Securing Your K8s Infrastructure With Calico and Tigera Secure

Seattle - Oct 16, 2019

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Drew Oetzel - Senior Technical Solutions Engineer

- Working with enterprise software since the late 90s
- 7 years at Splunk, honing his security skills
- 2.5 years at Mesosphere, then Heptio mastering the art of distributed systems, containers, and all that goes along with them
- Outside of tech ask him about history, gardening, or what he’s doing to try to curb his Reddit addiction!

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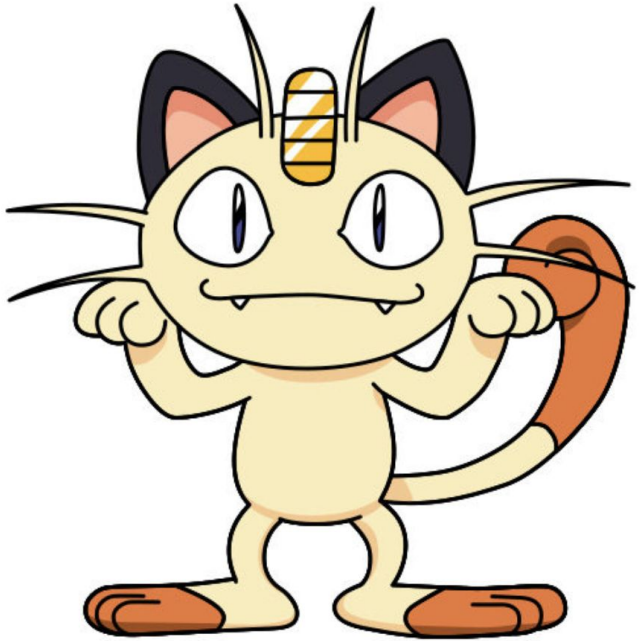
Who is Tigera?

A super secret Pokemon?



No, but we do have a conference room named after Meowth!

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Who Is Tigera?

Tigera Secure

- Zero Trust Network Security
- Visibility, Traceability and Remediation for Dynamic Applications
- Continuous Compliance & Enterprise Controls
- Security that Spans Multi-Cloud and Legacy Environments

Tigera Calico

- Open-source
- Scalable, distributed control plane
- Policy-driven network security
- No overlay required
- Widely deployed, and proven at scale

Bloomberg GitHub salesforce NTT Communications IBM CommonwealthBank orange virtustream EMC² YAHOO! box BBVA

SQUARESPACE Giant Swarm ebay idealo USA TODAY YAHOO! JAPAN at&t CenturyLink Ford JPMorganChase

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Tigera Strategic Partnerships

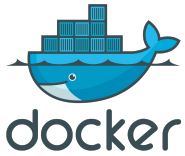
Integrated with ACS Engine, Collaborating on Azure Kubernetes Service (AKS) and Windows

Default network policy for Azure Container Service for Kubernetes (EKS) & Heptio/AWS Quick Start

Partnered to support network policy in Google Container Engine (GKE)

Partner to implement connectivity and security for IBM Kubernetes Service, IBM Cloud Private

OpenShift primed partner. Certified integration with OpenShift Container Platform



Default networking and policy for Docker EE Kubernetes

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Calico Review

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What is Calico

“Networking” for containers.

Open source project with worldwide contributors backed by the commercial enterprise Tigera, Inc.

Most used CNI plugin for Kubernetes worldwide.

www.projectcalico.org

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OK, BUT WHAT CAN CALICO DO FOR ME?

Efficiently hand out IPs to your pods. (IPAM)

- **Can use different subnets per namespace or rack / VPC**
- **Can assign static IP addresses to pods**

Secure your inner K8s networking with policies.

- **Secure your East/West traffic**
- **Prevent malicious behavior from spreading**
- **Block insider threat / insider error**

Mix and match components - can run Calico for just network policies with other CNIs

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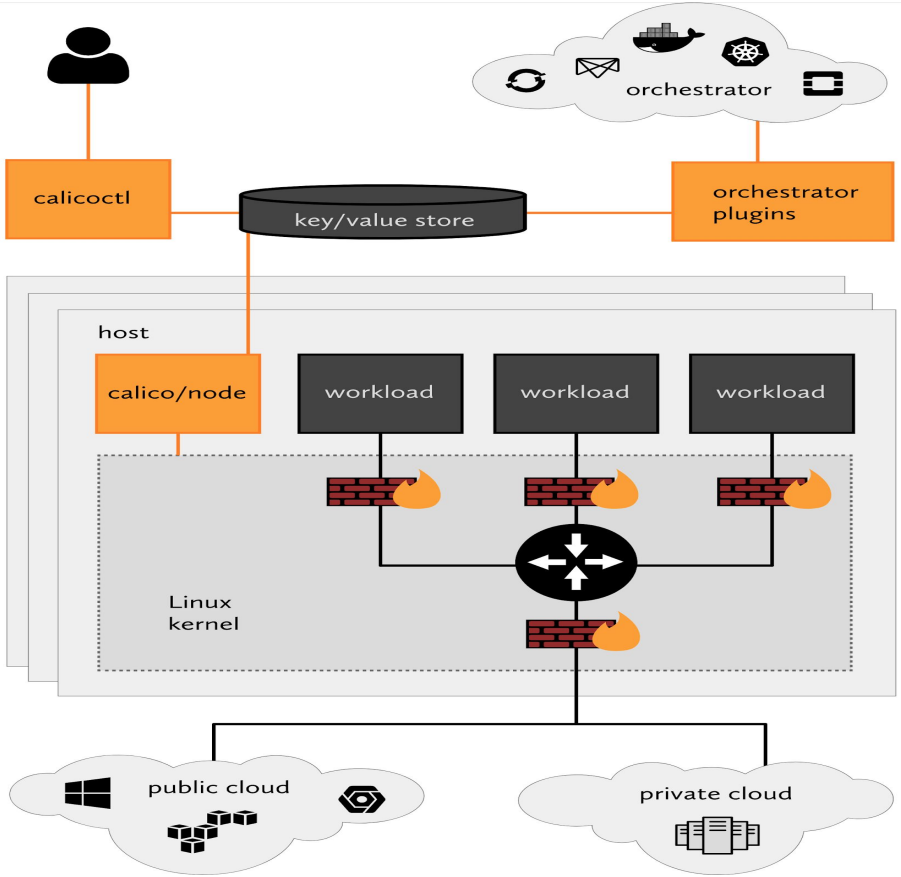
High Level Calico Architecture: Summary



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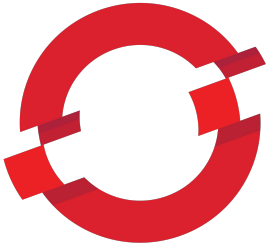
Calico CNI and IPAM in Action

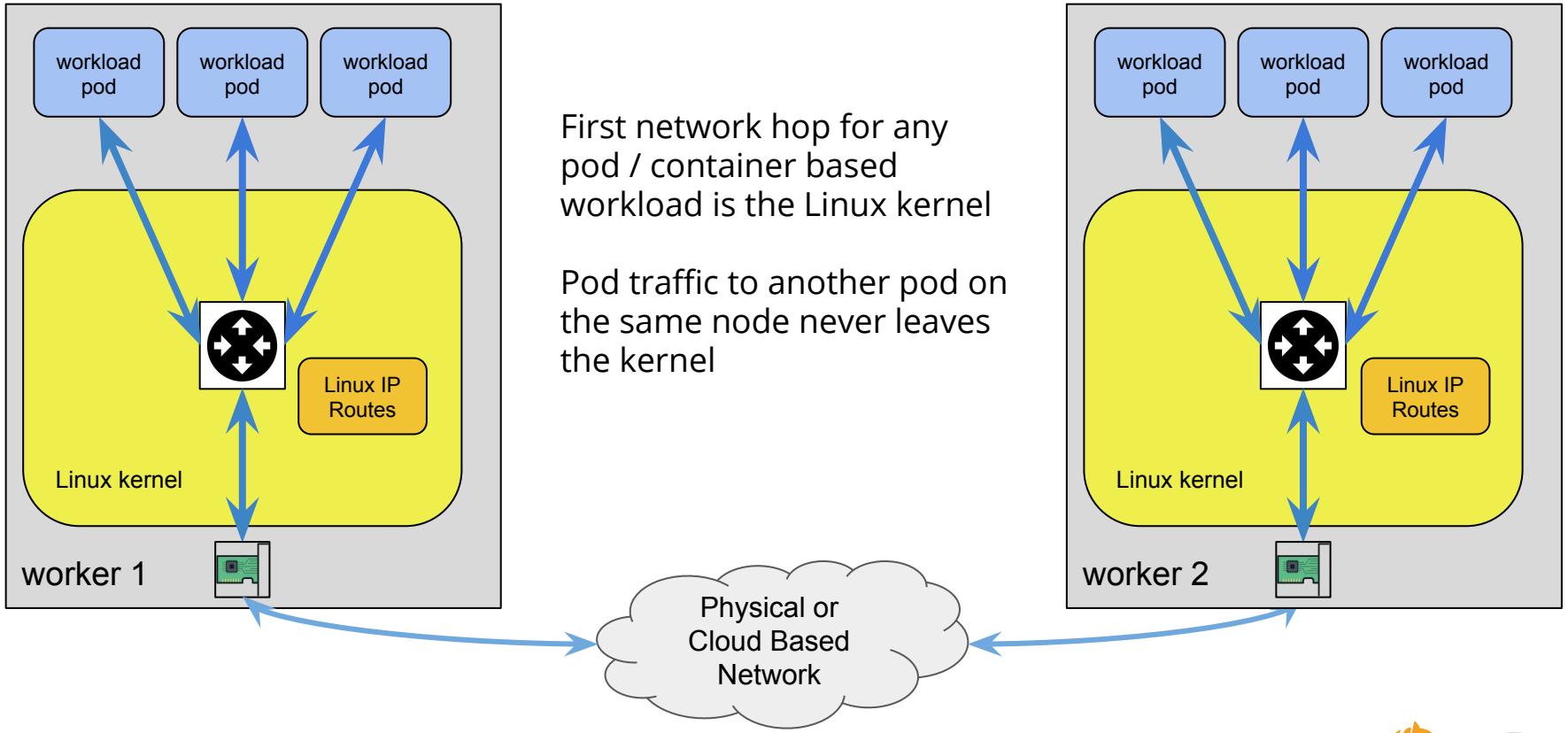
Where to run the Calico CNI?

Upstream K8s - bare metal or cloud



The artist formerly known as Mesosphere

Intra Pod and Intra Node Networking



First network hop for any pod / container based workload is the Linux kernel

Pod traffic to another pod on the same node never leaves the kernel

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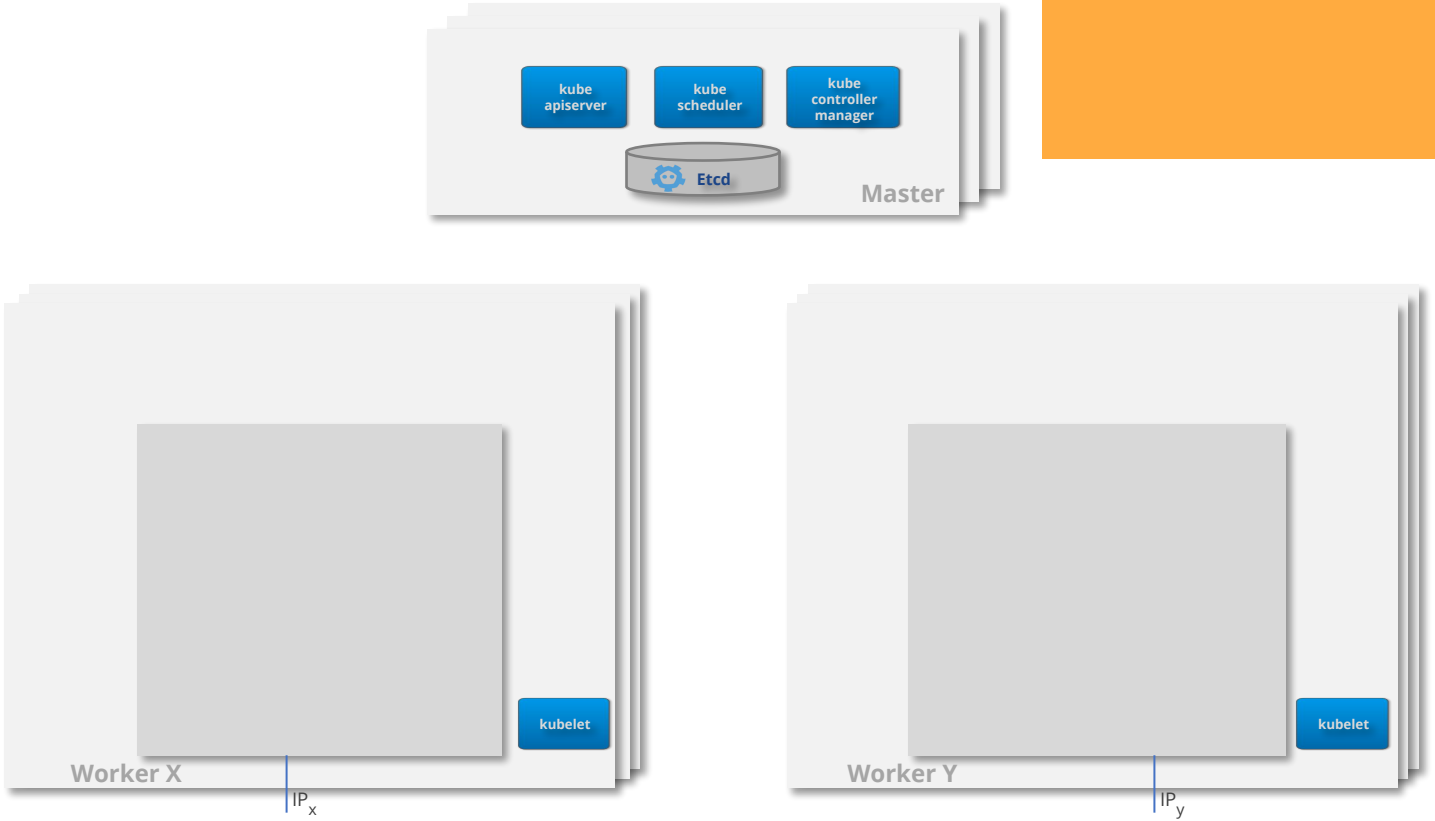
Pod Lifecycle

Lets start with baseline K8s nodes



Pod Lifecycle

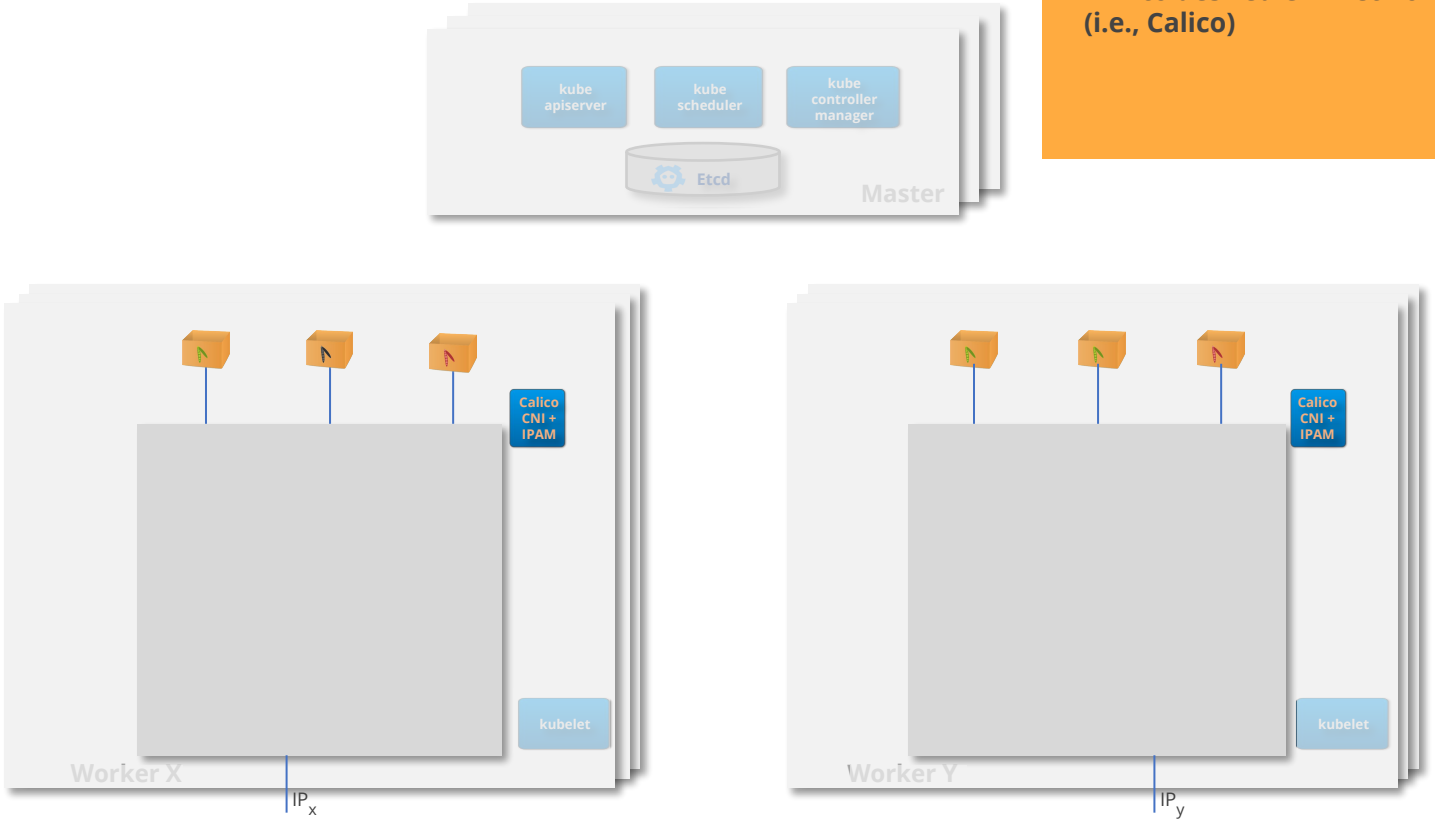
Pods get scheduled on worker nodes

Pod Lifecycle: CNI

Kubelet on worker node calls CNI

Pod Lifecycle: CNI

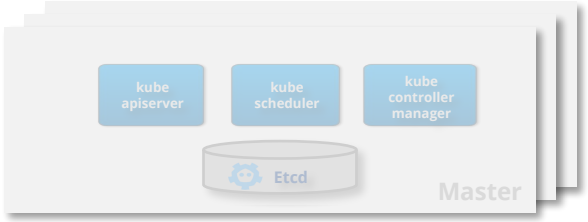
Configuration in /etc/cni/net.d provides link to desired CNI network plugin (i.e., Calico)

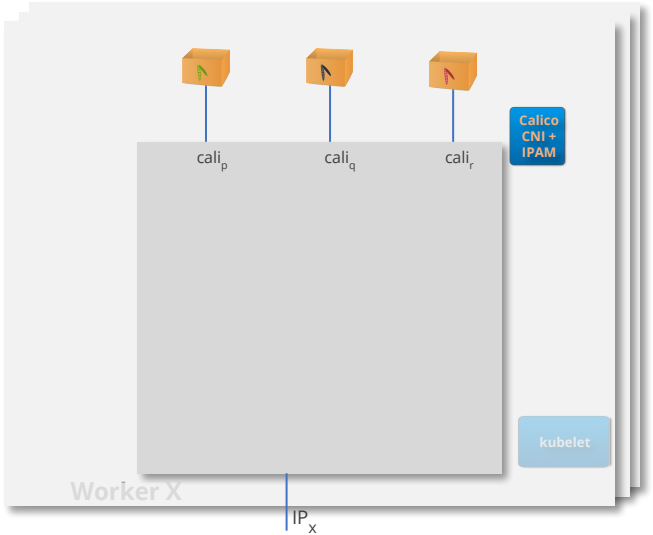


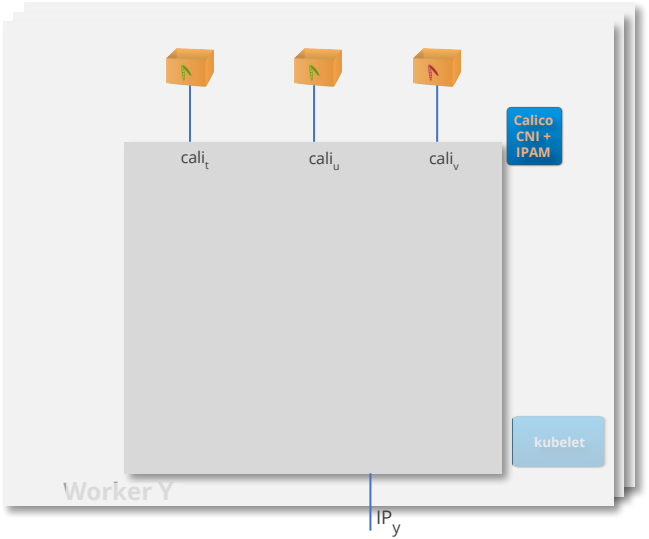
Pod Lifecycle: CNI

Calico-cni creates virtual ethernet (veth)

Appears as unnumbered cali* on host**

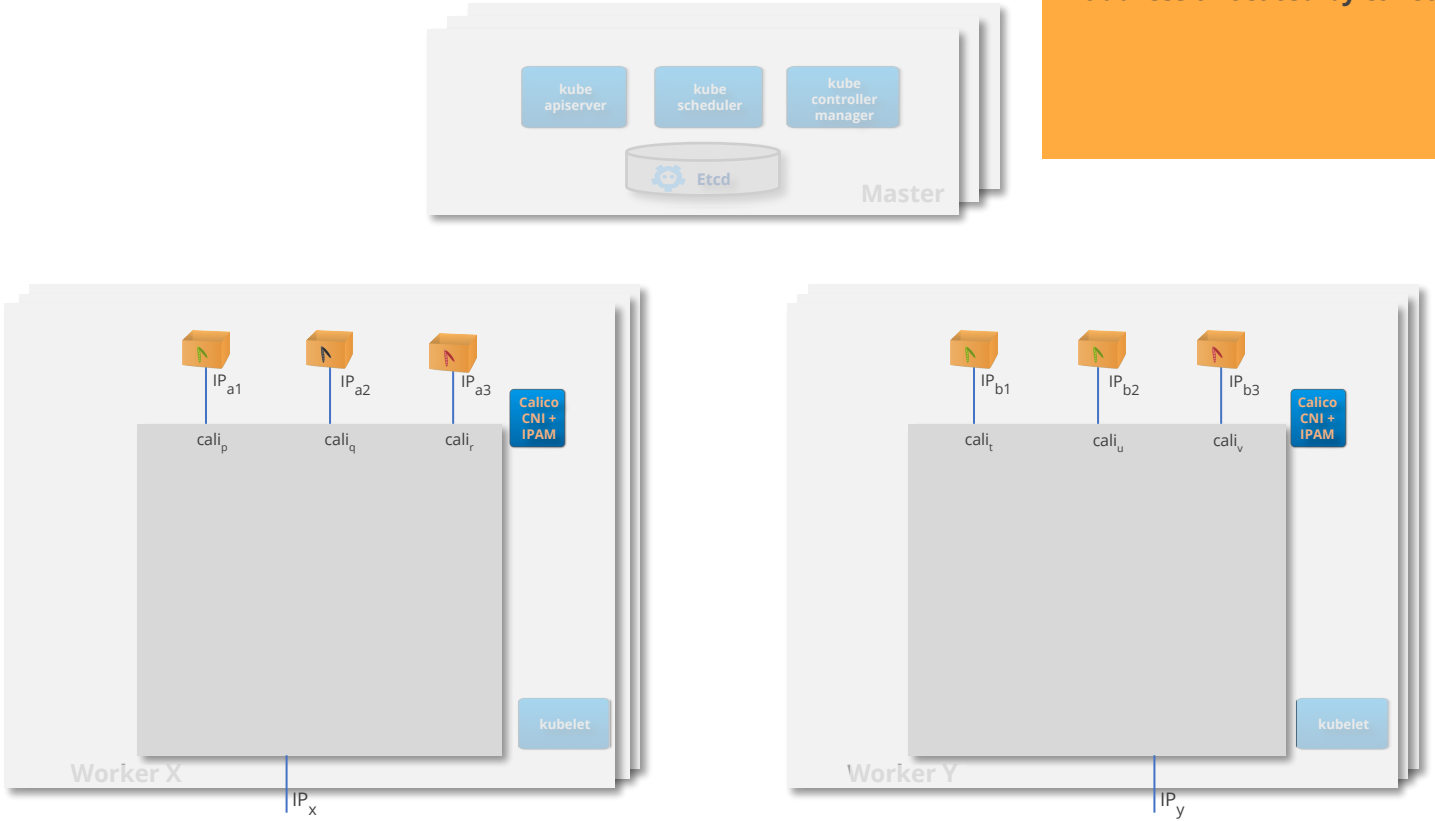






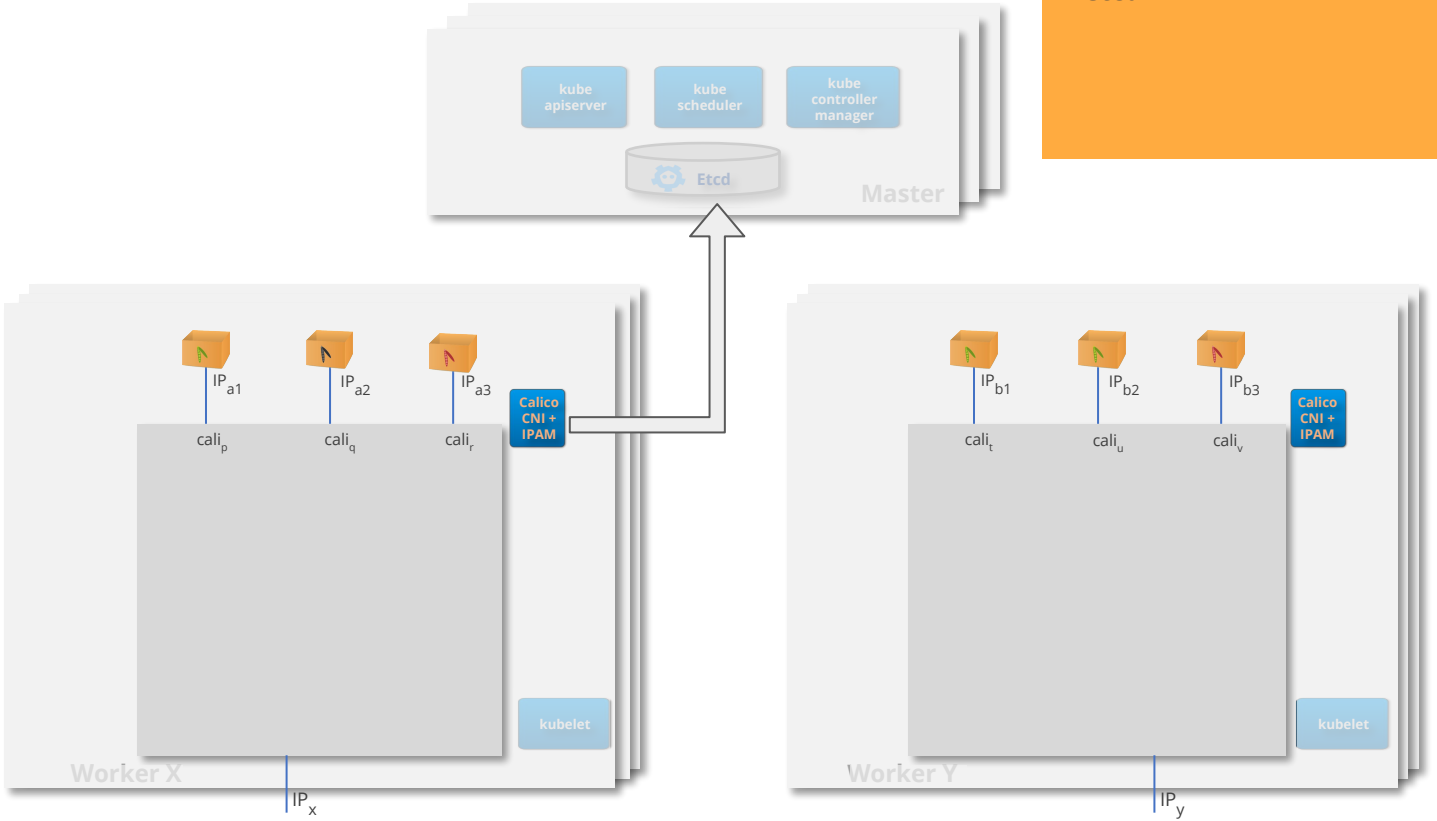
Pod Lifecycle: Address Block Assignment

And appears as eth0 inside pod, with IP address allocated by calico-ipam

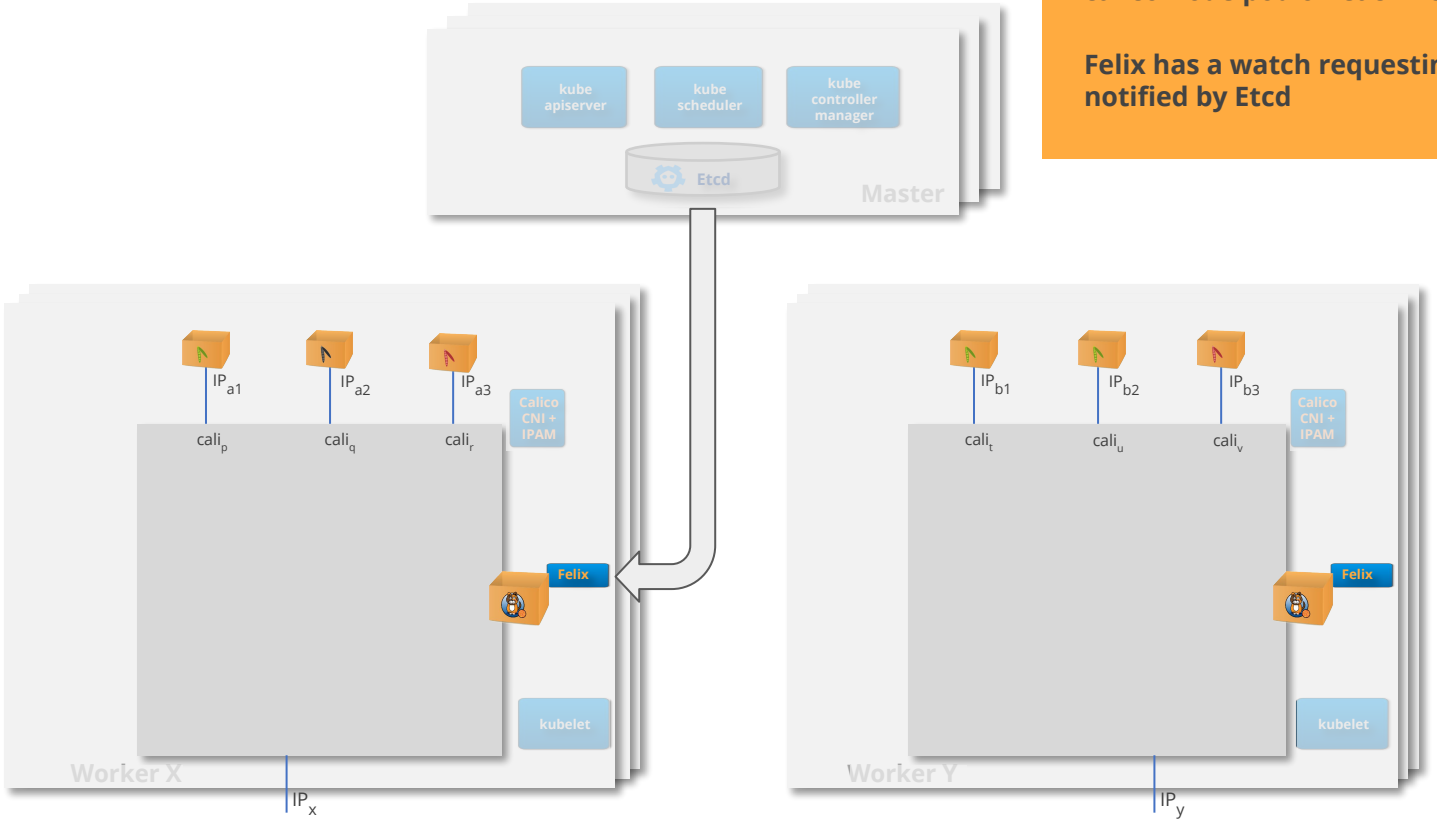


Pod Lifecycle

Workload (pod) information written to etcd



Pod Lifecycle

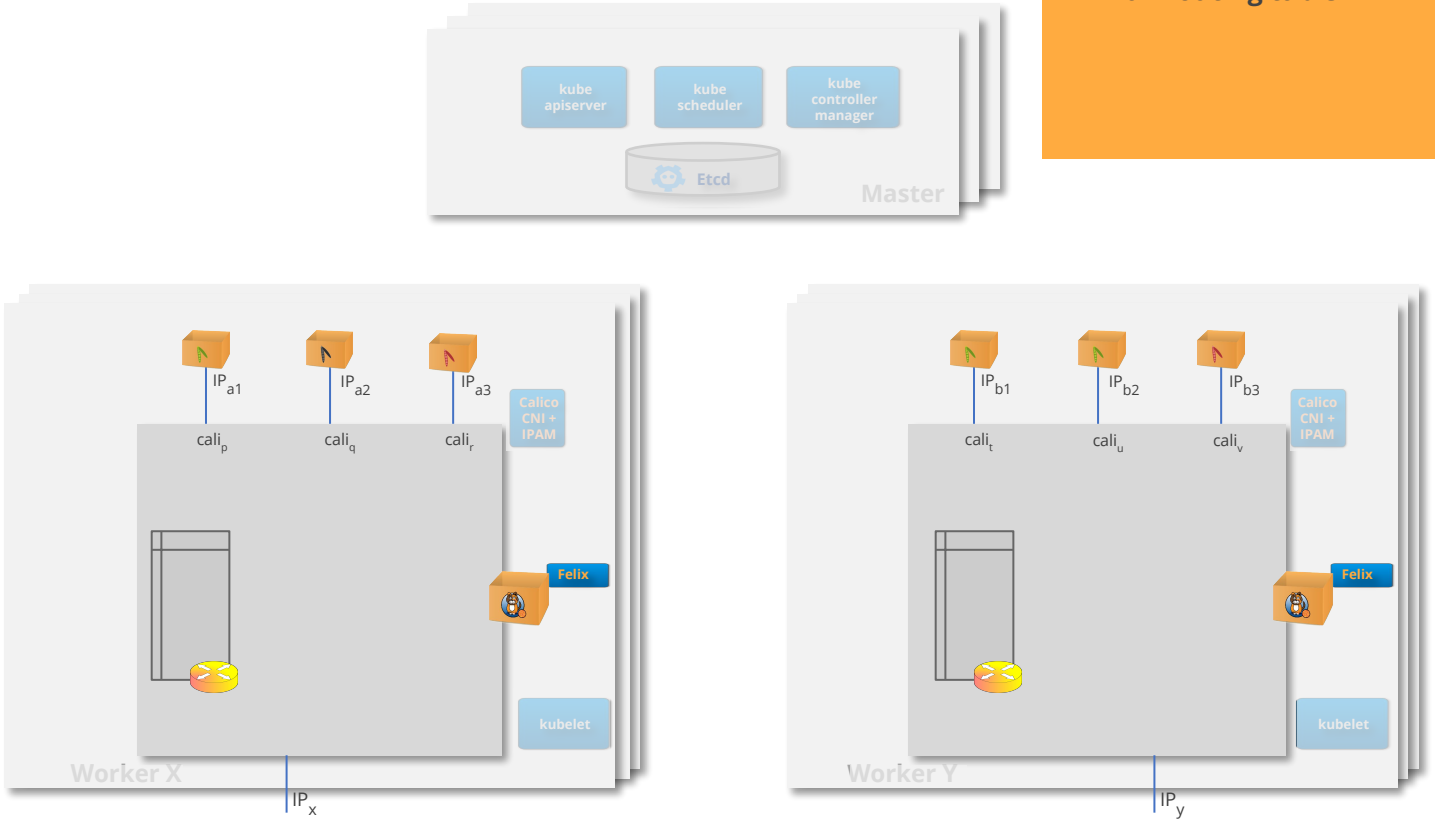


Felix daemon process runs inside the calico-node pod on each host

Felix has a watch requesting to be notified by Etcd

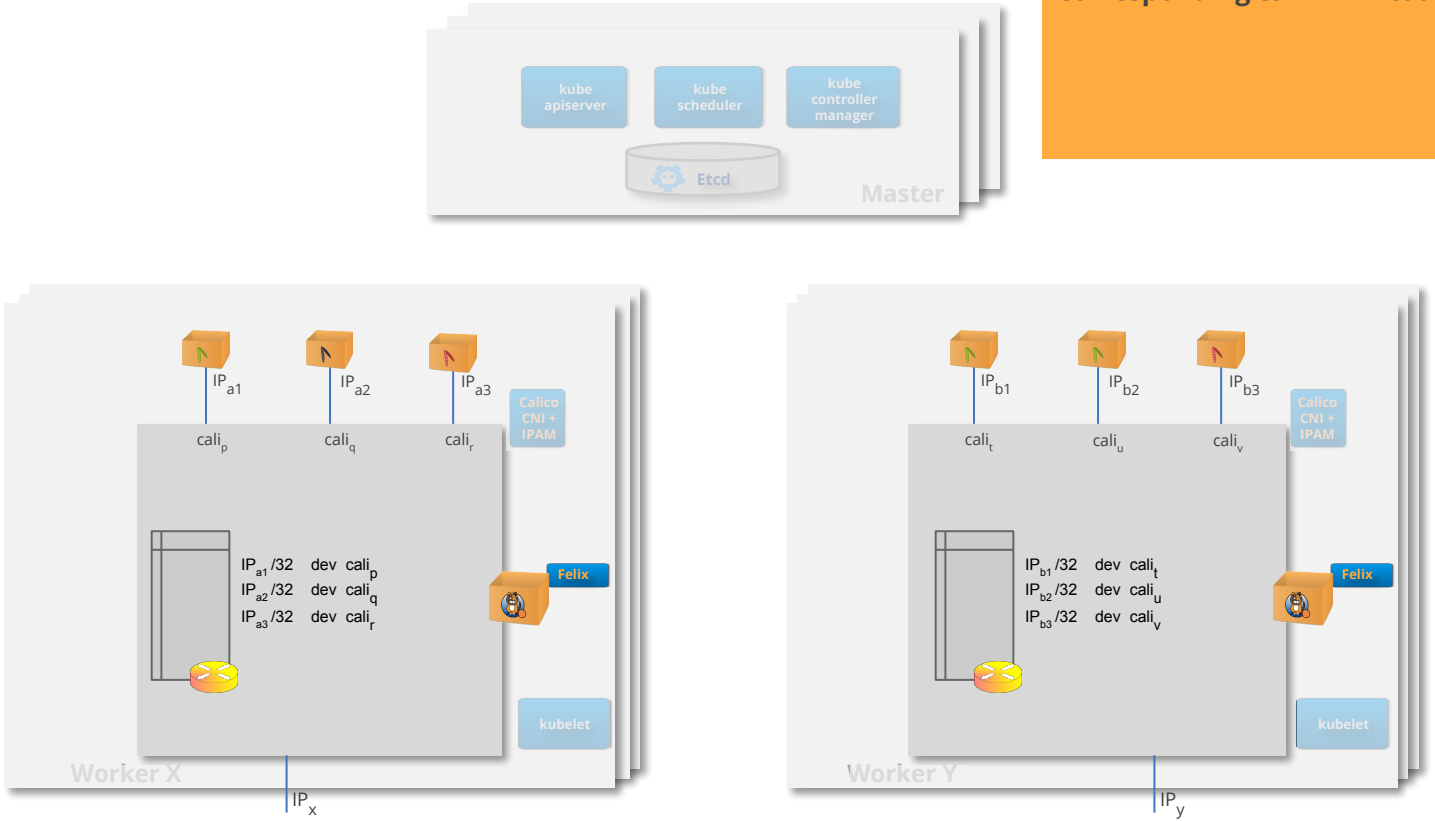
Pod Lifecycle

Felix adds local interface routes into Linux routing table



Pod Lifecycle

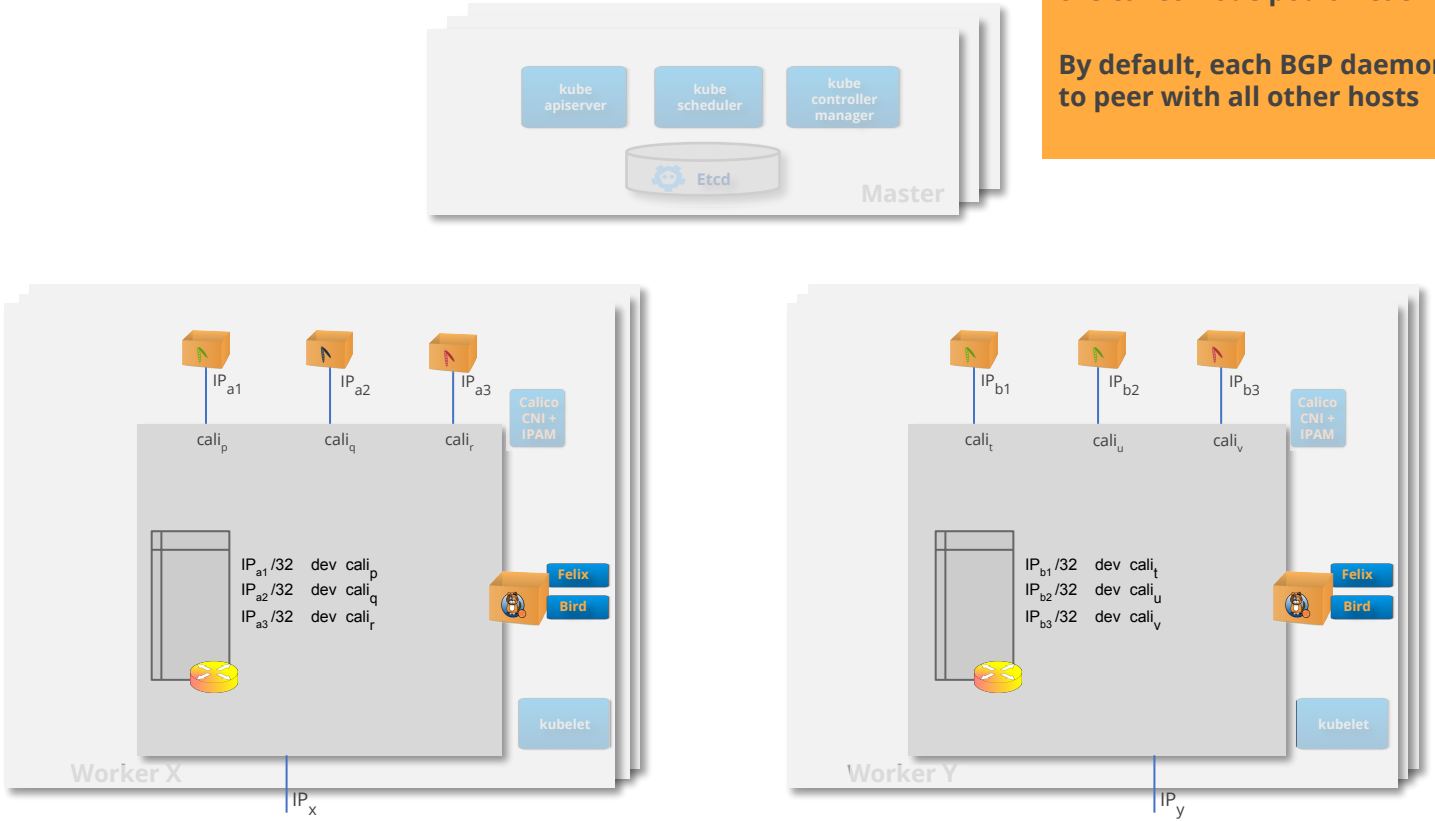
Route added for each pod's IP pointing to corresponding cali* virtual ethernet**



Pod Lifecycle

BGP daemon (BIRD) process runs inside the calico-node pod on each host

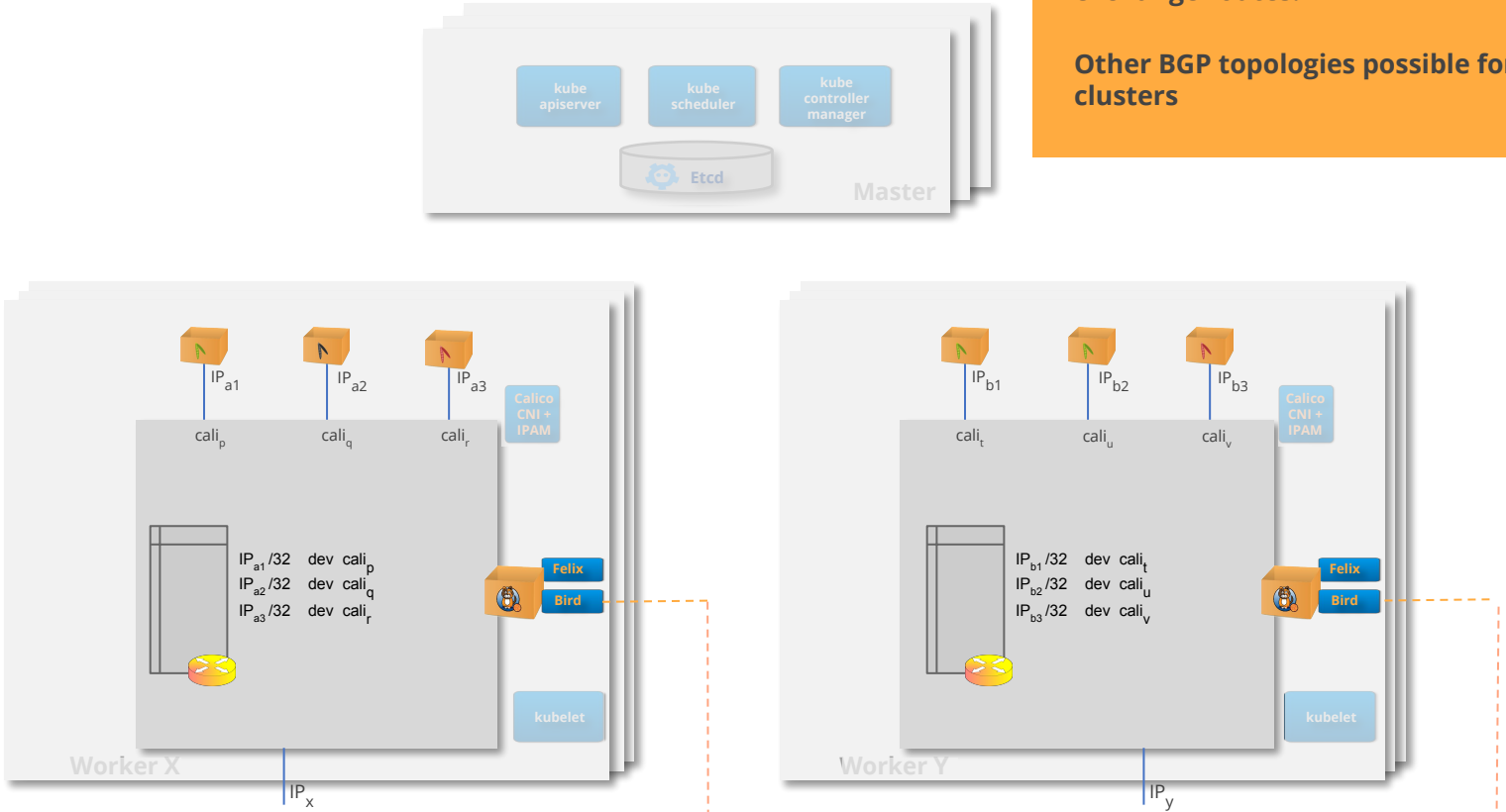
By default, each BGP daemon is configured to peer with all other hosts



Pod Lifecycle

Nodes create a BGP full mesh to exchange routes.

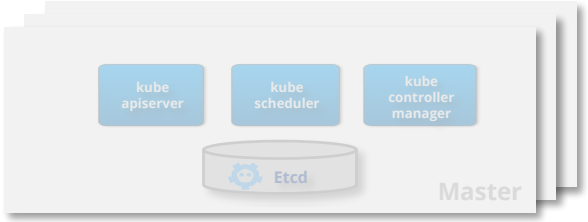
Other BGP topologies possible for large clusters

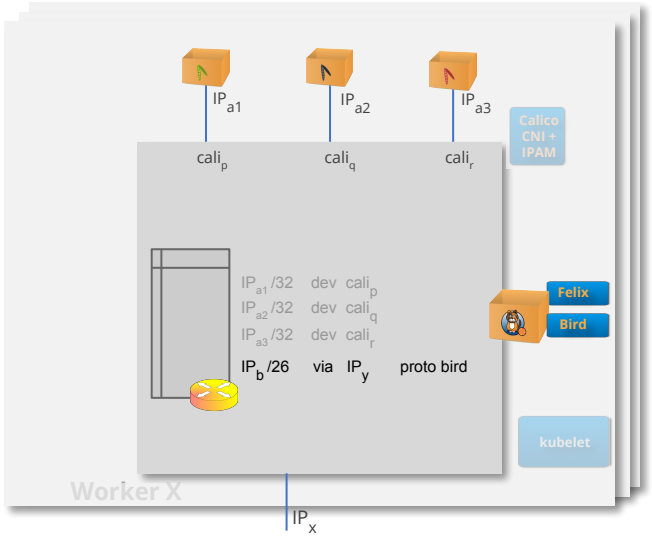


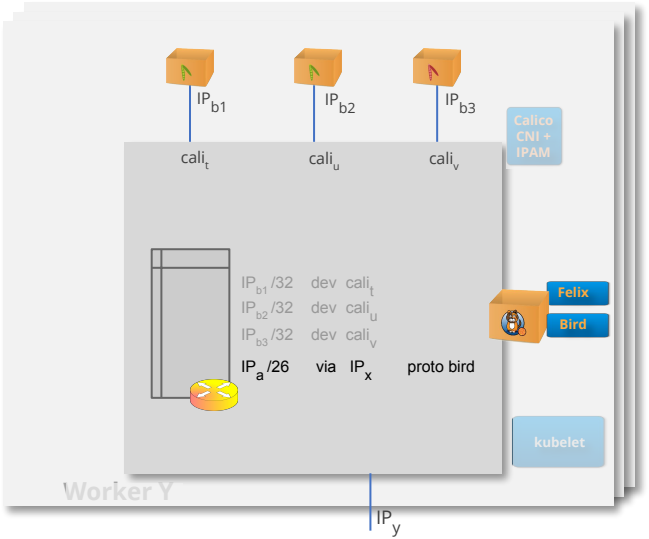
Pod Lifecycle

Routes for Pod IP addresses exchanged among nodes via BGP.

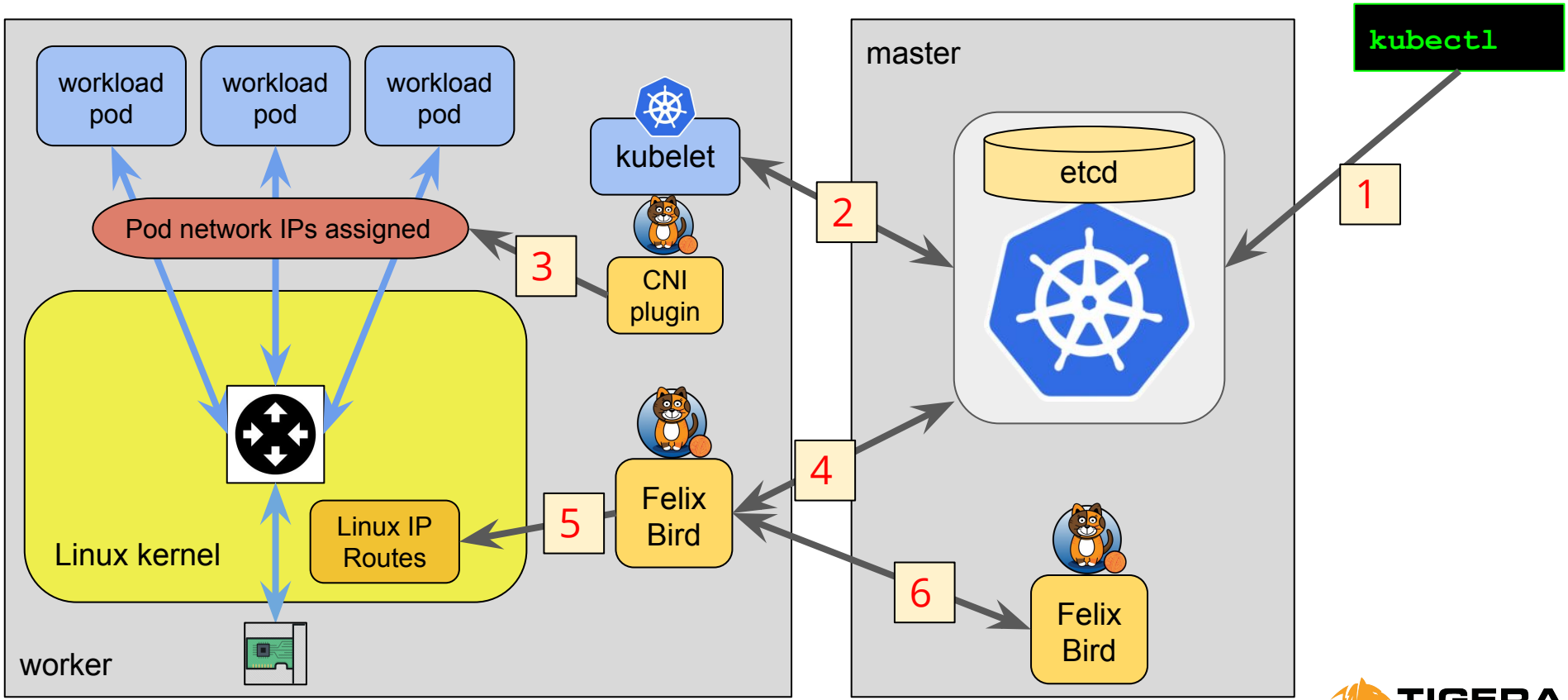
Each Linux node simply routes packets using the default routing table.







High Level Calico CNI Architecture



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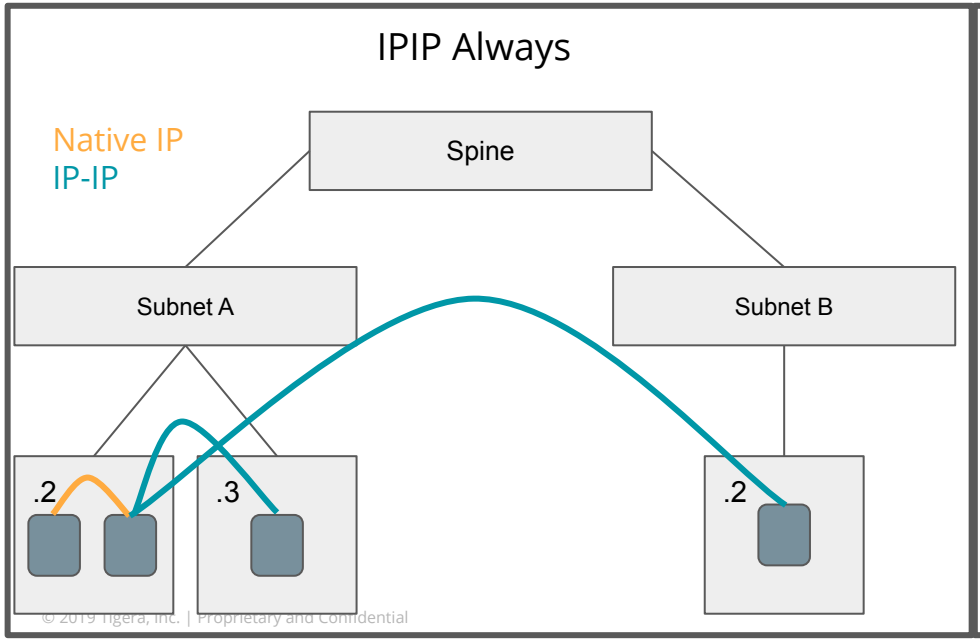
Overlay vs. Flat Network

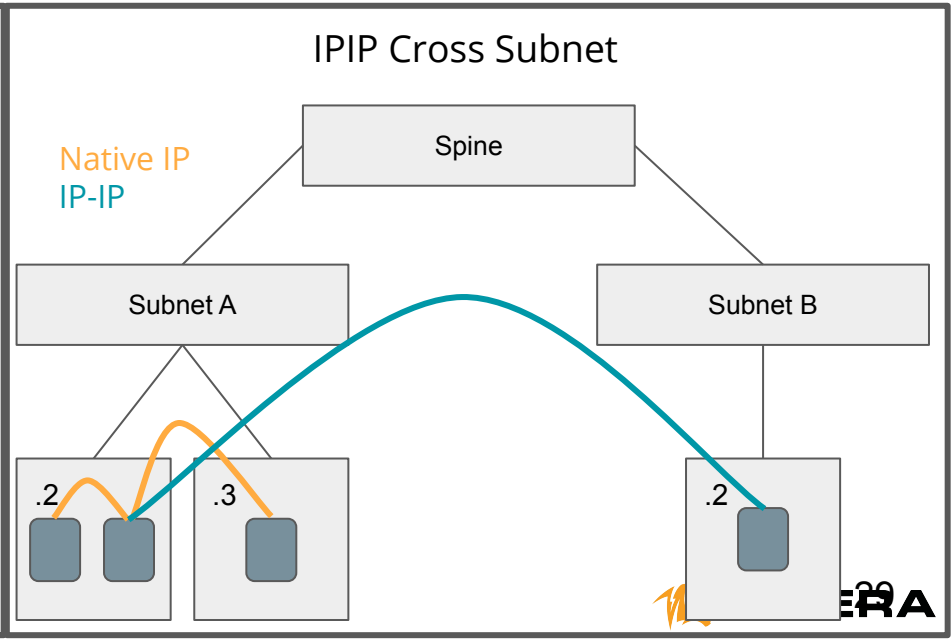
Calico Networking Options: To Overlay or Not To Overlay

- How much control you have over your networking infrastructure outside of Kubernetes will determine which of the various overlay options you should chose
  - If you have full control - e.g. private data center your pods can choose to not be overlayed - BGP enabled routers will get the packet to the right node
  - If you don't have full control - e.g. any of the public clouds, you can opt for IP in IP networking or a traditional VXLAN
    - IPIP is preferred since it's slightly more efficient with smaller headers than VXLAN
    - VXLAN is required in Azure cloud environments

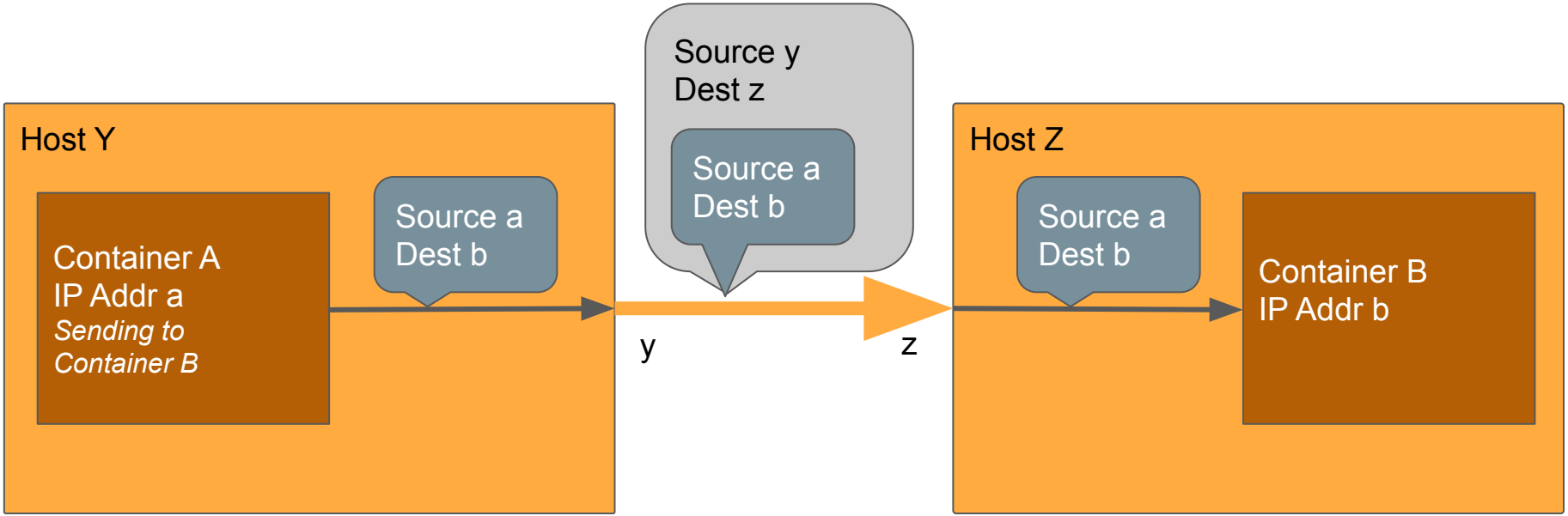
Calico Networking Options: IP in IP Options

- Calico can operate in two modes with IP in IP
  - IP in IP always encapsulates all IP traffic except traffic that never leaves the node
  - IP in IP cross subnet encapsulates traffic that crosses a subnet boundary, but not traffic for within the subnet





IP-IN-IP VISUALIZED



IP Pools and the Calico CNI

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IP Pools

- **IP Pools** can be associated with namespaces, workloads, or topology
- **Topology**: designate certain nodes with a node label in Kubernetes, then reference that label in the pool definition
- **Namespace**: add a Calico annotation to the namespace definition
- **Workload**: same as namespace – though any annotation set at the namespace level will take priority over a workspace annotation
  - Example annotation added to namespace or workload yaml:
    `annotations: "cni.projectcalico.org/ipv4pools": "[\"dmz-pool\"]"`
  - Note all the "\" escapes are necessary

IP Pool Definition - Topology

`dmz_pool.yaml`

```
apiVersion: projectcalico.org/v3
kind: IPPool
metadata:
   name: dmz-pool
spec:
   cidr: 10.0.1.0/24
   ipipMode: Always
    natOutgoing: true
    nodeSelector: type: "dmz-node"
```

This will define an IP Pool named dmz-pool.

When running multiple subnets for pods it's usually a good idea to set natOutgoing to true and IPIP mode to always.

nodeSelector is one way to specify IP pool use per topology

IP Pools – Namespaces and workloads

dmz_ns.yaml

```
apiVersion: v1
kind: Namespace
metadata:
  name: dmz
  labels:
    location: dmz
  annotations:
 "cni.projectcalico.org/ipv4pools": "[\"dmz-pool\"]"
```

To assign an IP Pool to a namespace add and annotation to the namespace definition referencing the IP Pools name.

Do Labs 1 & 2

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Declarative Network Policy

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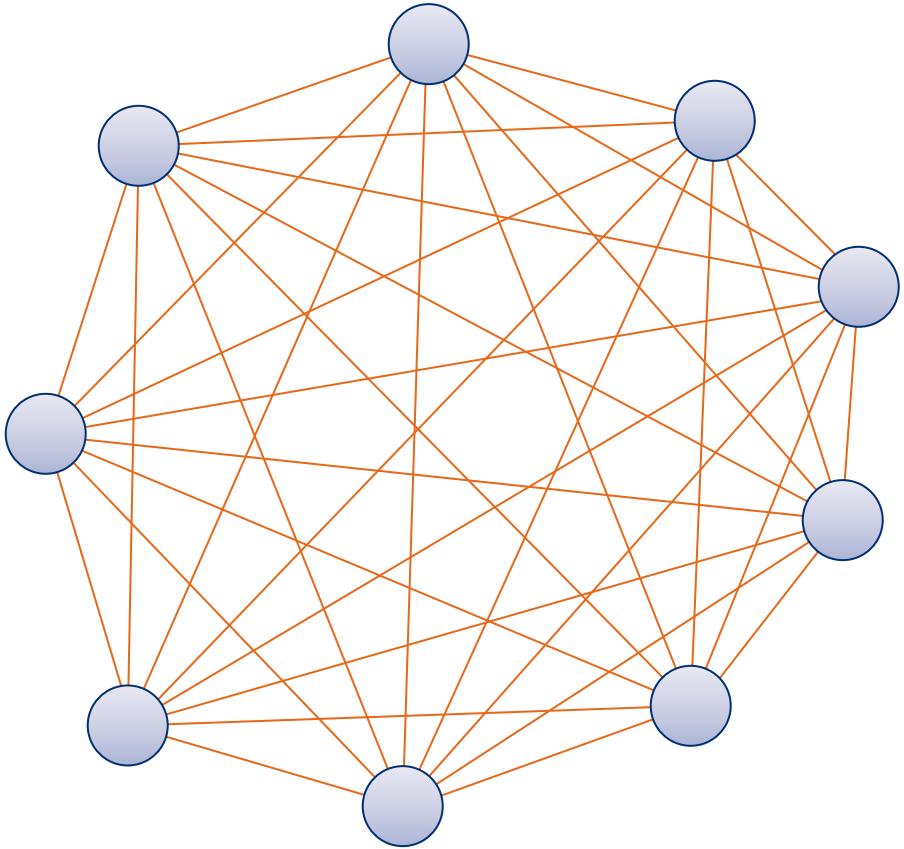
Motivation For Network Policy

Consider a Kubernetes cluster of n services. Of the n^2 possible connections between all your services, only a tiny, tiny fraction of them are actually useful for your application.



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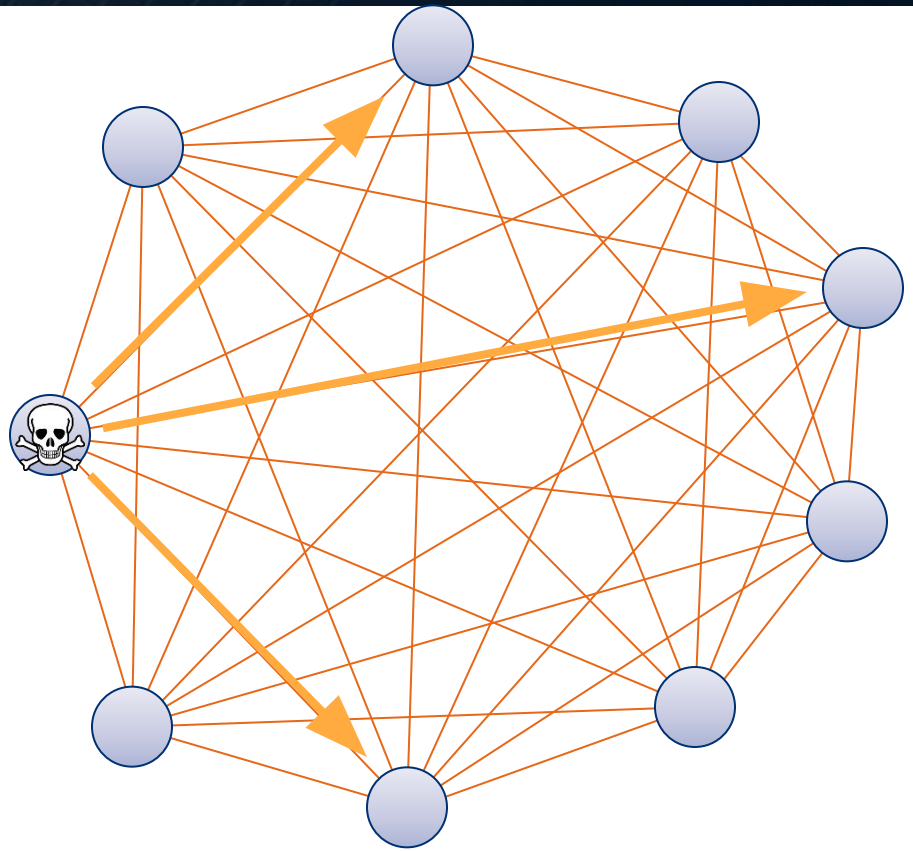
Pathways for Attack

The rest are only useful for an attacker.



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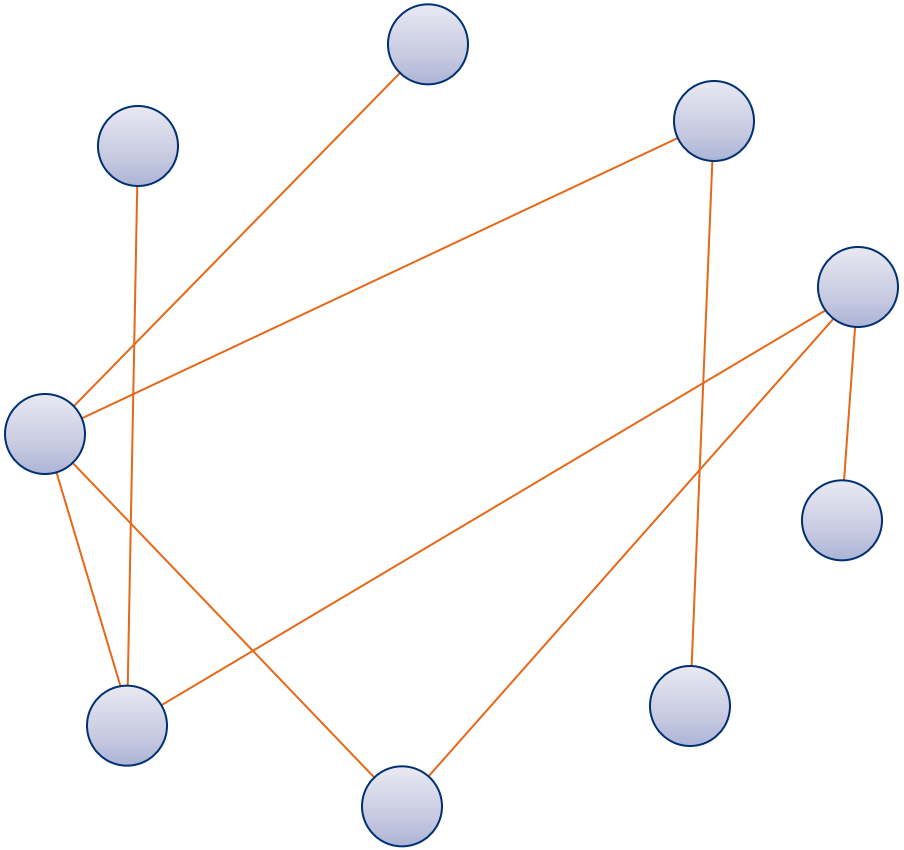
Identifying Unused Connections

We know that our frontend load balancers don’t connect directly to the backend database. Dev containers do not connect to prod, and so on.

Each connection path that we can eliminate will reduce complexity and improve security.



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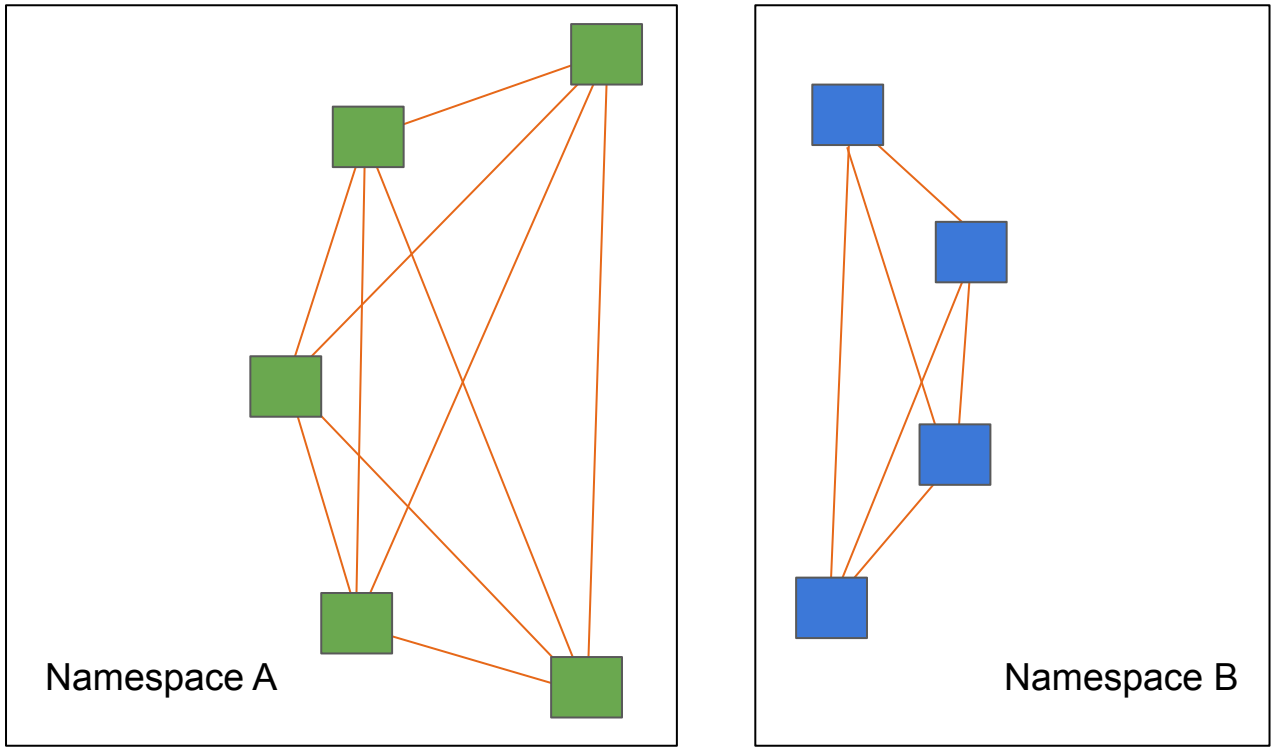
Namespace Isolation



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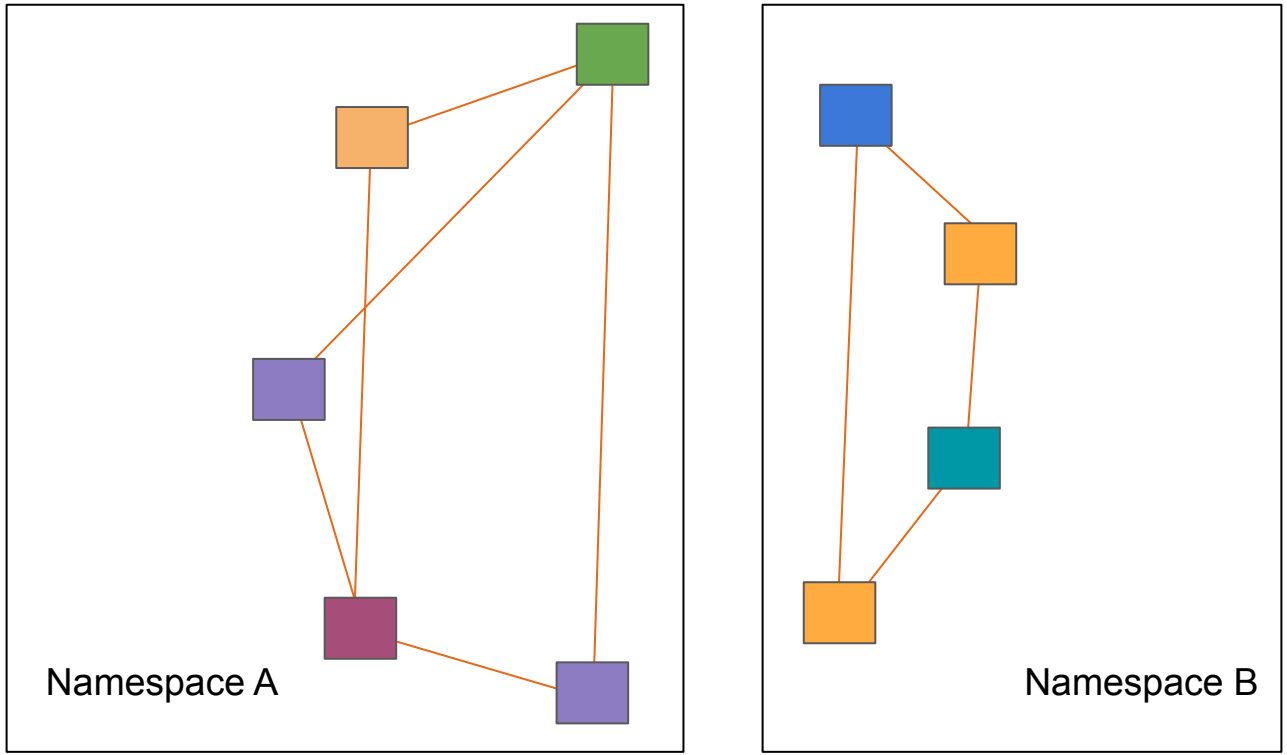
Custom Isolation



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Example Network Policy Use Cases

- Stage separation - isolate dev / test / prod instances
- Translation of traditional firewall rules - e.g. 3-tier
- “Tenant” separation - e.g. typically use namespaces for different teams within a company - but without network policy, they are not network isolated
- Fine-grained firewalls - reduce attack surface within microservice-based applications
- Compliance - e.g. PCI, HIPAA
- Any combination of the above

Key Kubernetes Concept: Labels

- Labels are key/value pairs that are attached to objects, such as pods.
- Labels are intended to be used to specify identifying attributes of objects that are meaningful and relevant to users, but do not directly imply semantics to the core system.
- Labels can be used to organize and to select subsets of objects.
- Labels can be attached to objects at creation time and subsequently added and modified at any time.
- Each Key must be unique for a given object.

```
"labels": {
  "key1" : "value1",
  "key2" : "value2"
}
```

Source: https://kubernetes.io/docs/concepts/overview/working-with-objects/labels/

Key Kubernetes Concept: Label Selectors

Via a *label selector*, the client/user can identify a set of objects. The label selector is the **core grouping primitive in Kubernetes.**

- Equality-based (==, !=)
- Set membership (in, notin, exists)

```
environment = production
tier != frontend
```

```
environment in (production, qa)
tier notin (frontend, backend)
partition
!partition
```


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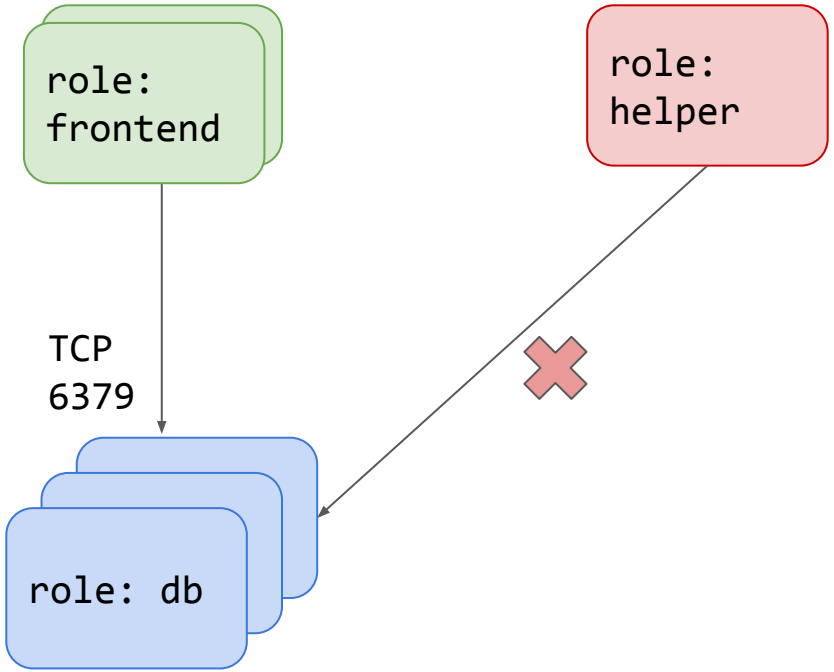
Kubernetes NetworkPolicy Resource

- Specifies how groups of pods are allowed to communicate with each other and other network endpoints using:
  - Pod label selector
  - Namespace label selector
  - Protocol + Ports
  - More to come in the future
- Pods selected by a NetworkPolicy:
  - Are isolated by default
  - Are allowed incoming traffic if that traffic matches a NetworkPolicy ingress rule.
- Requires a controller to implement the API

https://kubernetes.io/docs/concepts/services-networking/network-policies/

Kubernetes Network Policy Example

```
apiVersion: networking.k8s.io/v1
kind: NetworkPolicy
metadata:
  name: my-network-policy
  namespace: my-namespace
spec:
  podSelector:
    matchLabels:
      role: db
  ingress:
  - from:
    - podSelector:
        matchLabels:
          role: frontend
    ports:
    - protocol: TCP
      port: 6379
```



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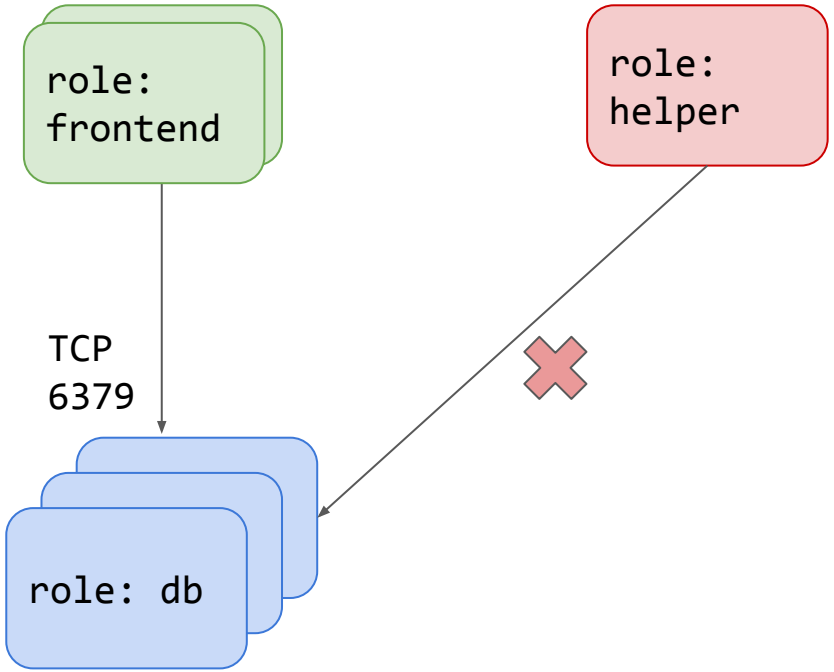

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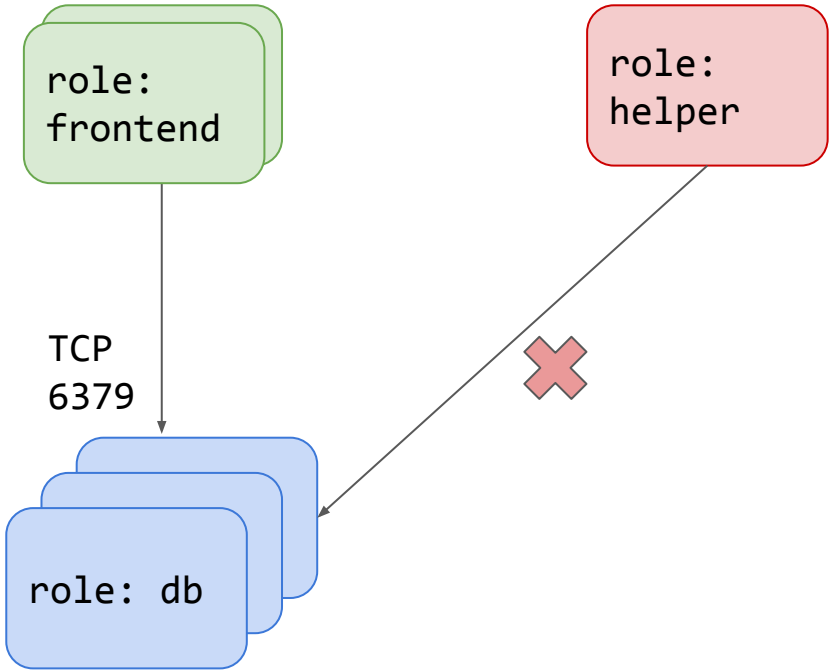

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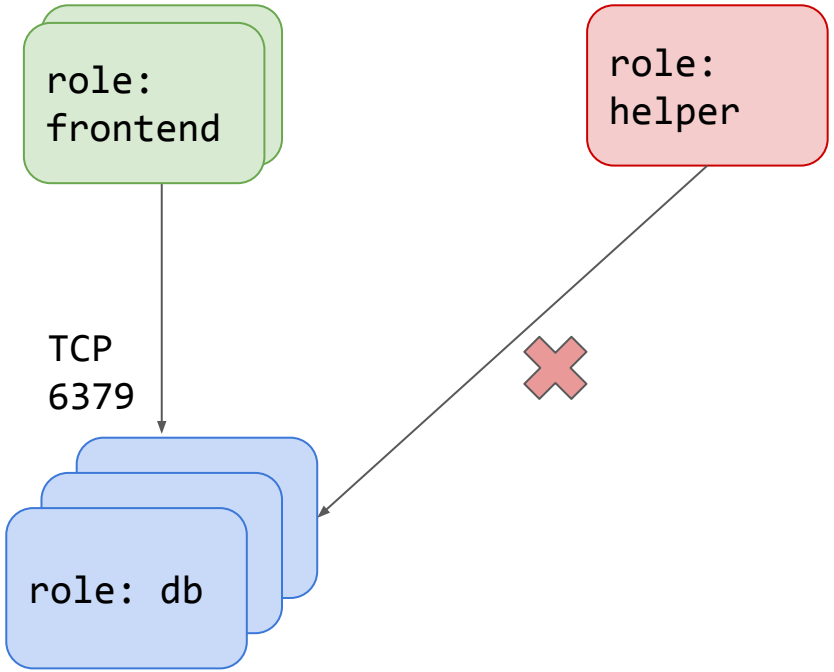

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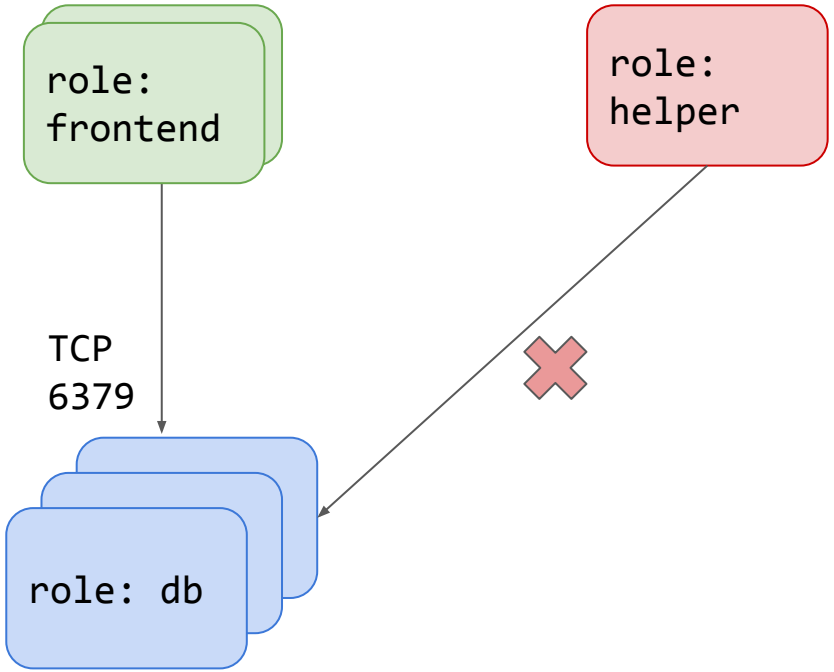
      port: 6379
```



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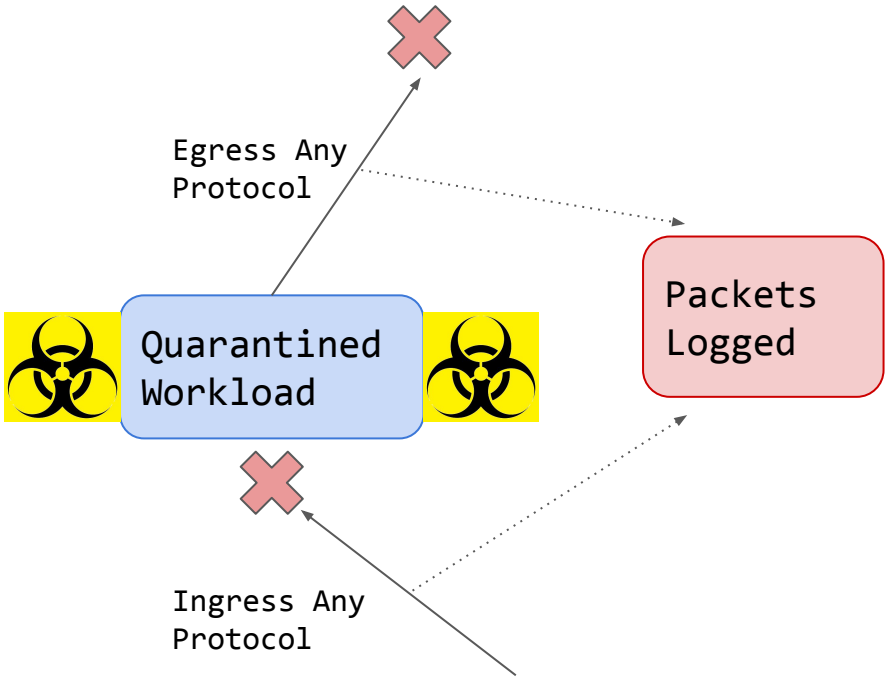
Advanced use cases beyond Kubernetes Network Policy

- **Global** network policies (rather than being limited to apply to pods in a single namespace)
- Ability to specify policy rules that **reference labels of pods in other namespaces** (rather than only being allowed to allow/deny all pods from another namespace)
- Ability to specify policy rules that **reference service account labels**
- **Richer label expressions** and **traffic specification** (e.g. port ranges, protocols other than tcp/udp, negative matching on protocol type, ICMP type)
- **Deny** rules
- **Policy order**/prioritization (which becomes necessary when you have mix of deny and allow rules)
- **Network sets** - ability to apply labels to a set of IP addresses, so they can be selected by label selector expressions
- Support for **non-Kubernetes nodes** (e.g. standalone hosts) within the policy domain,
- Policy options specific to **host endpoints** (apply-on-forward, pre-DNAT, doNotTrack)
- If you need these capabilities, use Calico directly instead of via Kubernetes Network Policy API
- https://docs.projectcalico.org/v3.7/security/calico-network-policy

Calico Network Policy Example

```
apiVersion: projectcalico.org/v3
kind: GlobalNetworkPolicy
metadata:
  name: security-operations.quarantine
spec:
  order: 200
  selector: quarantine == "true"
  ingress:
    - action: Log
      source: {}
      destination: {}
    - action: Deny
      source: {}
      destination: {}
  egress:
    - action: Log
      source: {}
      destination: {}
    - action: Deny
      source: {}
      destination: {}
    types:
    - Ingress
    - Egress
```



TIGERA

Calico Network Policy Example

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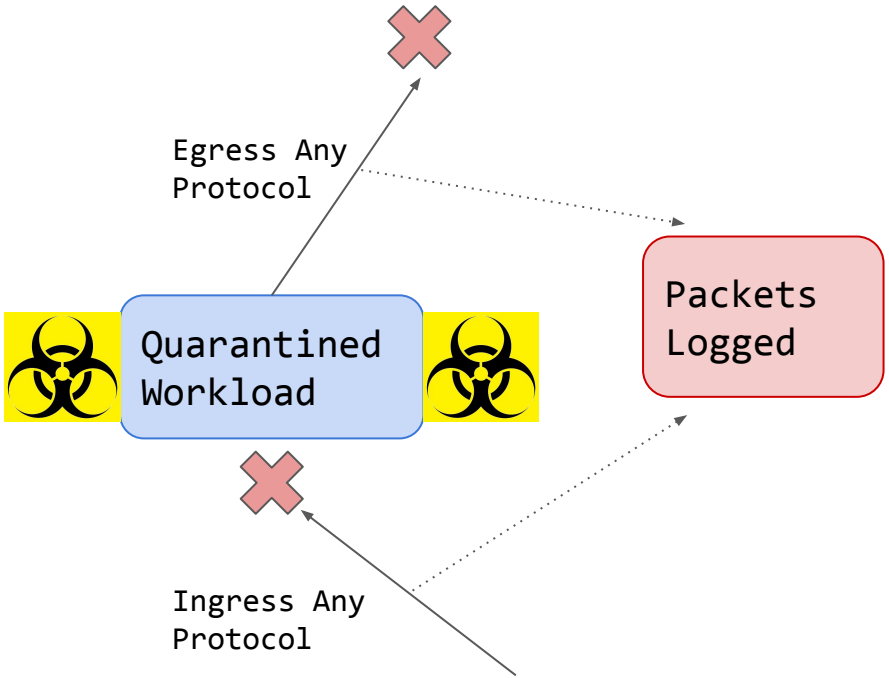
      source: {}
      destination: {}
  egress:
    - action: Log
      source: {}
      destination: {}
    - action: Deny
      source: {}
      destination: {}
    types:
    - Ingress
    - Egress
```



TIGERA

Calico Network Policy Example

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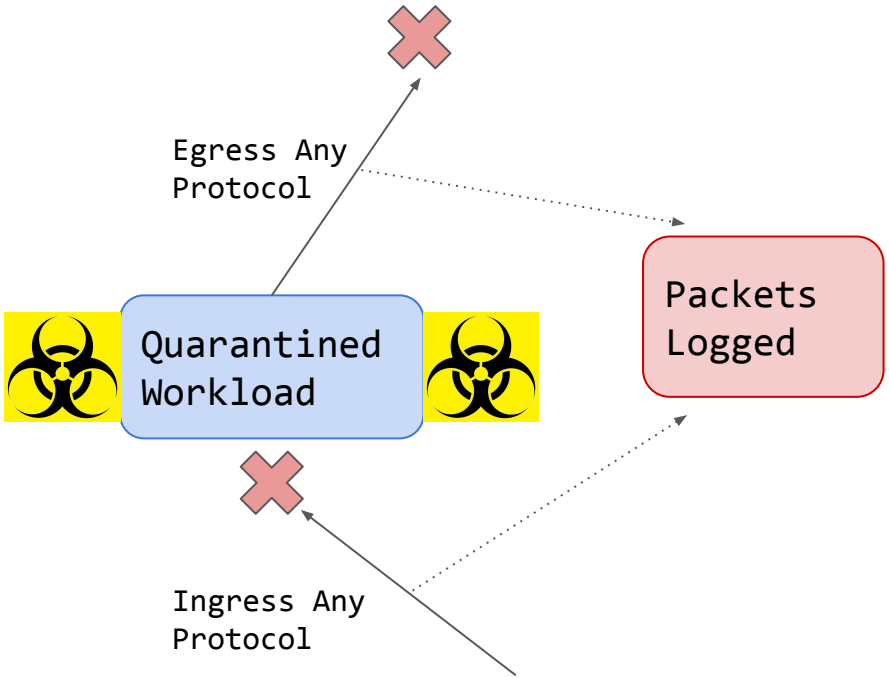
      source: {}
      destination: {}
    - action: Deny
      source: {}
      destination: {}
  types:
  - Ingress
  - Egress
```



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Calicoctl: The Calico Command Line

- Calicoctl is the command line utility for advanced Calico configuration
- Download: https://github.com/projectcalico/calicoctl/releases
- Reference: https://docs.projectcalico.org/latest/reference/calicoctl/
- Already installed on your training servers

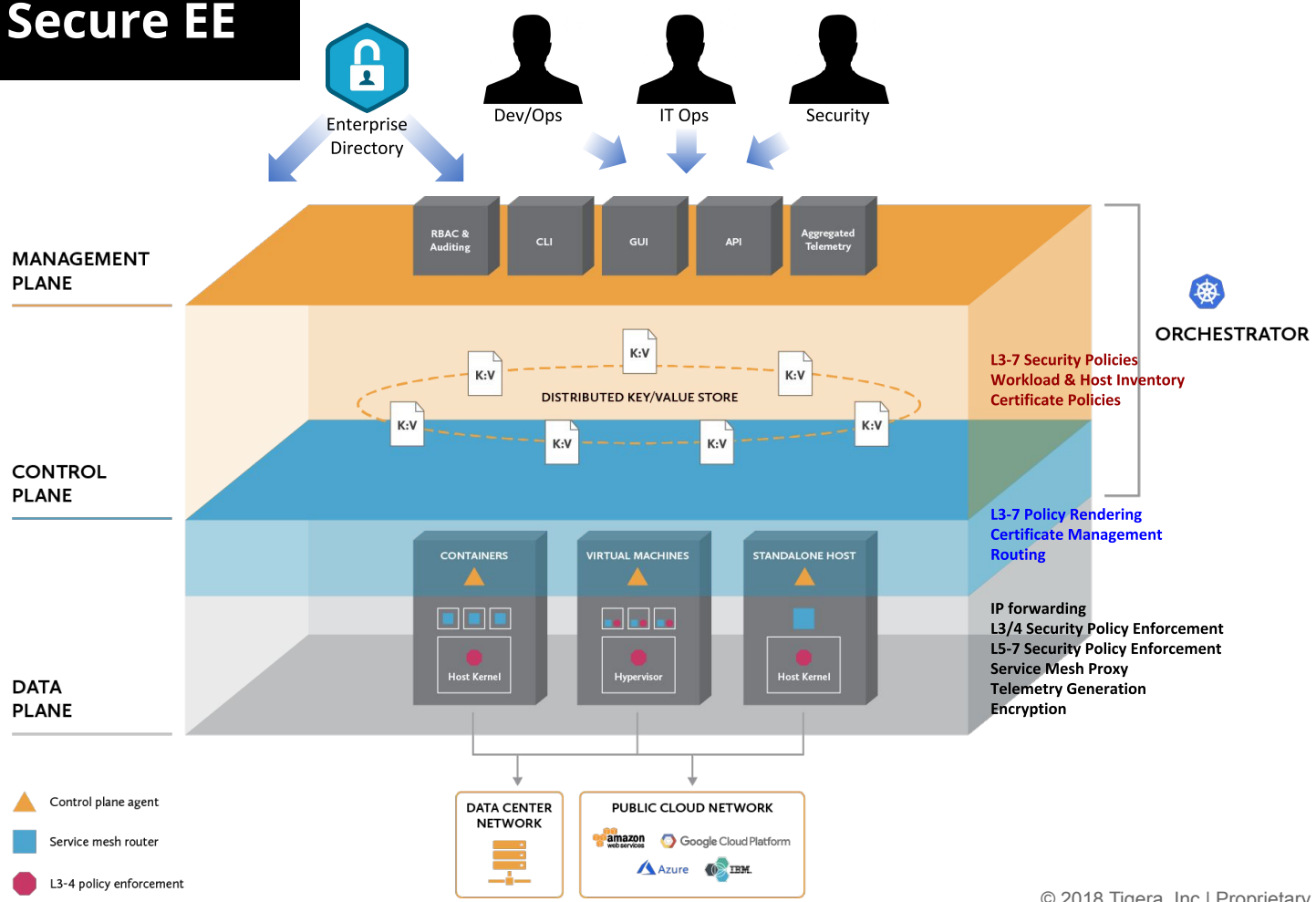
FELIX TIP: Calicoctl is available for Linux, MacOS and Windows. Download it for your favorite desktop operating system!

Do Lab 3

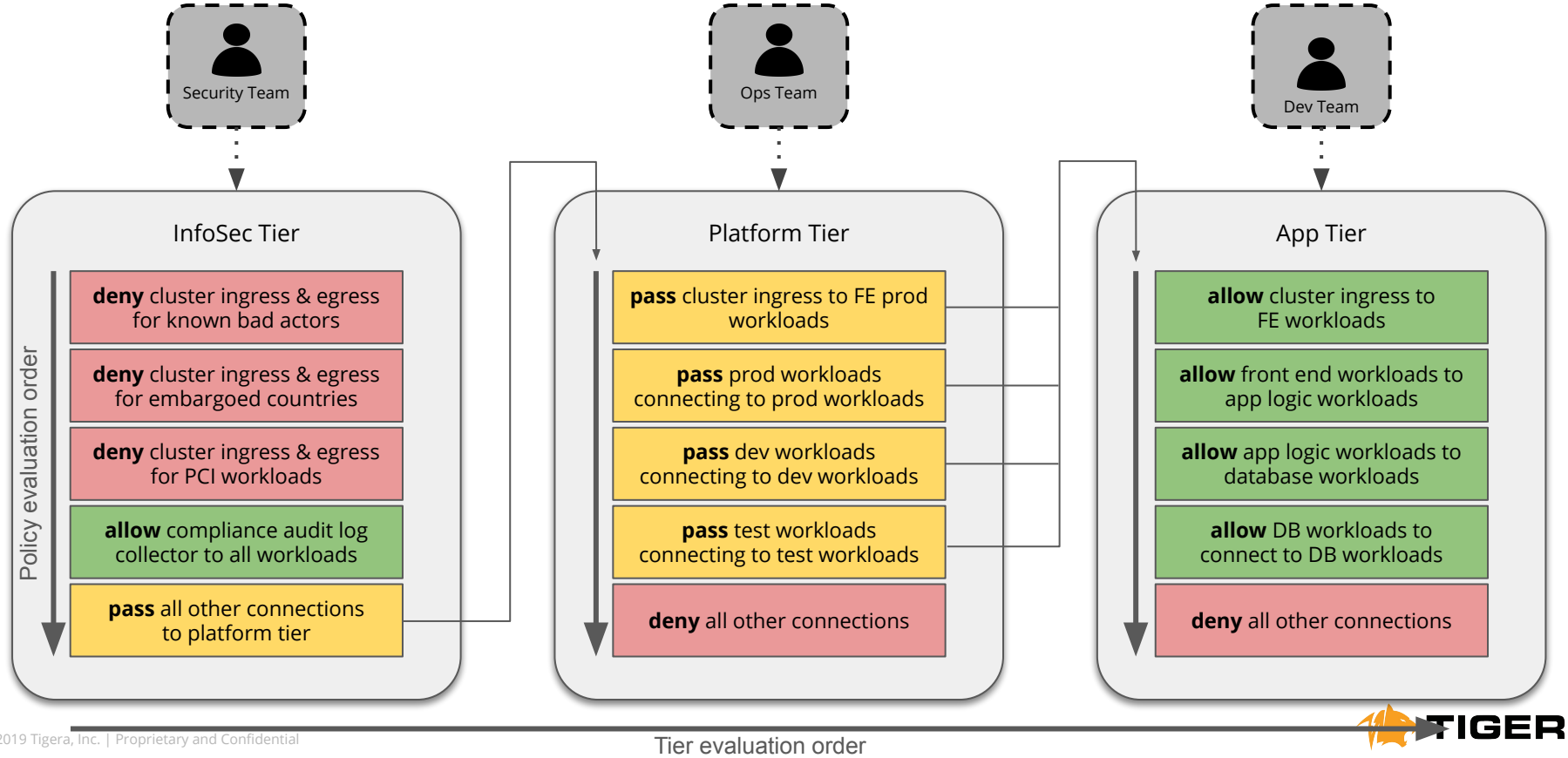
TIGERA

Anatomy of TSEE

Tigera Secure EE



CONTINUOUS COMPLIANCE
HIERARCHICAL POLICIES AND TIERS

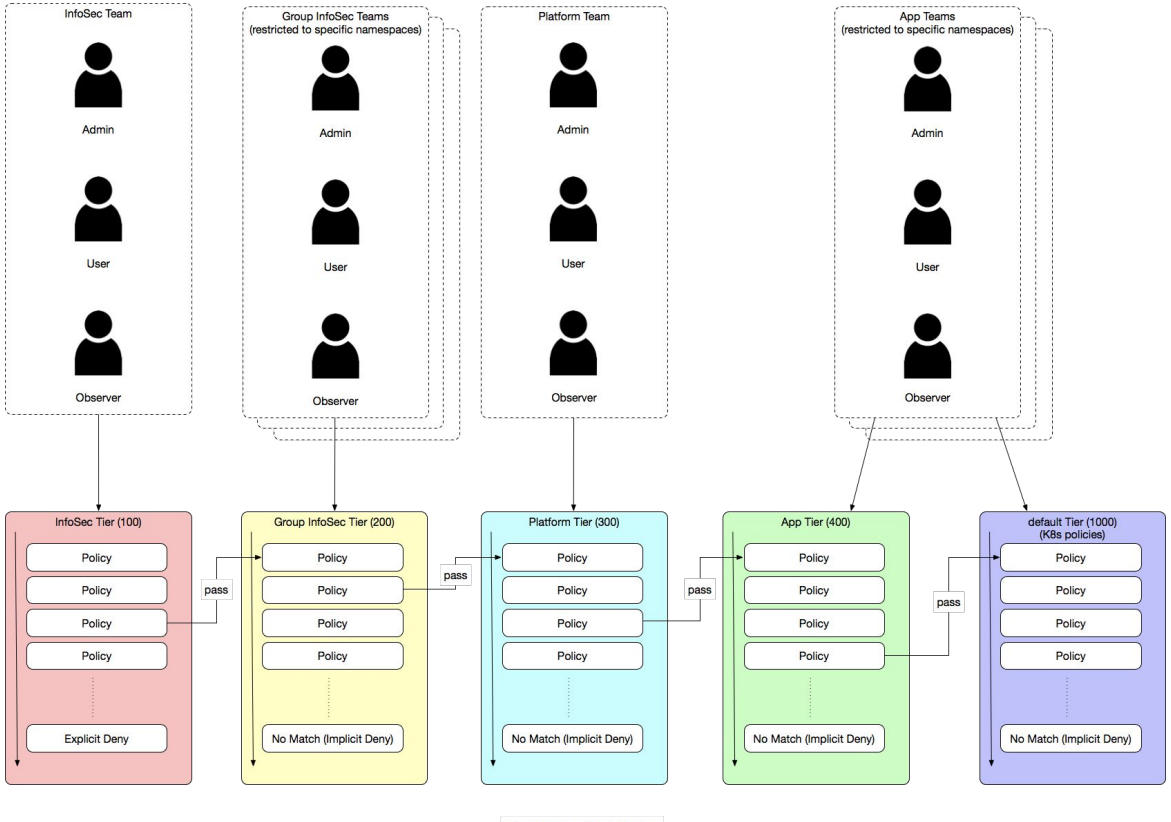


TIGERA

Objective: Organizational Control in Policy Management

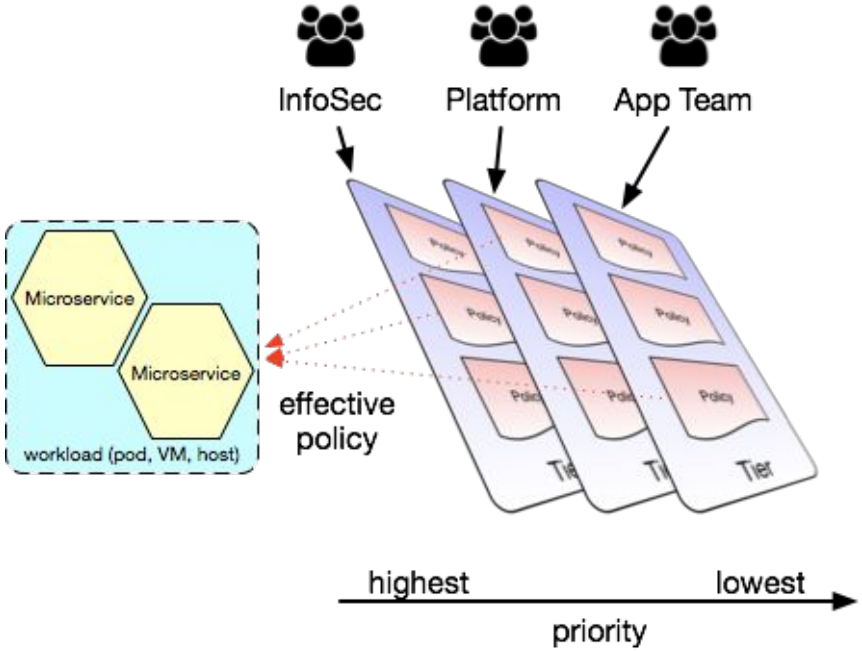
Policy precedence is a requirement.

Namespaces constrain access to tenant specific policies.



TSEE Policy Tiers

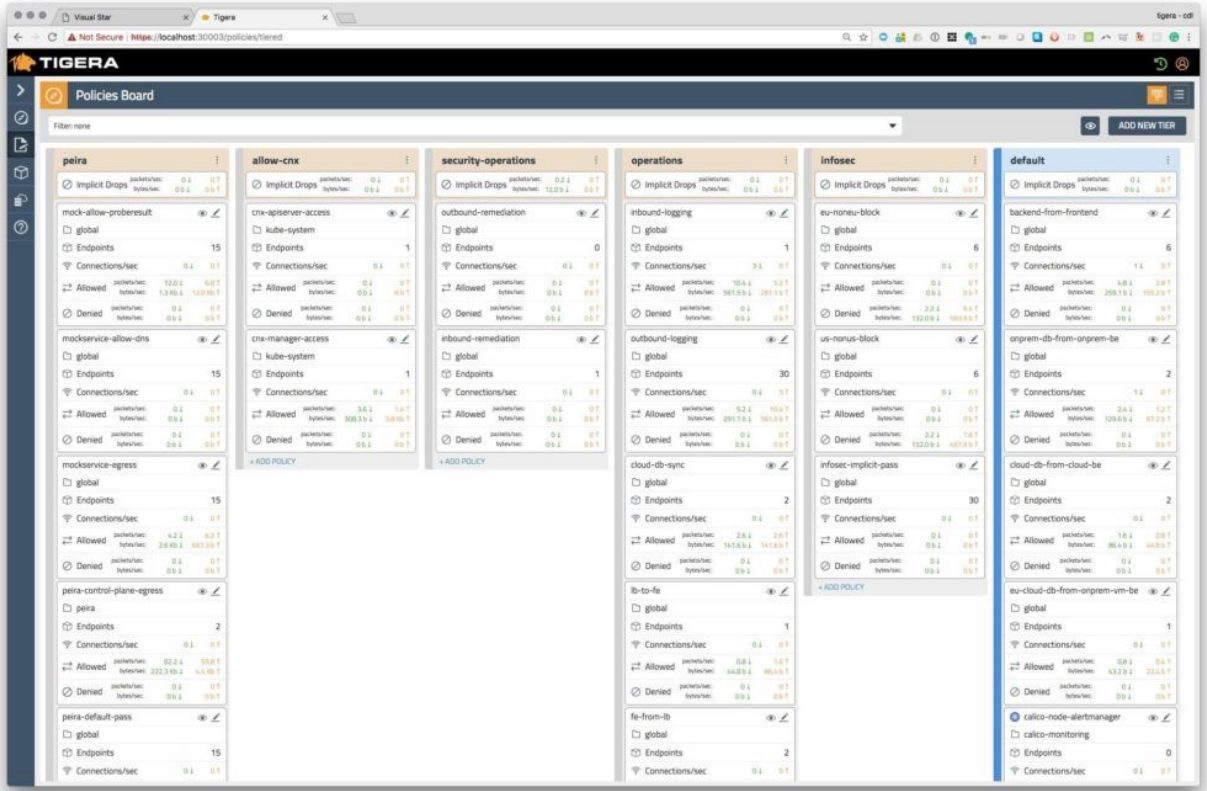
TSEE enables policies to be specified and evaluated in tiers.



Each tier is a sequence of policies that are executed in order.

RBAC can be used to control access to tiers and and tenants (by using namespaces and controlling access via resource type and namespace).

TSEE Policy Tier Deployment Example



Building Policies

Key Design Considerations

- Zero trust = “default deny” = all (ingress / egress) traffic is whitelisted
- Calico policy (recommended) vs K8s network policy
- L3-L7 rules
- One policy for each service
- Policy workflow automation (more on this in CI/CD section)

TIGERA

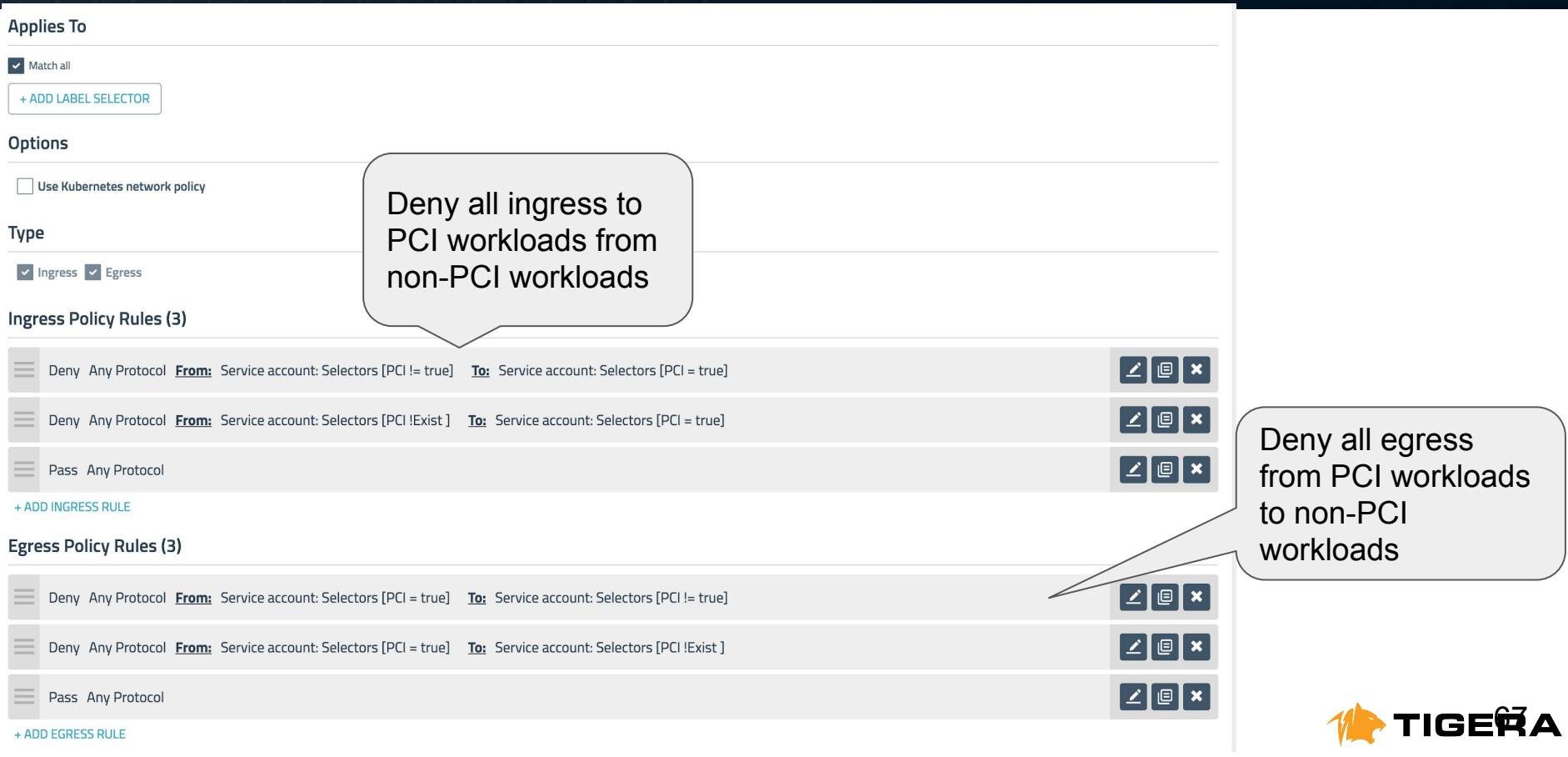
Label, Label, Label

- Semantic attributes of your endpoint, namespace and serviceaccount
- Collaborate and converge to a standard
- Audit (and/or enforce) your deployments for alignment with the standard
- We recommend: *application, service (producer/consumer, or similar), version, stage, release, owner (TBD add example)*
- Additional Attributes for consideration
  - BU, organization, cost center, security level, compliance status
  - Review the CMDB (if you have one)

Namespace vs Global

Scope	**Namespace**	**GlobalNetworkPolicy**
Matches on	Endpoints within a specific namespace	Endpoints across all namespaces
When to use	Individual microservices	- Common services (logging, build systems, DNS, SMTP relay, SSH etc) - Security and Compliance controls (PCI rules, export compliance, bad actor blacklist) - Incident response workflows (quarantine, forensics)
Tier	Typically in lower tiers.	Higher Tiers for priority evaluation
Label selector for rules	- Endpoints (within the namespace) - Namespace and SvcAccounts (cross namespace)	- Namespace & ServiceAccount (be cautious with endpoint selector) - Explore Admission controller for governance

Global network policy (PCI Example)



Namespace scope policy

Applies To

Policy Label selector: [app = backend]

Options

☐ Use Kubernetes network policy

Type

☑ Ingress ☑ Egress

Ingress Policy Rules (3)

Allow Protocol is TCP **From:** Endpoints [app = microservice1] **To:** Ports [Port is 8080]

Endpoints 1↓ 0↑ | Connections/sec 0↓ 0↑
Allowed packets/sec: 1.6↓ 0.8↑ bytes/sec: 86.4 b↓ 44.8 b↑ | Denied packets/sec: 0↓ 0↑ bytes/sec: 0 b↓ 0 b↑
Passed packets/sec: 0↓ 0↑ bytes/sec: 0 b↓ 0 b↑

Allow Protocol is TCP **From:** Endpoints [app = microservice2] **To:** Ports [Port is 8080]

Endpoints 1↓ 0↑ | Connections/sec 0↓ 0↑
Allowed packets/sec: 1.6↓ 0.8↑ bytes/sec: 86.4 b↓ 44.8 b↑ | Denied packets/sec: 0↓ 0↑ bytes/sec: 0 b↓ 0 b↑
Passed packets/sec: 0↓ 0↑ bytes/sec: 0 b↓ 0 b↑

Deny Any Protocol

Endpoints 0↓ 0↑ | Connections/sec 0↓ 0↑
Allowed packets/sec: 0↓ 0↑ bytes/sec: 0 b↓ 0 b↑ | Denied packets/sec: 0↓ 0↑ bytes/sec: 0 b↓ 0 b↑
Passed packets/sec: 0↓ 0↑ bytes/sec: 0 b↓ 0 b↑

Egress Policy Rules (1)

Allow Protocol is TCP **To:** Endpoints [app = logging] Ports [Port is 8080]

Endpoints 0↓ 1↑ | Connections/sec 0↓ 0↑
Allowed packets/sec: 0.4↓ 0.8↑ bytes/sec: 22.4 b↓ 43.2 b↑ | Denied packets/sec: 0↓ 0↑ bytes/sec: 0 b↓ 0 b↑
Passed packets/sec: 0↓ 0↑ bytes/sec: 0 b↓ 0 b↑

Key Takeaways

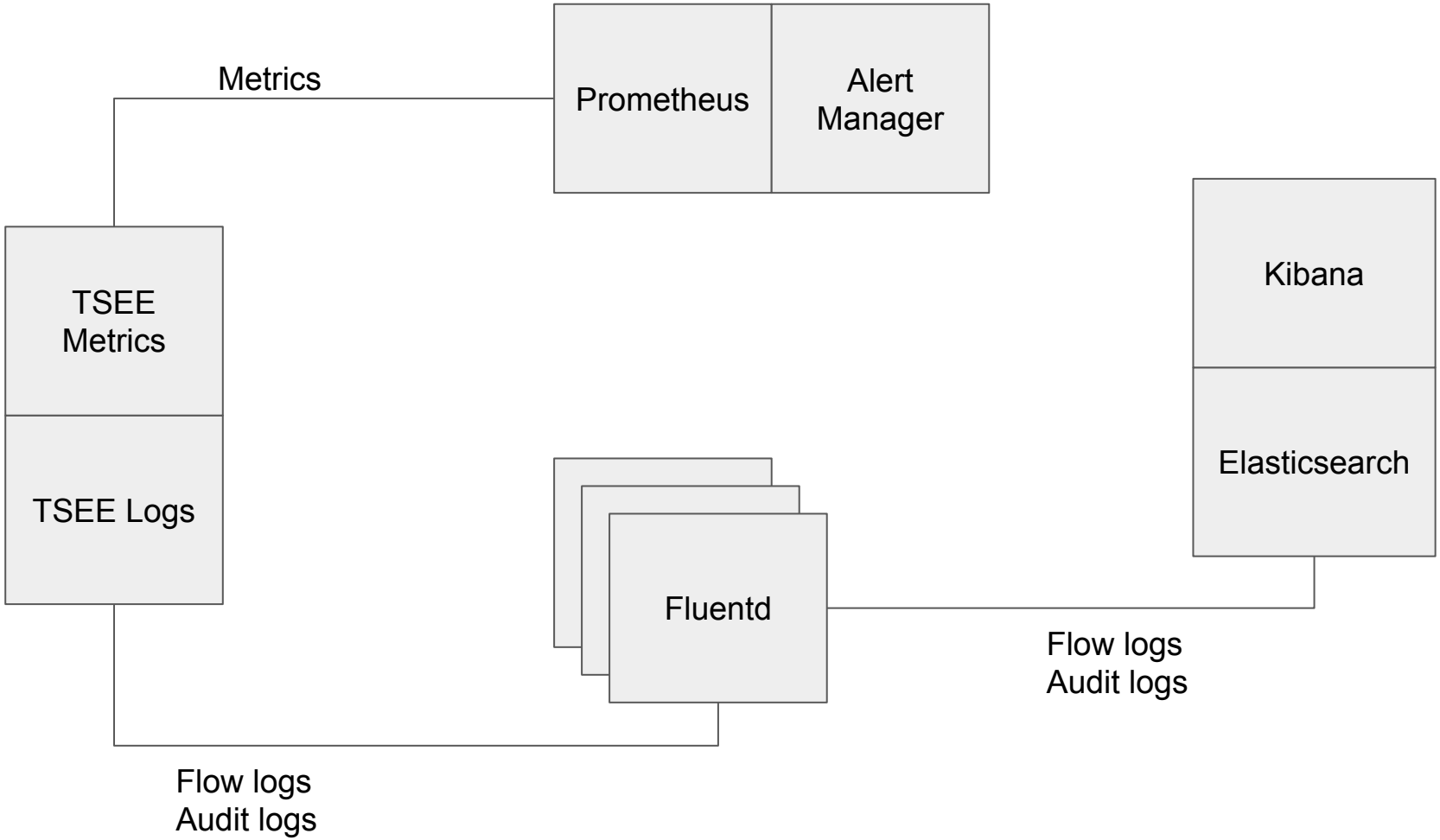
- Zero trust networking and security
- Label design before policy design
- 1 policy per service
- For x-namespace traffic use namespace and serviceaccount selectors

Do Lab 4

TIGERA

Logs, Logging, and Metrics

TIGERA


Metrics
Prometheus
Alert Manager
TSEE Metrics
TSEE Logs
Kibana
Elasticsearch
Fluentd
Flow logs
Audit logs
Flow logs
Audit logs

Fluentd: Tigera-es-config Config-map

```
bikrams-MBP:stage0 bikram$ kgcmm calico-monitoring tigera-es-config -o yaml
apiVersion: v1
data:
  tigera.elasticsearch.access-mode: insecure
  tigera.elasticsearch.audit-retention: "367"
  tigera.elasticsearch.cluster-name: cluster
  tigera.elasticsearch.compliance-report-retention: "7"
  tigera.elasticsearch.flow-filtering: "true"
  tigera.elasticsearch.flow-filters.conf: |-
    <filter flows>
      @type grep
      <exclude>
        key source_namespace
        pattern (^istio|^kube|^calico)
      </exclude>
      <exclude>
        key dest_namespace
        pattern (^istio|^kube|^calico)
      </exclude>
    </filter>
  tigera.elasticsearch.flow-retention: "8"
  tigera.elasticsearch.flows-index-shards: "5"
  tigera.elasticsearch.host: elasticsearch-tigera-elasticsearch.calico-monitoring.svc.cluster.local
  tigera.elasticsearch.port: "9200"
  tigera.elasticsearch.scheme: http
  tigera.elasticsearch.snapshot-retention: "367"
kind: ConfigMap
```

Excluding flows from certain namespaces

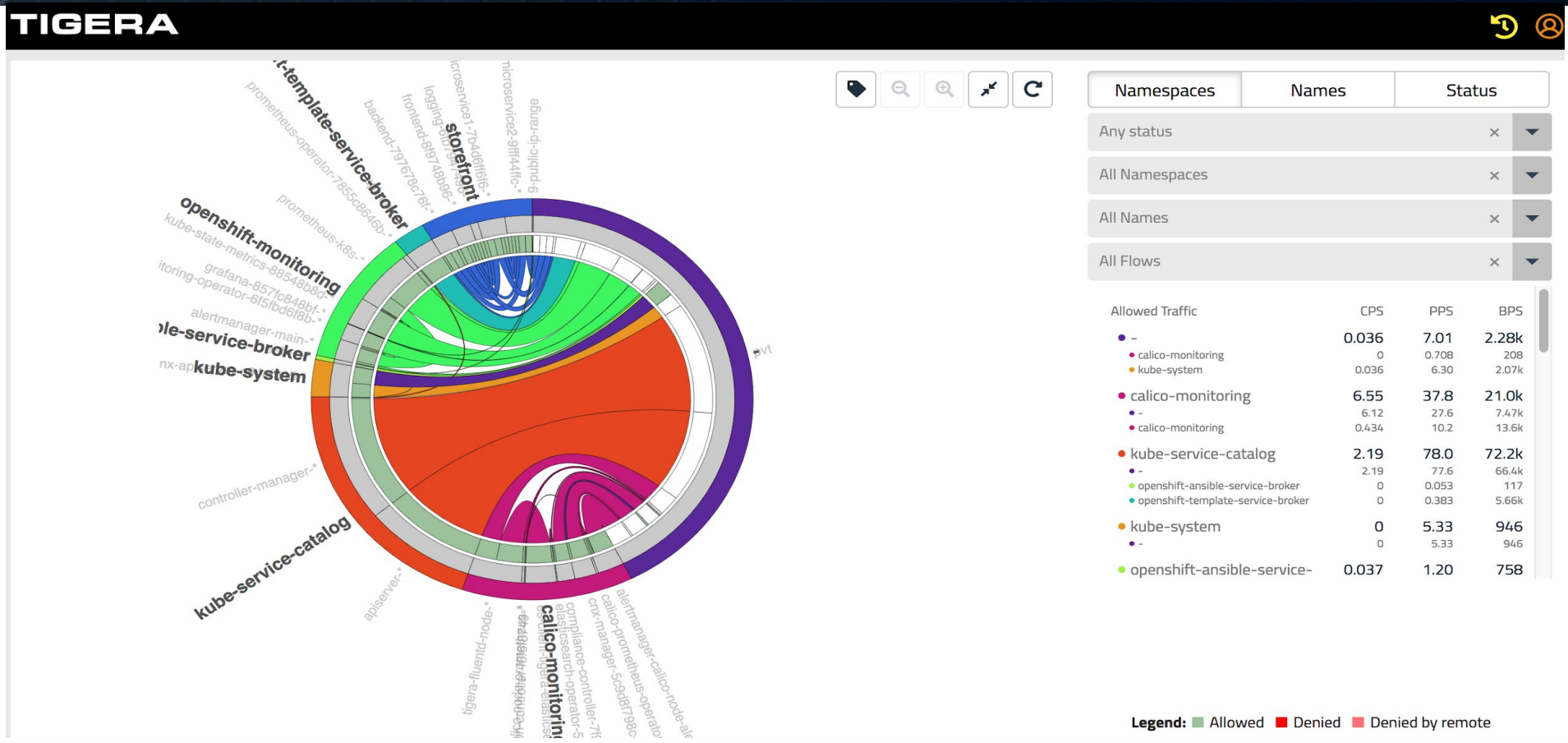
TIGERA

Flow Logs Aggregation and Push Interval

```
apiVersion: projectcalico.org/v3
kind: FelixConfiguration
metadata:
  name: default
spec:
  flowLogsFileAggregationKindForAllowed: 1
  FlowLogsFlushInterval: 10s
  CloudWatchLogsFlushInterval: 10s
```

Ref: https://docs.tigera.io/v2.4/reference/calicoctl/resources/felixconfig#spec

Flow Logs


TIGERA
Namespaces
Names
Status
Any status
All Namespaces
All Names
All Flows
Allowed Traffic
CPS
PPS
BPS
- 0.036 7.01 2.28k
calico-monitoring 0 0.708 208
kube-system 0.036 6.30 2.07k
calico-monitoring 6.55 37.8 21.0k
- 6.12 27.6 7.47k
calico-monitoring 0.434 10.2 13.6k
kube-service-catalog 2.19 78.0 72.2k
- 2.19 77.6 66.4k
openshift-ansible-service-broker 0 0.053 117
openshift-template-service-broker 0 0.383 5.66k
kube-system 0 5.33 946
- 0 5.33 946
openshift-ansible-service- 0.037 1.20 758
storefront
openshift-monitoring
kube-service-catalog
kube-system
calico-monitoring
Legend: Allowed Denied Denied by remote

Key Elements

1. Metrics & Alerts
2. Logging
3. Dashboards
4. Incident Response Workflows

Metrics

- Denied bytes and packet count (Instance, policy)
- Policy rule bytes, connection, count
  - Action, Traffic Direction, Policy, Rule Direction, Rule Index, Instance, Tier, Namespace

Recommended Alerts

1. Denied packet count
2. Denied packet rate
3. PCI violation (Denied packet count on PCI policy)
4. Export compliance violation (Denied packet count on embargo policy)

Alerts (Example)

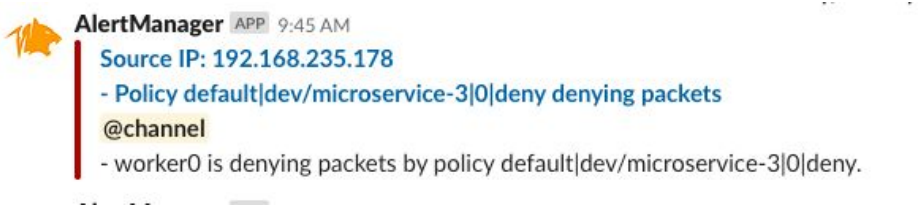
DeniedPacketsCount (0 active)

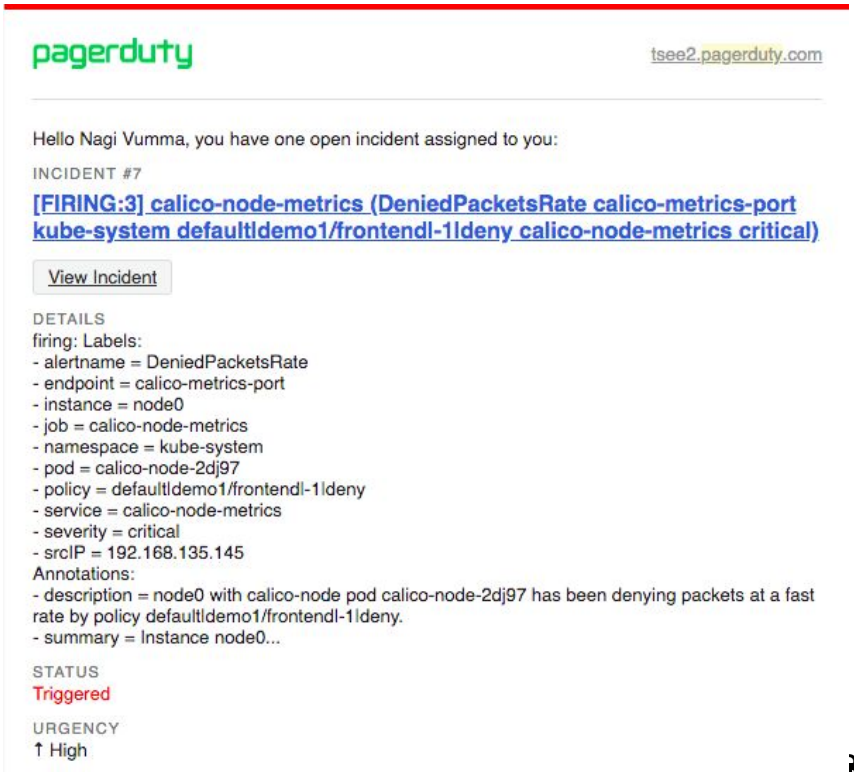
```
alert: DeniedPacketsCount
expr: count_over_time(calico_denied_packets{policy!="security|quarantine|1|deny"}[5s])
  > 0
labels:
  severity: critical
annotations:
  description: '{{$labels.instance}} is denying packets by policy {{$labels.policy}}.'
  summary: Policy {{$labels.policy}} denying packets
```

DeniedPacketsRate (0 active)

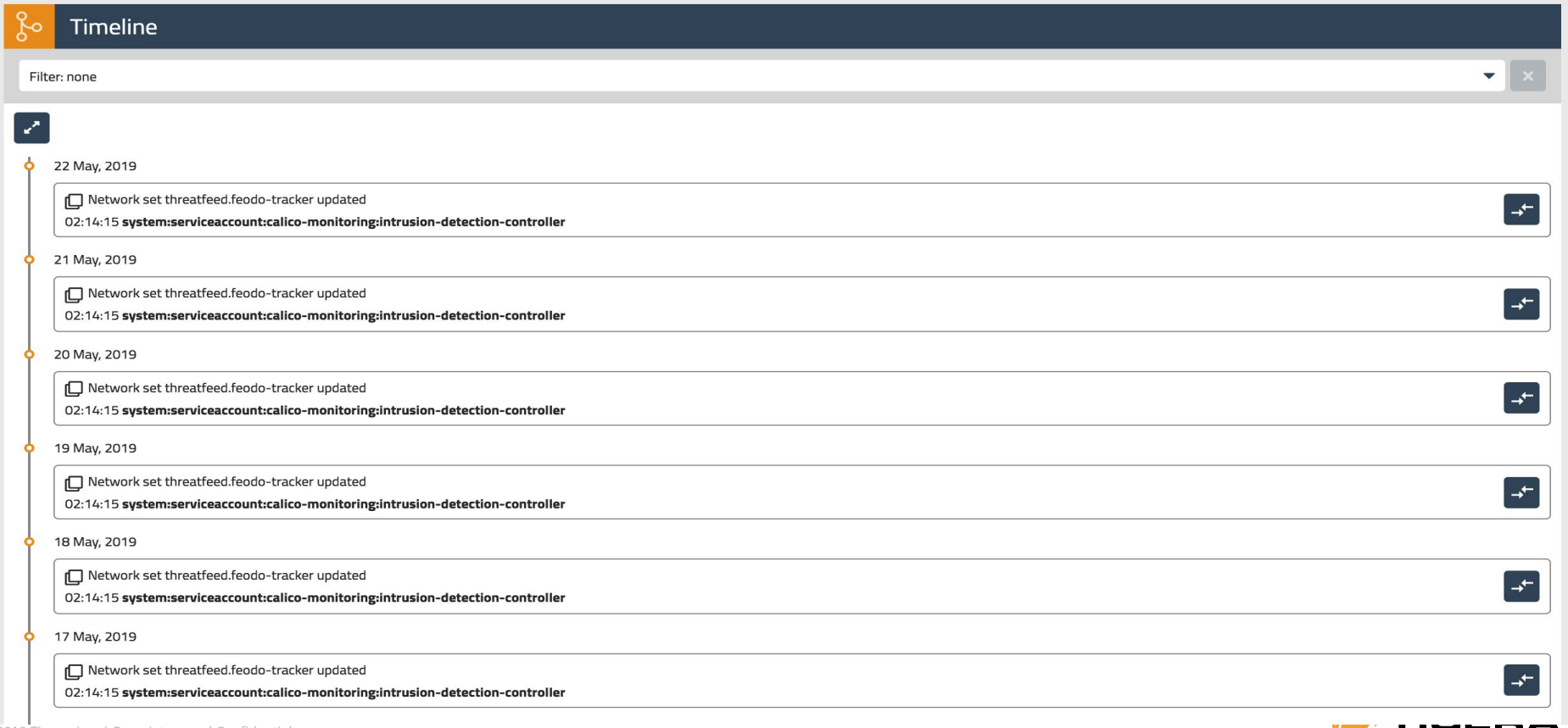
```
alert: DeniedPacketsRate
expr: rate(calico_denied_packets[10s])
  > 50
labels:
  severity: critical
annotations:
  description: '{{$labels.instance}} with calico-node pod {{$labels.pod}} has been
    denying packets at a fast rate {{$labels.sourceIp}} by policy {{$labels.policy}}.'
  summary: Instance {{$labels.instance}} - Large rate of packets denied
```

Alert Manager (Slack, PagerDuty or your favorite alerting tool)





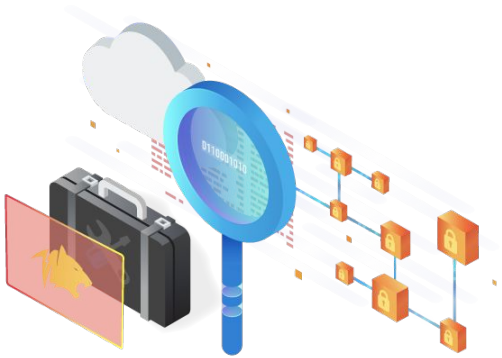
Audit Logs



Tigera Secure Enables Key Security Capabilities

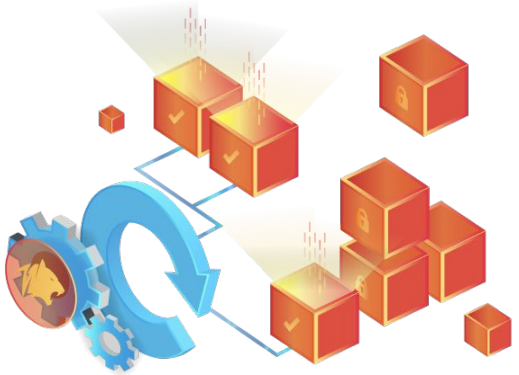
Zero Trust Network Security

Extend your security controls to Kubernetes



Visibility & Threat Detection

Monitor traffic, detect and prevent threats



Continuous Compliance

Continuous reporting, alert on non-compliance

More Tigera Webinars

NEXT Webinar

Kubernetes, Helm, and Network Security - Best Practices at Scale

https://www.brighttalk.com/webcast/17114/362773

'MUST SEE' ON-DEMAND WEBINAR

Atlassian Case Study - Moving to Kubernetes on AWS with Zero Trust Security

https://www.tigera.io/webinars/aws-tigera-atlassian

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Q&A

Schedule a Demo: tigera.io/demo

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