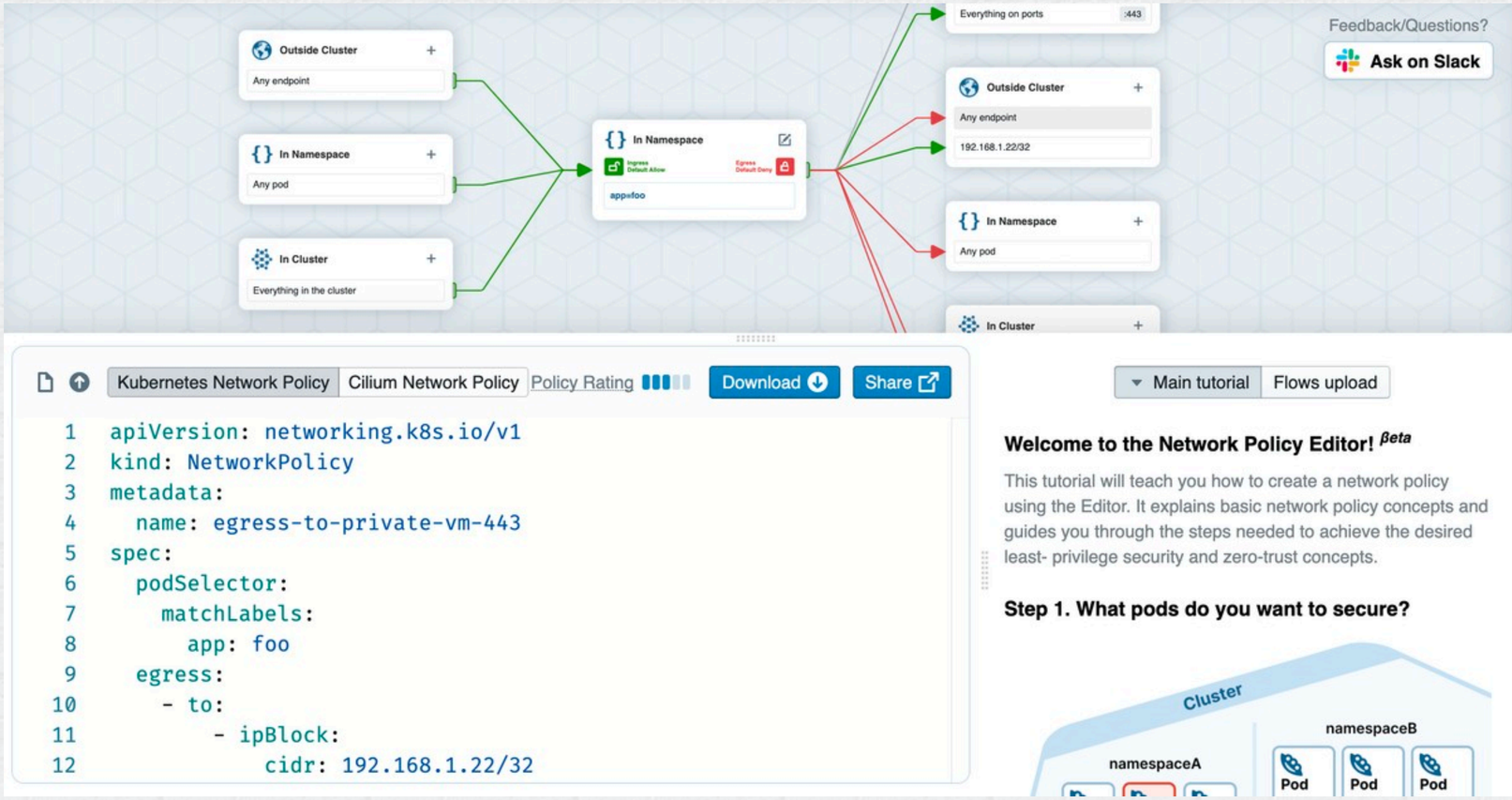
PaC – Cloud Control-Planes



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Policy Management with Kyverno

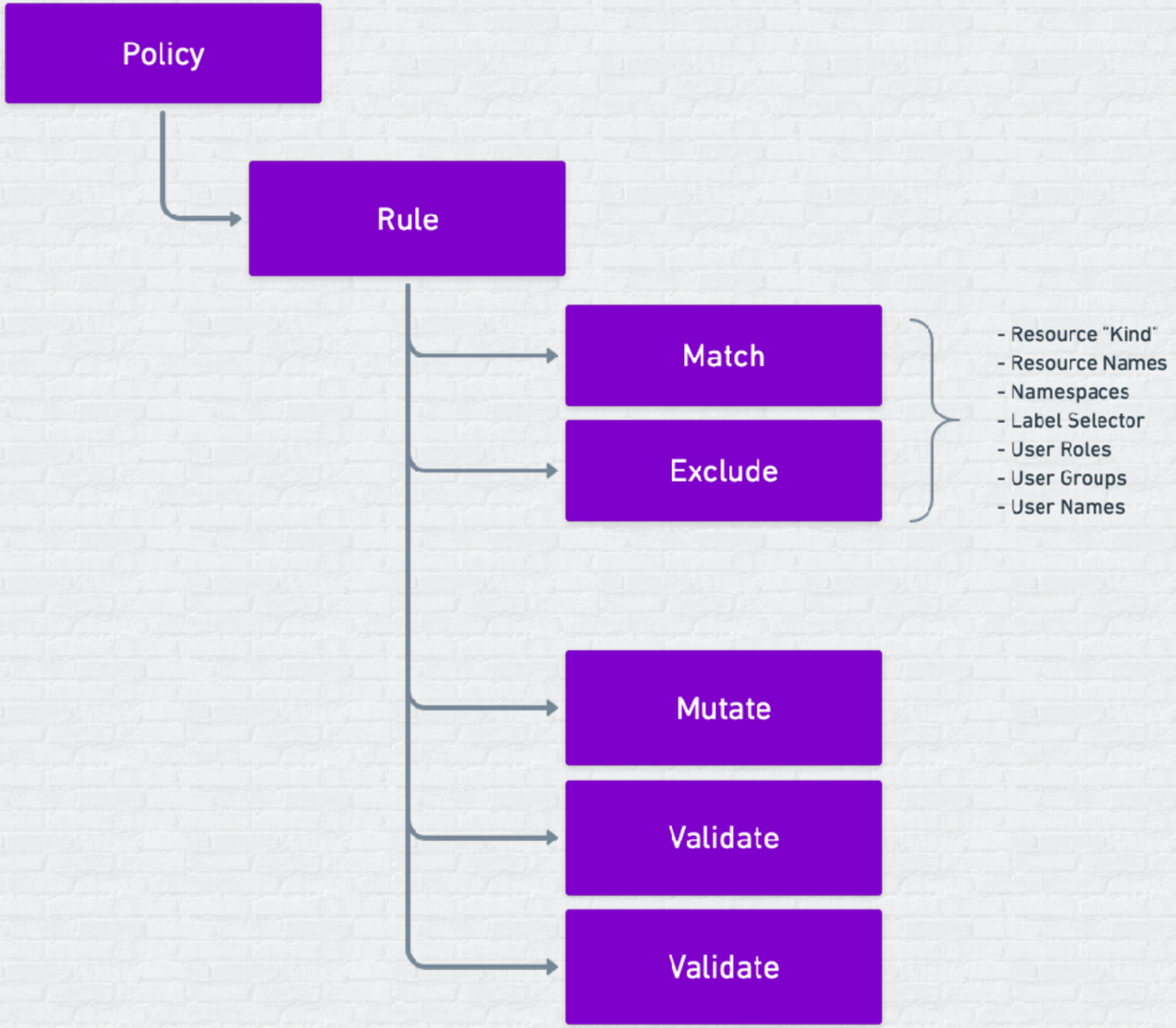
What is Kyverno?

- Policy-Engine specifically designed for Kubernetes
- Policies are created and managed as native Kubernetes resources and authored in YAML
- Validating and Mutating Policies and Webhooks are Supported by Kyverno

Kyverno Concepts

- Install Kyverno CRDs, Webhooks, Service Accounts and Namespaces
- Policies => Validating or Mutating Policy Definitions
- Selectors => Matches Resources in Request based on Policy

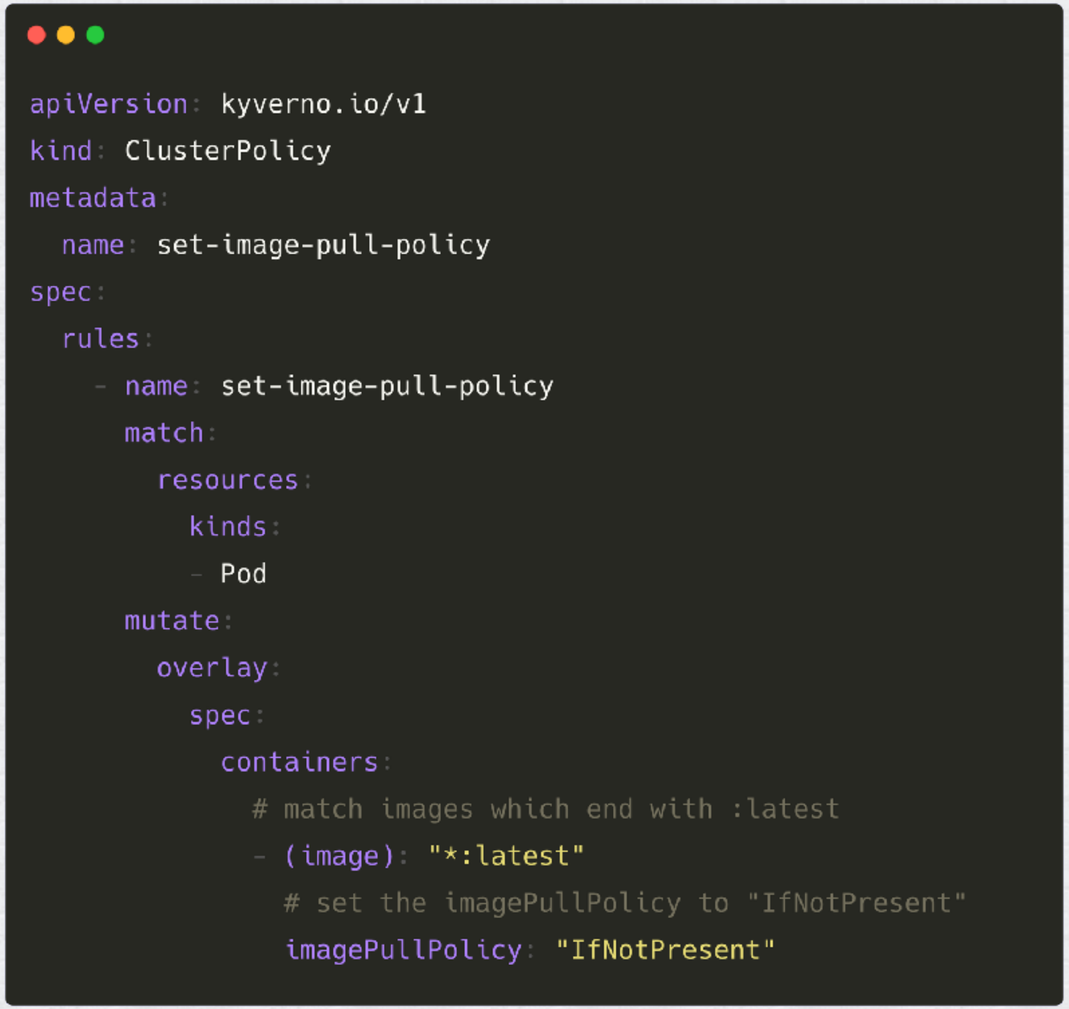
Kyverno Policy Structure



Basic Kyverno Validate Policy


```yaml
apiVersion: kyverno.io/v1
kind: ClusterPolicy
metadata:
  name: require-labels
spec:
  validationFailureAction: enforce
  rules:
  - name: check-for-labels
    match:
      resources:
        kinds:
        - Namespace
    validate:
      message: "The label `purpose` is required."
      pattern:
        metadata:
          labels:
            purpose: "?*"
```

Kyverno Mutate Policy



```yaml
apiVersion: kyverno.io/v1
kind: ClusterPolicy
metadata:
  name: set-image-pull-policy
spec:
  rules:
    - name: set-image-pull-policy
      match:
        resources:
          kinds:
          - Pod
      mutate:
        overlay:
          spec:
            containers:
              # match images which end with :latest
              - (image): "*:latest"
                # set the imagePullPolicy to "IfNotPresent"
                imagePullPolicy: "IfNotPresent"
```

Kyverno Generate Policy

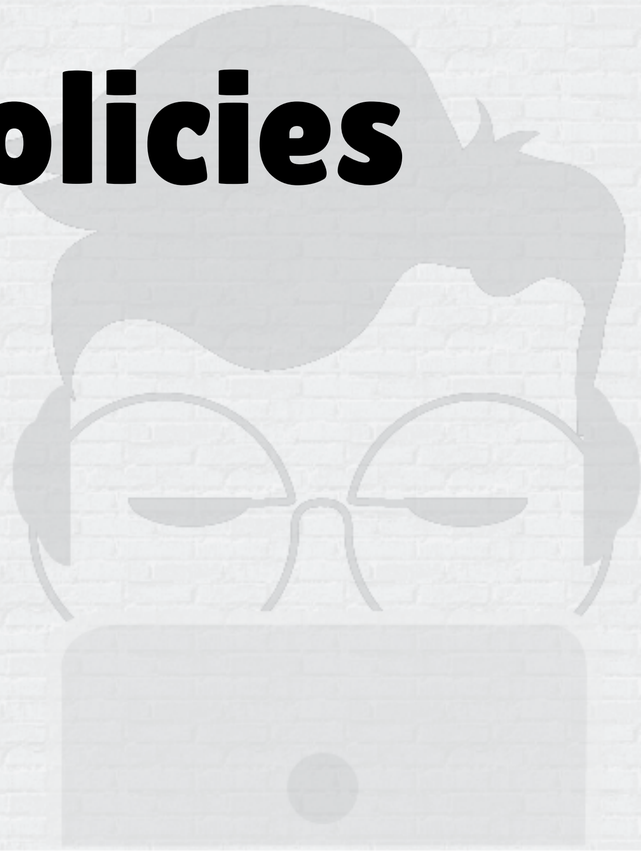
```yaml
apiVersion: kyverno.io/v1
kind: ClusterPolicy
metadata:
  name: default
spec:
  rules:
  - name: deny-all-traffic
    match:
      resources:
        kinds:
        - Namespace
    exclude:
      resources:
        namespaces:
        - kube-system
        - default
        - kube-public
        - kyverno
    generate:
      kind: NetworkPolicy
      name: deny-all-traffic
      namespace: "{{request.object.metadata.name}}"
      data:
        spec:
          # select all pods in the namespace
          podSelector: {}
          policyTypes:
          - Ingress
          - Egress
```

Kyverno Benefits

- No additional DSL required.
- Mutate, Validate AND Generate
- Background Capabilities
- Audit/Enforce
- Reporting - Out of the box

Lab: Kyverno

Kubernetes Network Policies



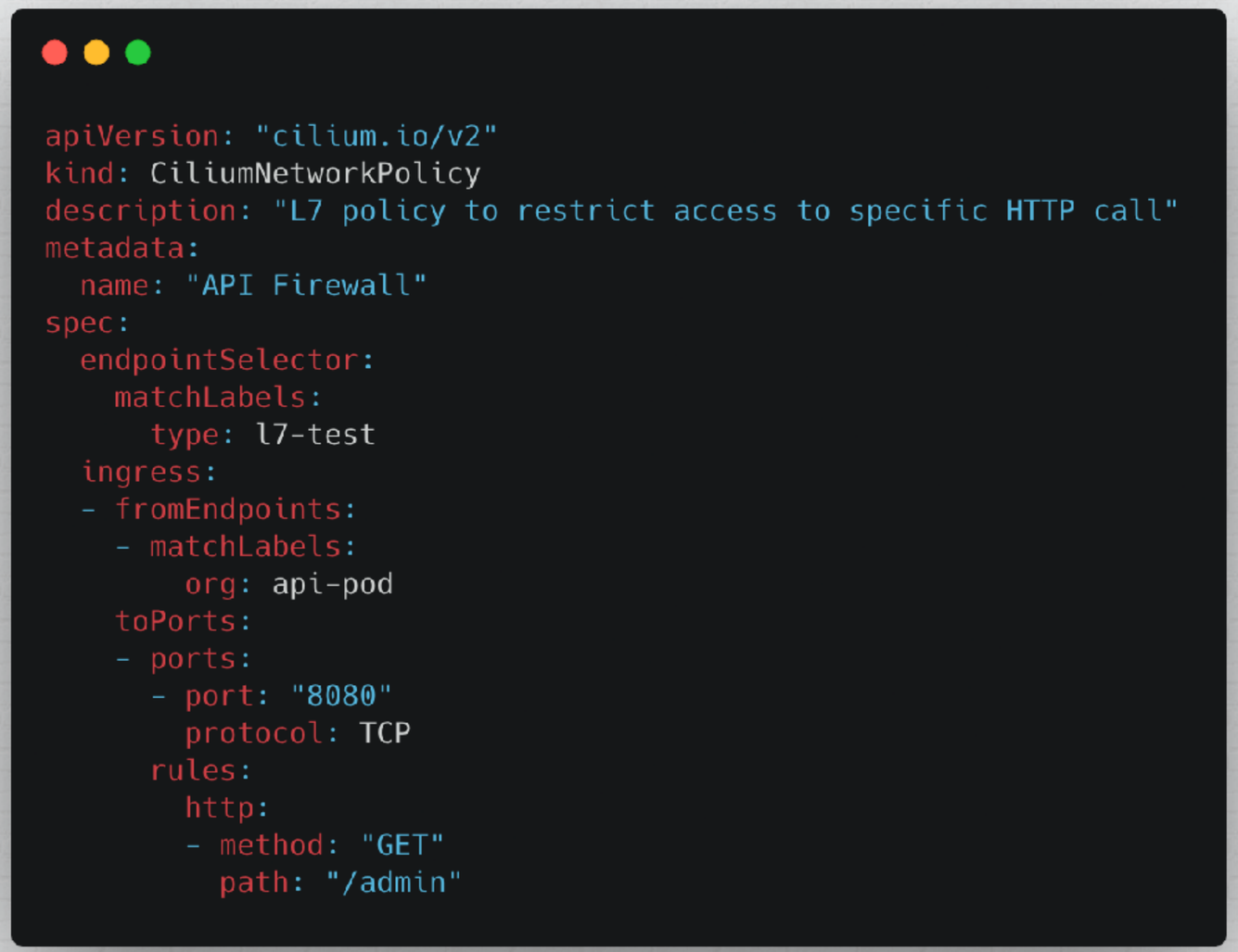
NetworkPolicy – Local and Global

- NetworkPolicy is namespaced (local)
- Certain CNIs provide Global variants of Network Policy that can be applied across the cluster
- NetworkPolicy cannot do more than L3/L4
- NetworkPolicy cannot log security events

Cilium – Network Security

- Cilium is a popular OSS CNI (with an Enterprise Option)
- Leverages BPF for Network Security, Routing and Observability
- Adds several features including:
  - Encryption
  - UI and Filter Panel
  - L7 Network Policy Control

Layer 7 Policy Example

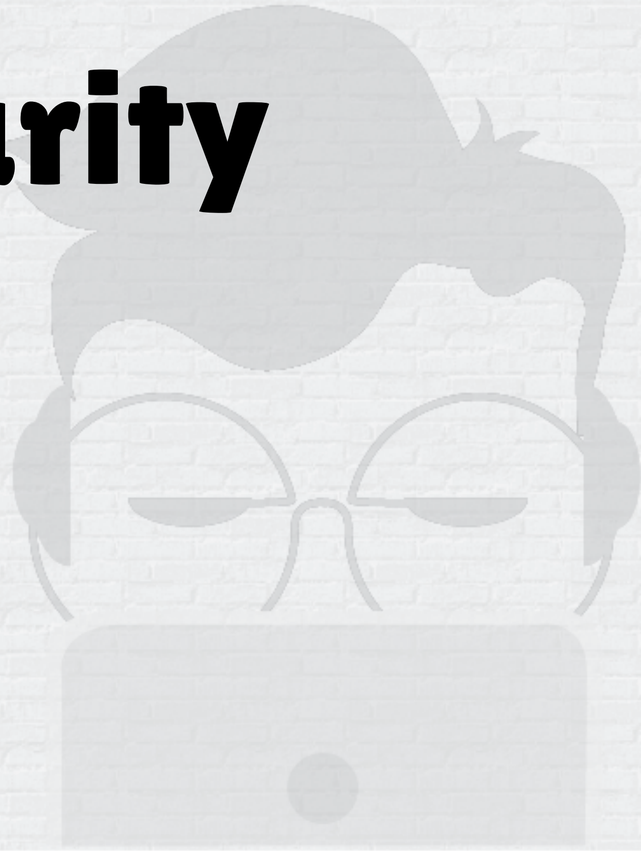


```yaml
apiVersion: "cilium.io/v2"
kind: CiliumNetworkPolicy
description: "L7 policy to restrict access to specific HTTP call"
metadata:
  name: "API Firewall"
spec:
  endpointSelector:
    matchLabels:
      type: l7-test
  ingress:
  - fromEndpoints:
    - matchLabels:
        org: api-pod
    toPorts:
    - ports:
      - port: "8080"
        protocol: TCP
      rules:
        http:
        - method: "GET"
          path: "/admin"
```

Database Security Policy

```yaml
apiVersion: "cilium.io/v2"
kind: CiliumNetworkPolicy
description: "Allow only permitted requests to empire Cassandra server"
metadata:
  name: "secure-empire-cassandra"
specs:
  - endpointSelector:
      matchLabels:
        app: cass-server
    ingress:
    - fromEndpoints:
      - matchLabels:
          app: empire-outpost
      toPorts:
      - ports:
        - port: "9042"
          protocol: TCP
        rules:
          l7proto: cassandra
          l7:
          - query_action: "select"
            query_table: "system\\..*"
          - query_action: "select"
            query_table: "system_schema\\..*"
          - query_action: "insert"
            query_table: "attendance.daily_records"
    - fromEndpoints:
      - matchLabels:
          app: empire-hq
      toPorts:
      - ports:
        - port: "9042"
          protocol: TCP
        rules:
          l7proto: cassandra
          l7:
          - {}
```

PaC – Workload Security



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PaC Applicability

- PaC - Used to compose eBPF Signatures, LSM Configurations to protect workloads
- PaC Frameworks - help you abstract from the complex details

Tools and Frameworks

Monitoring Security Anomalies with Falco

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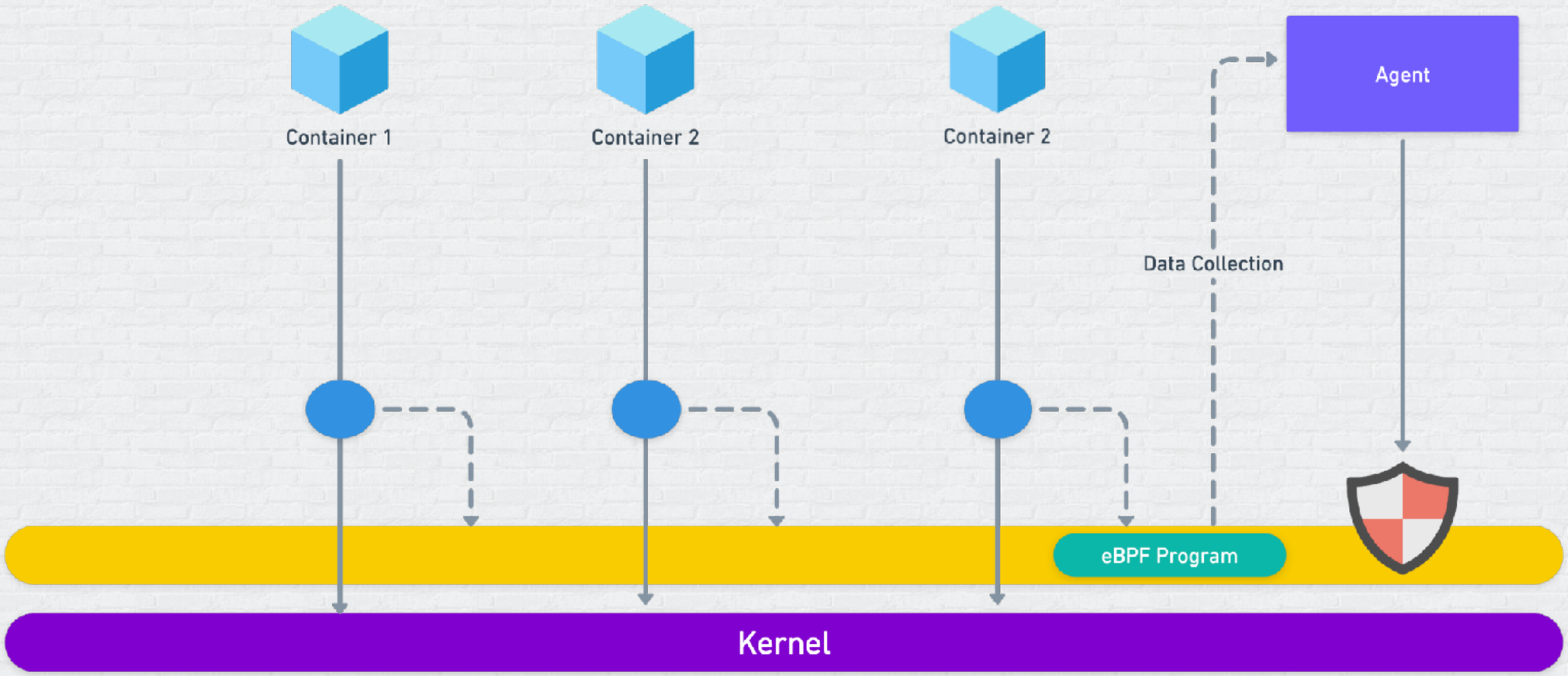
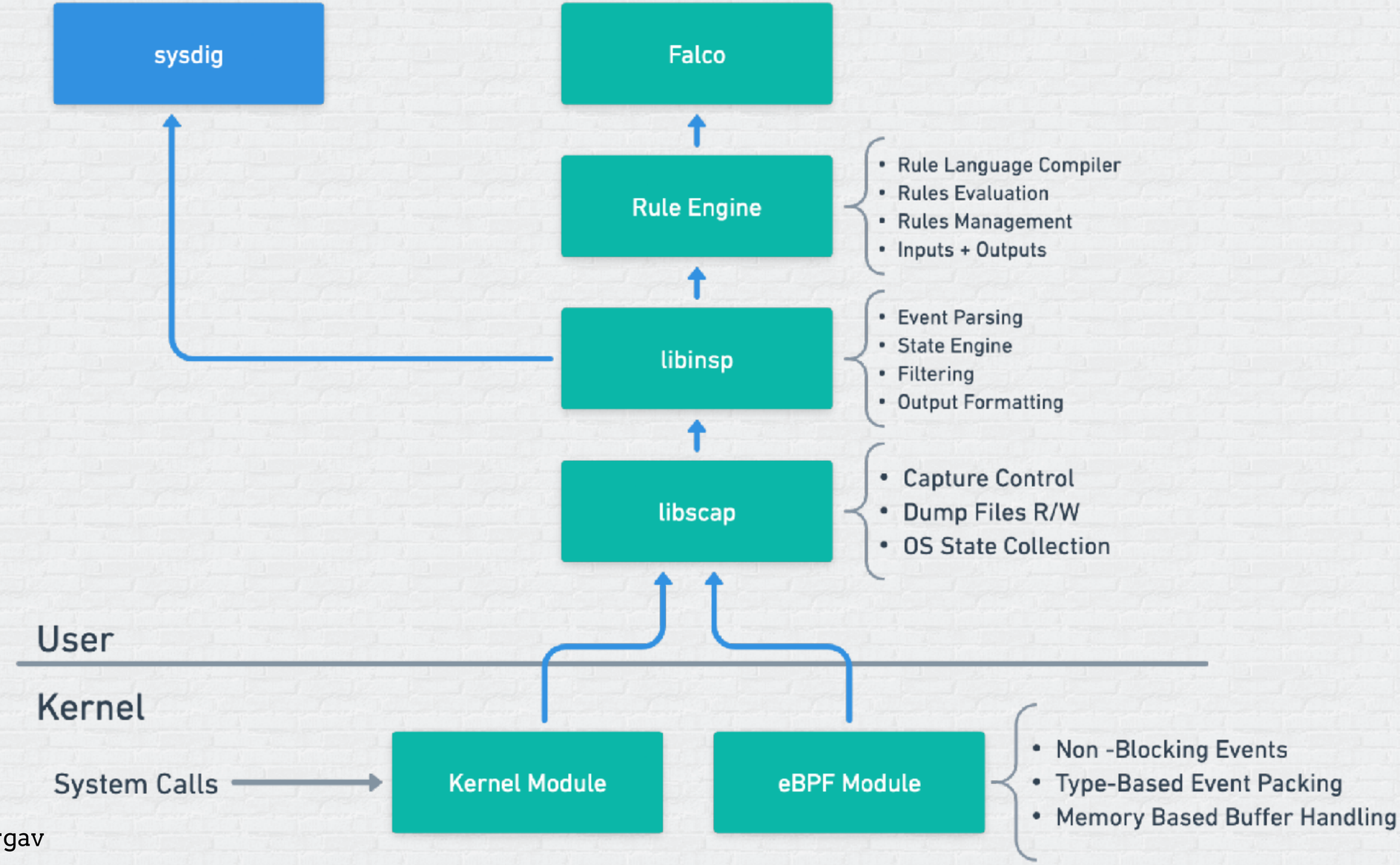
How Falco works



Falco Under the hood



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Falco Rules

```
- macro: open_read
  condition: (evt.type=open or evt.type=openat) and evt.is_open_read=true and fd.typechar='f' and
fd.num>=0
- list: sensitive_file_names
  items: [/etc/secret]
- rule: Secret file is accessed
  desc: >
    secret
condition: >
    fd.name in (sensitive_file_names) and open_read
output: "Sensitive Secret file accessed"
  priority: CRITICAL
  tags: [filesystem, secret]
```