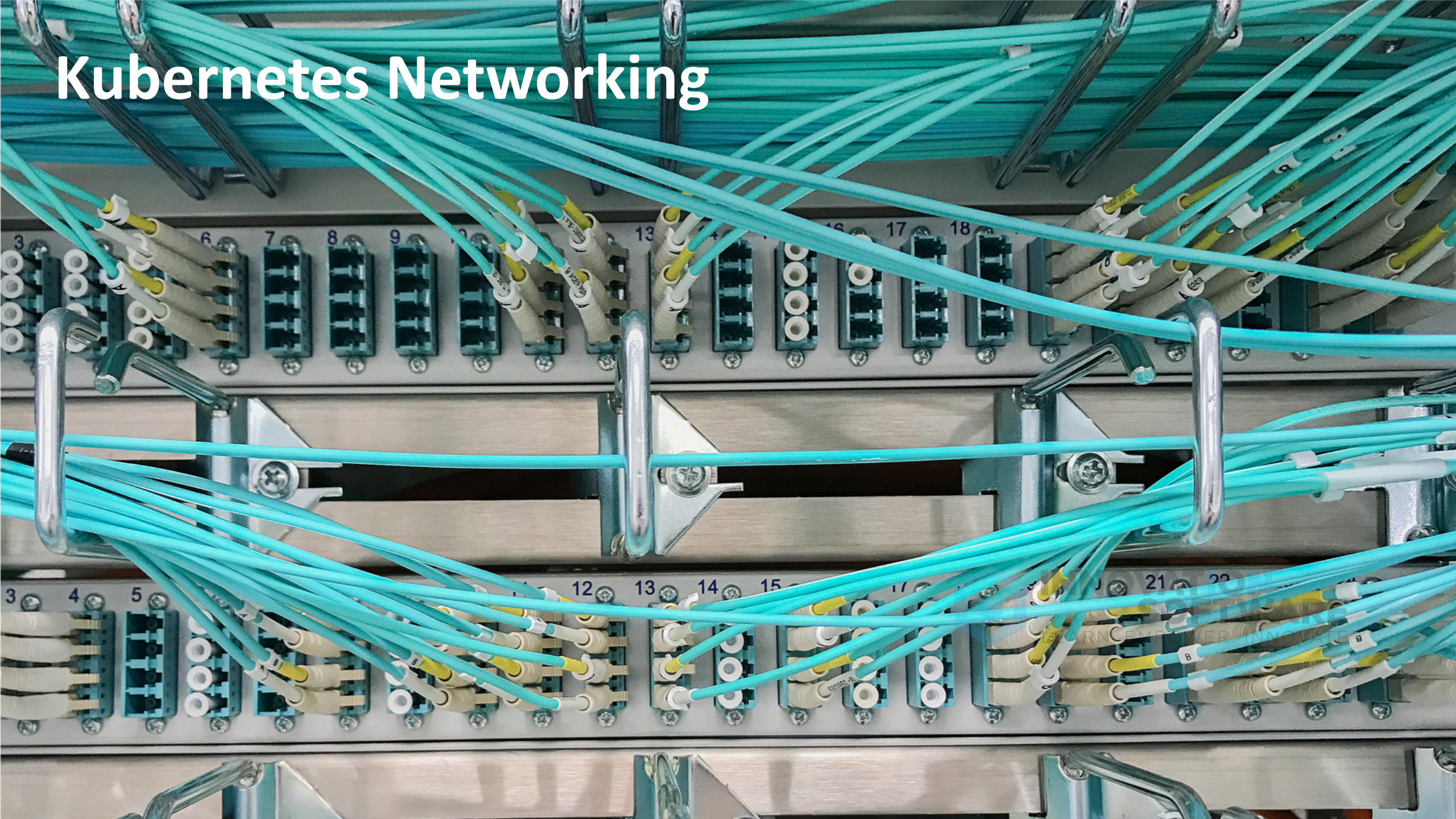
Kubernetes Networking



Networking Problems and Solutions

1. Highly-coupled container-to-container communications => linux
2. Pod-to-Pod communications => various
3. Pod-to-Service communications => service
4. External-to-Service communications => service or ingress

Kubernetes Networking Model Requirements

- all containers can communicate with all other containers without NAT
- all nodes can communicate with all containers (and vice-versa) without NAT
- the IP that a container sees itself as is the same IP that others see it as

Container to Container Communication

- Containers live inside of pods
- Group of one or more containers that are always co-located and co-scheduled, and run in a shared context
- Containers within a POD share an IP address and port space, and can find each other via localhost (net namespace).
- Communicate with each other using standard inter-process communications (ipc namespace).

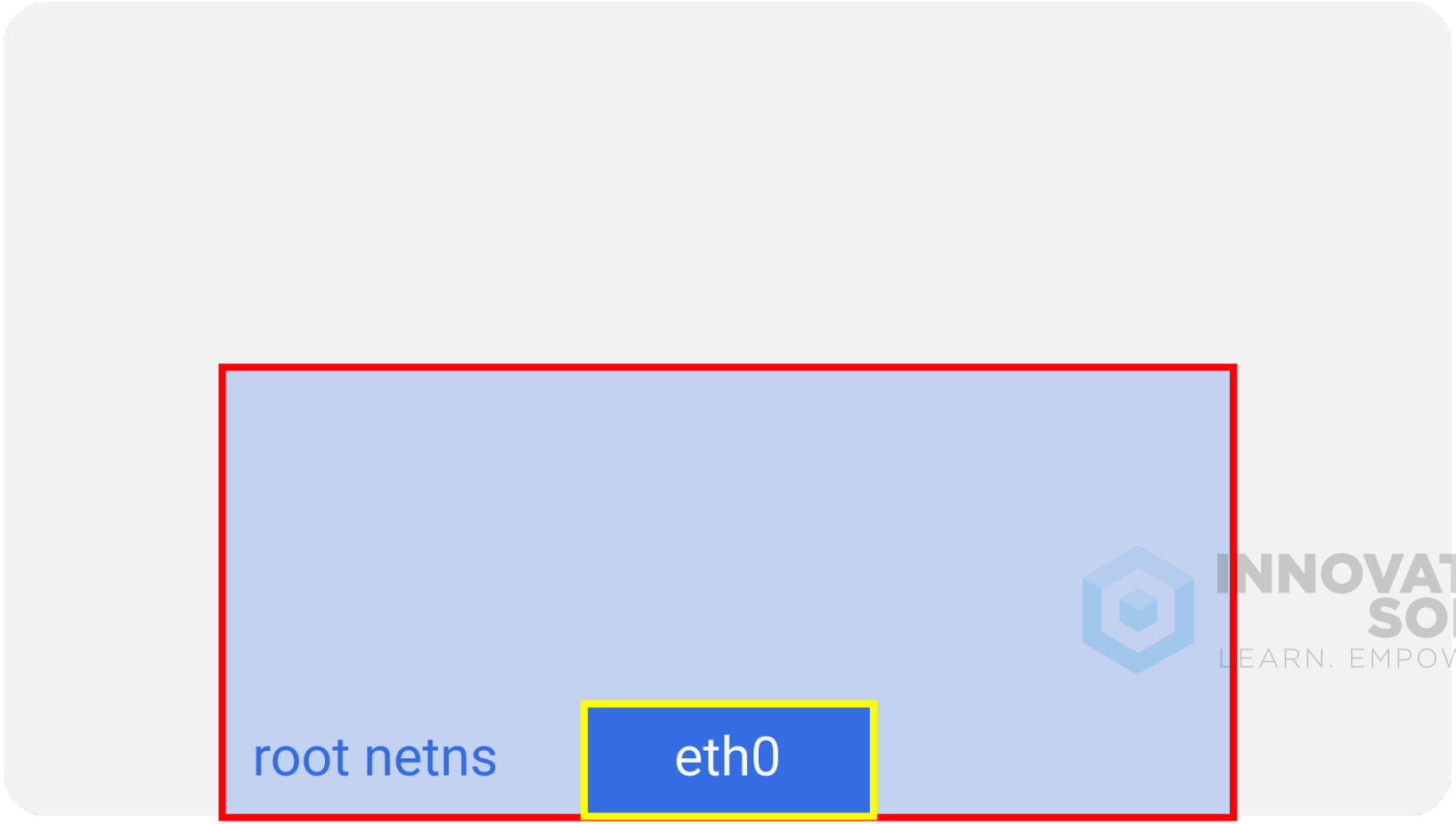
Pod to Pod Requirements

- Pods can communicate with all other pods without NAT
- Regardless of which host they land on
- Every pod gets its own IP address
- No need to explicitly create links between pods

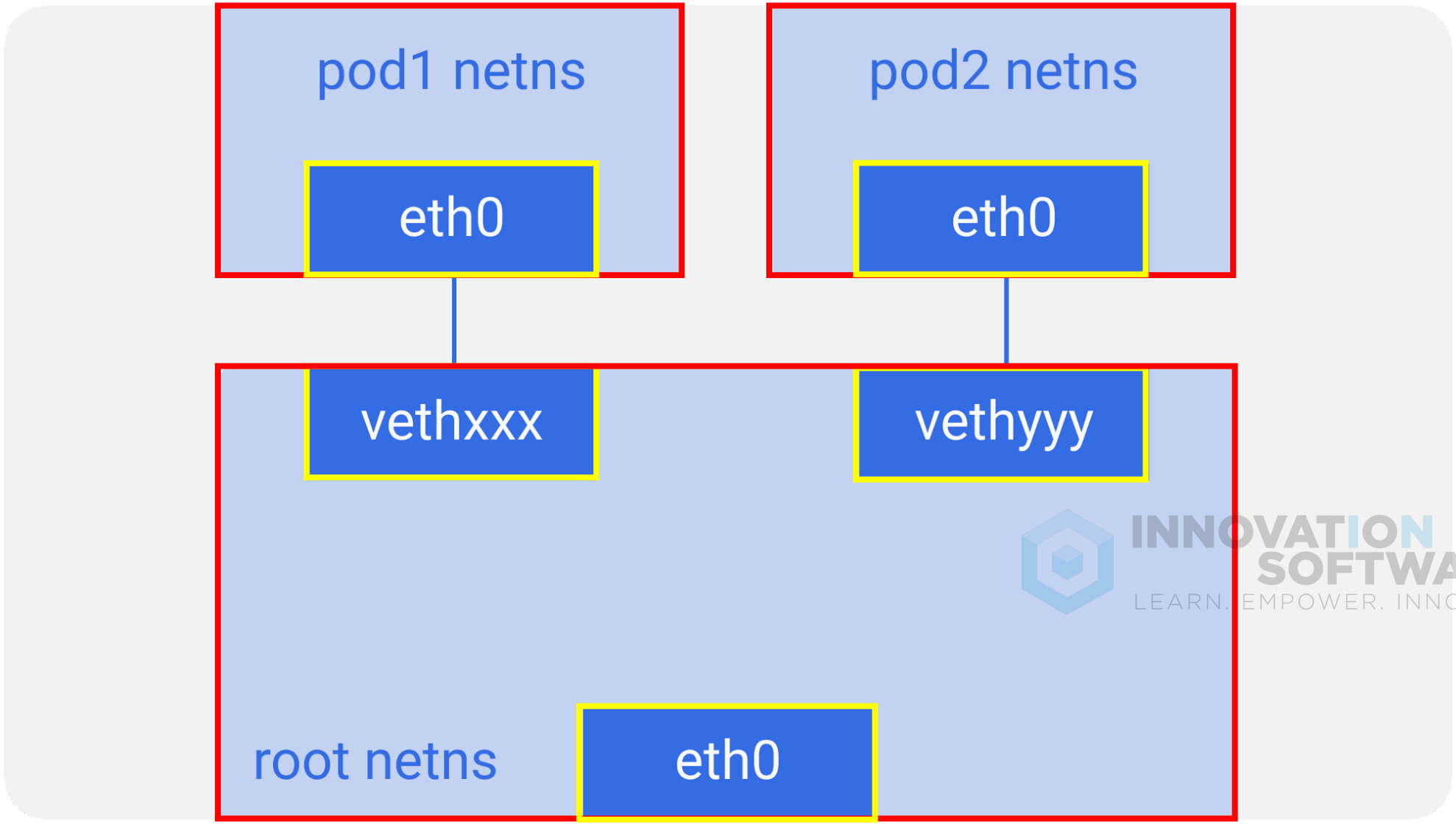
Pod Networking Approaches

- **Using an overlay network**
  - An overlay network obscures the underlying network architecture from the pod network through traffic encapsulation (for example vxlan).
  - Encapsulation reduces performance, though exactly how much depends on your solution.
- **Without an overlay network**
  - Configure the underlying network fabric (switches, routers, etc.) to be aware of pod IP addresses.
  - This does not require the encapsulation provided by an overlay, and so can achieve better performance.

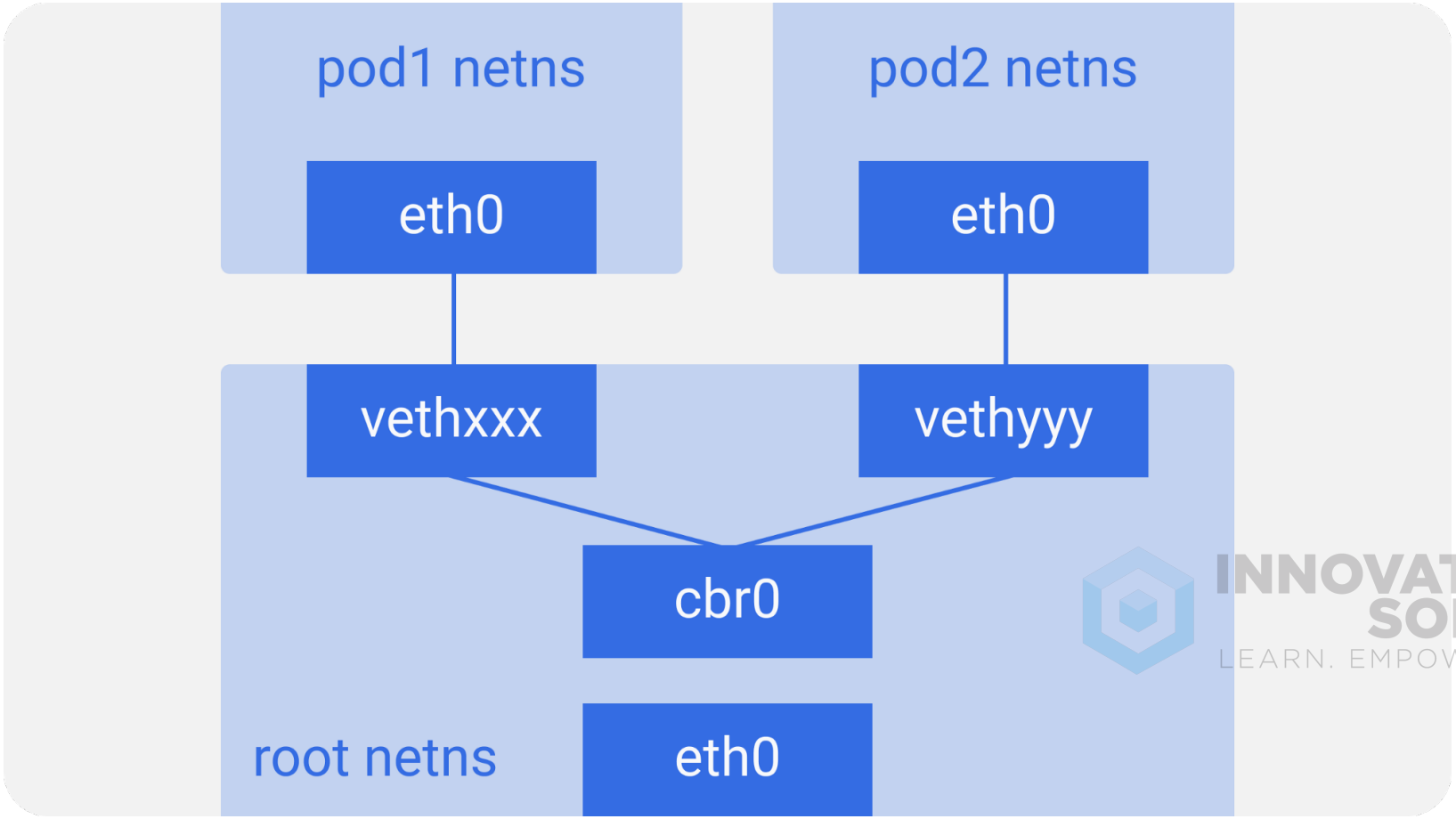
Node Namespace



Node Namespaces

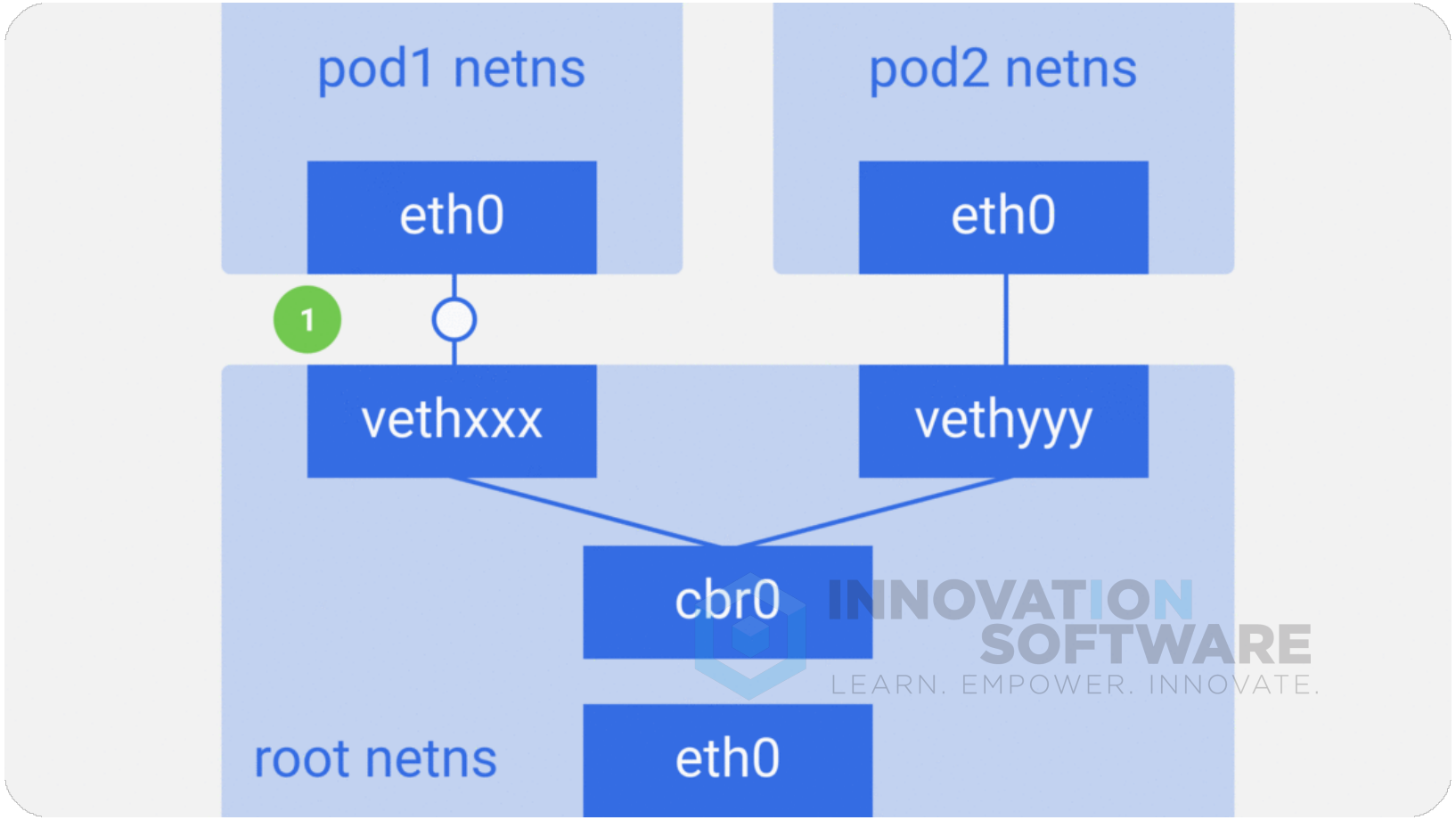


Pod to Host



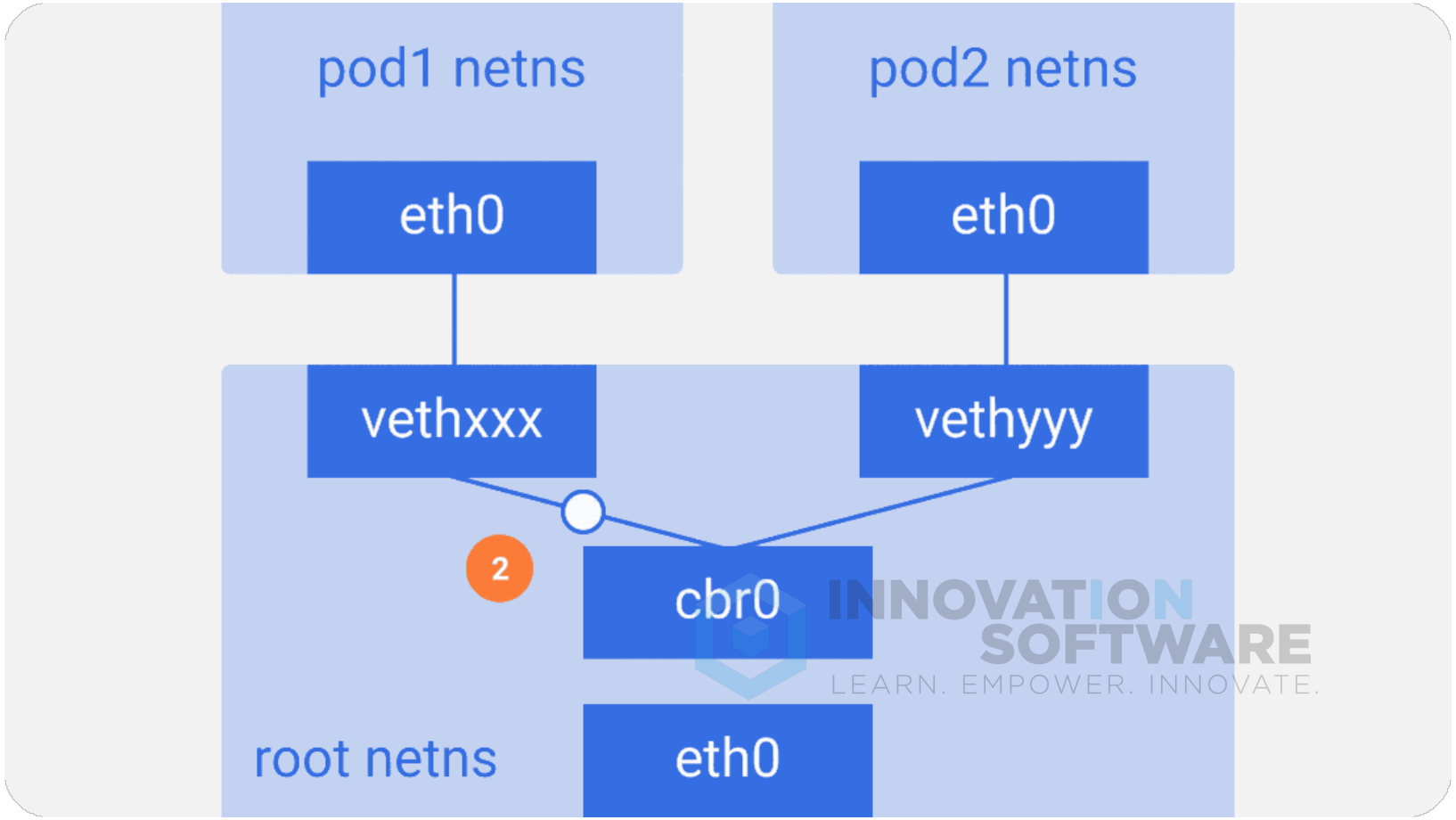
Single Host POD to POD Network

1. Packet leaves pod1's netns at eth0 and enters the root netns at vethxxx.



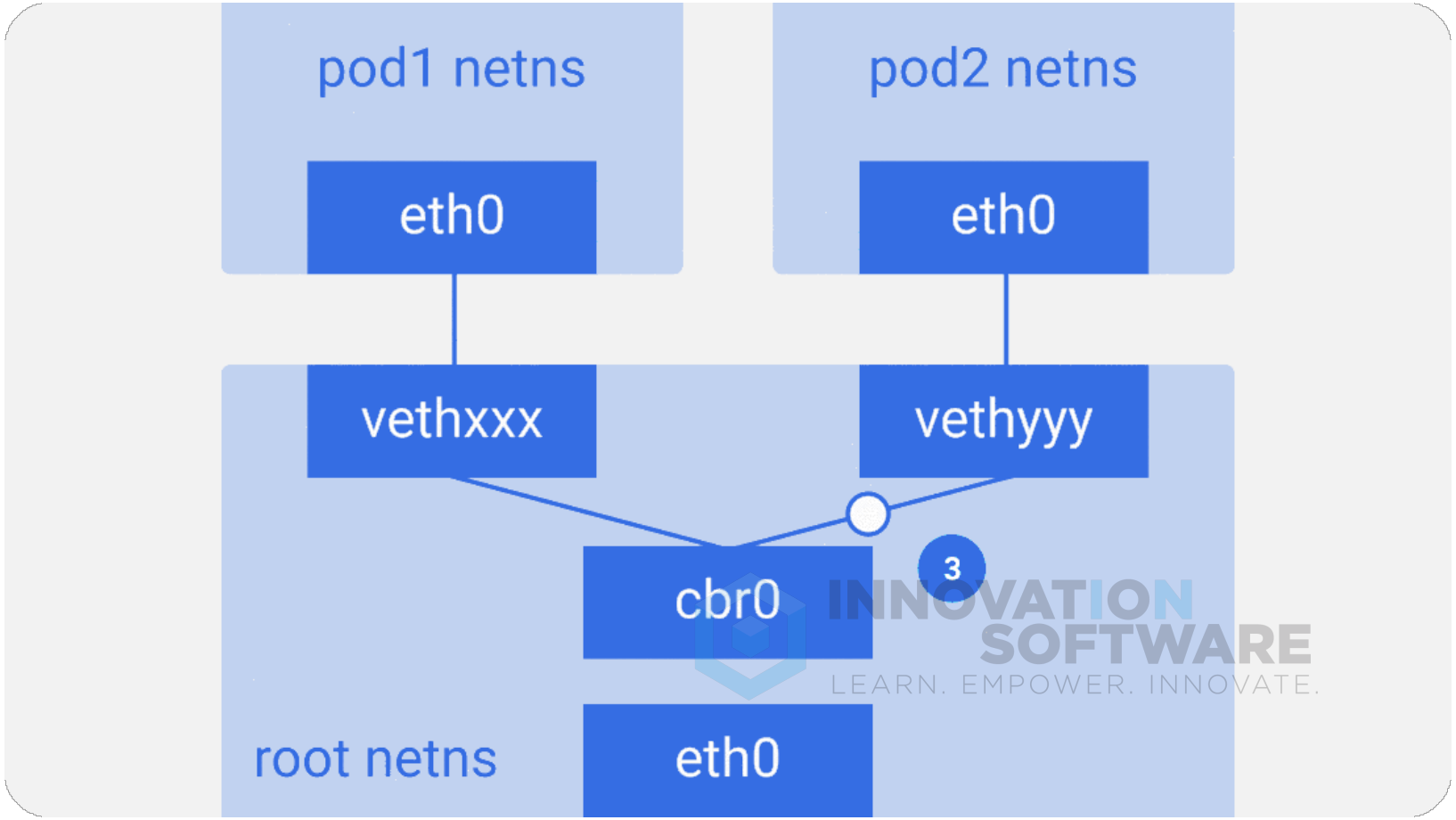
Single Host POD to POD Networking

2. It's passed on to cbr0, which discovers the destination using an ARP request, saying "who has this IP?"



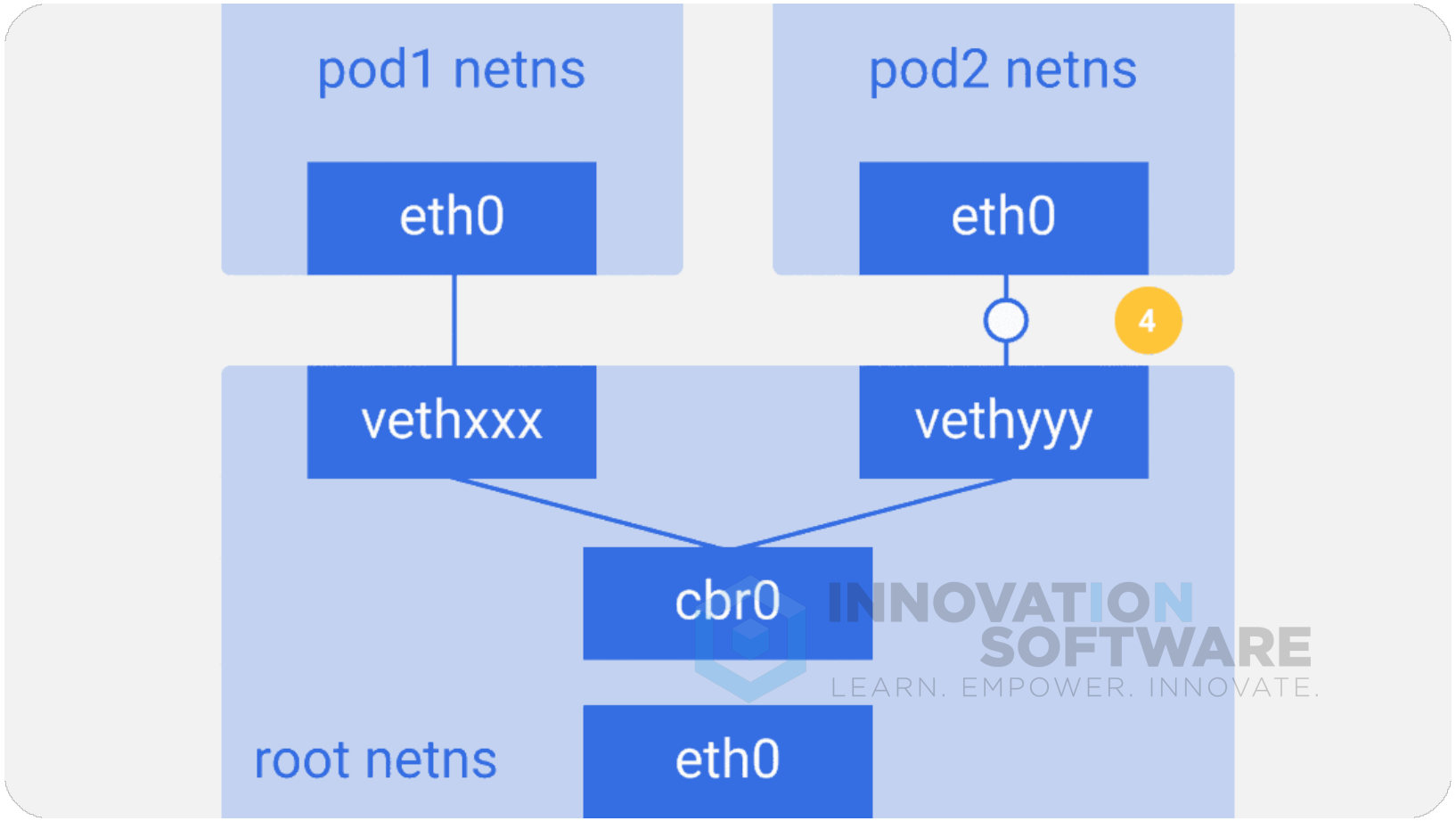
Single Host POD to POD Networking

3. vethyyy says it has that IP, so the bridge knows where to forward the packet.



Single Host POD to POD Networking

4. The packet reaches vethyyy, crosses the pipe-pair and reaches pod2's netns.

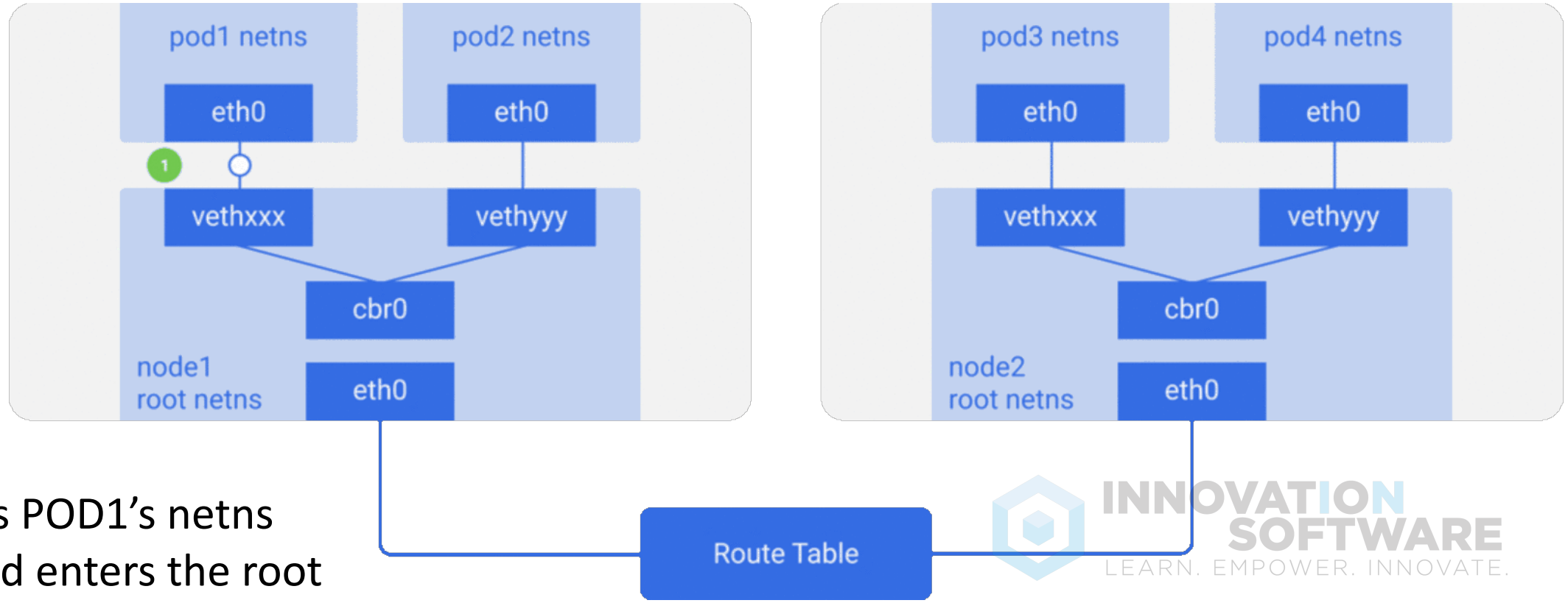


Kubernetes Inter-node Communication

Inter-node Communication

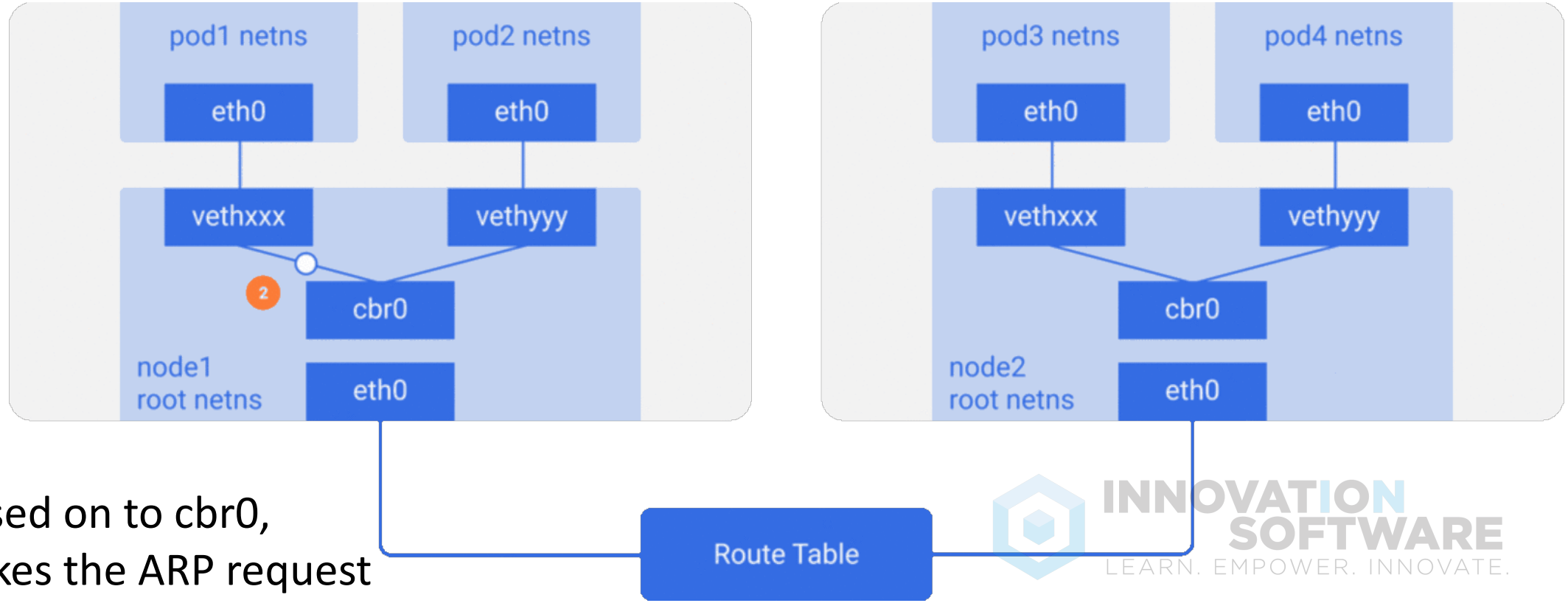
- PODs must be reachable across nodes
- Kubernetes doesn’t care how:
  - L2 (ARP across nodes)
  - L3 (IP routing across nodes)
  - Overlay networks

Inter-node Communication



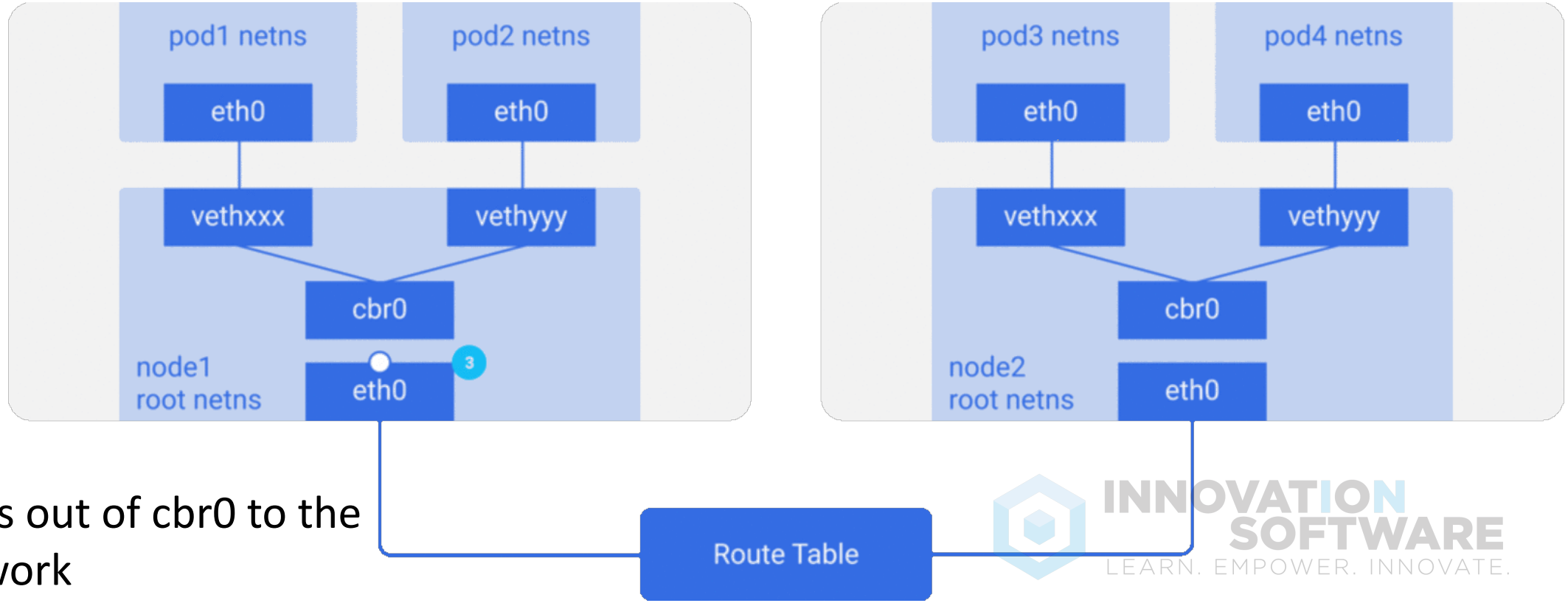
1. It leaves POD1's netns at eth0 and enters the root netns at vethxxx.

Inter-node Communication



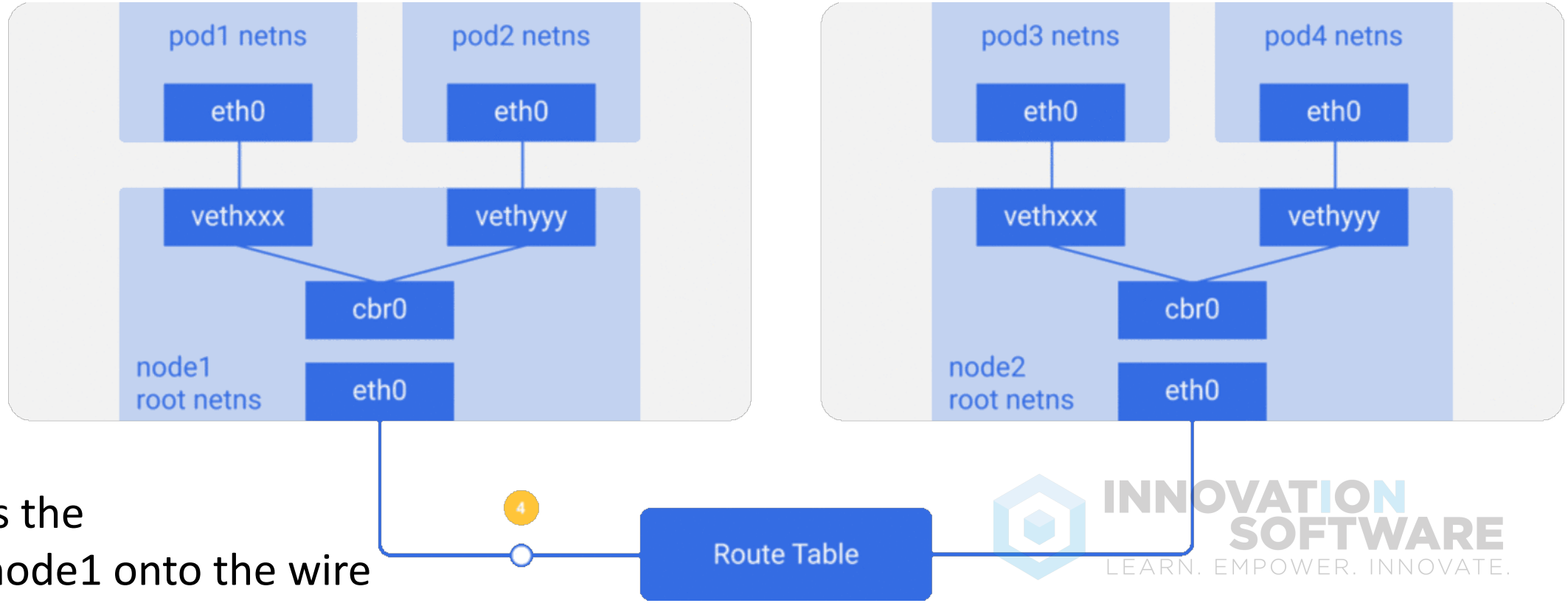
2. It's passed on to cbr0, which makes the ARP request to find the destination.

Inter-node Communication



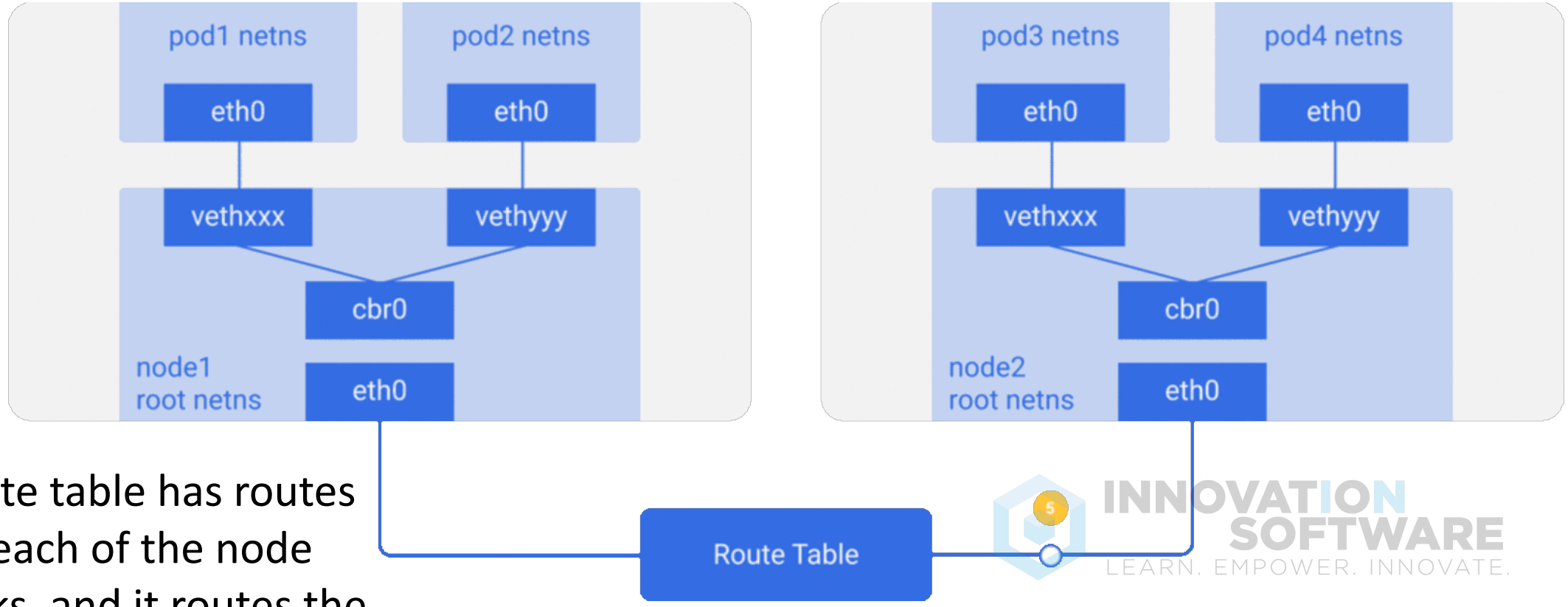
3. It comes out of cbr0 to the main network interface eth0 since nobody on this node has the IP address for POD4.

Inter-node Communication



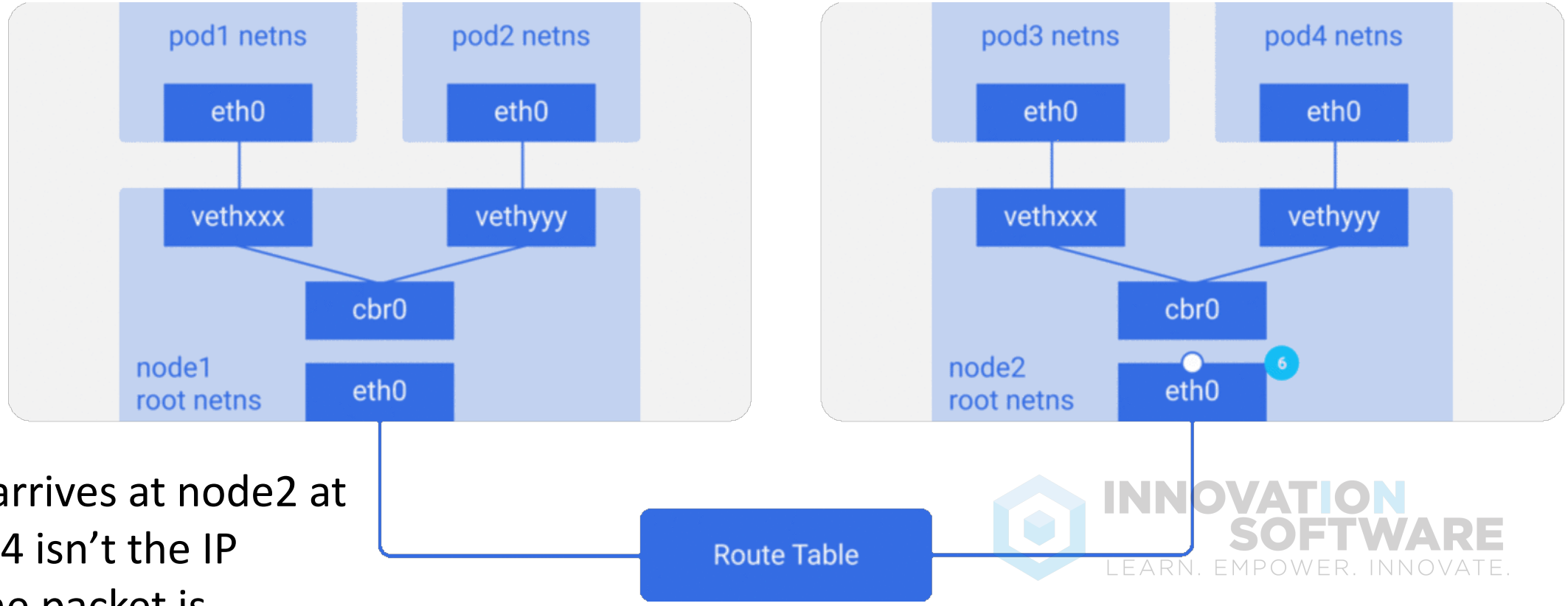
4. It leaves the machine node1 onto the wire with src=POD1 and dst=POD4.

Inter-node Communication



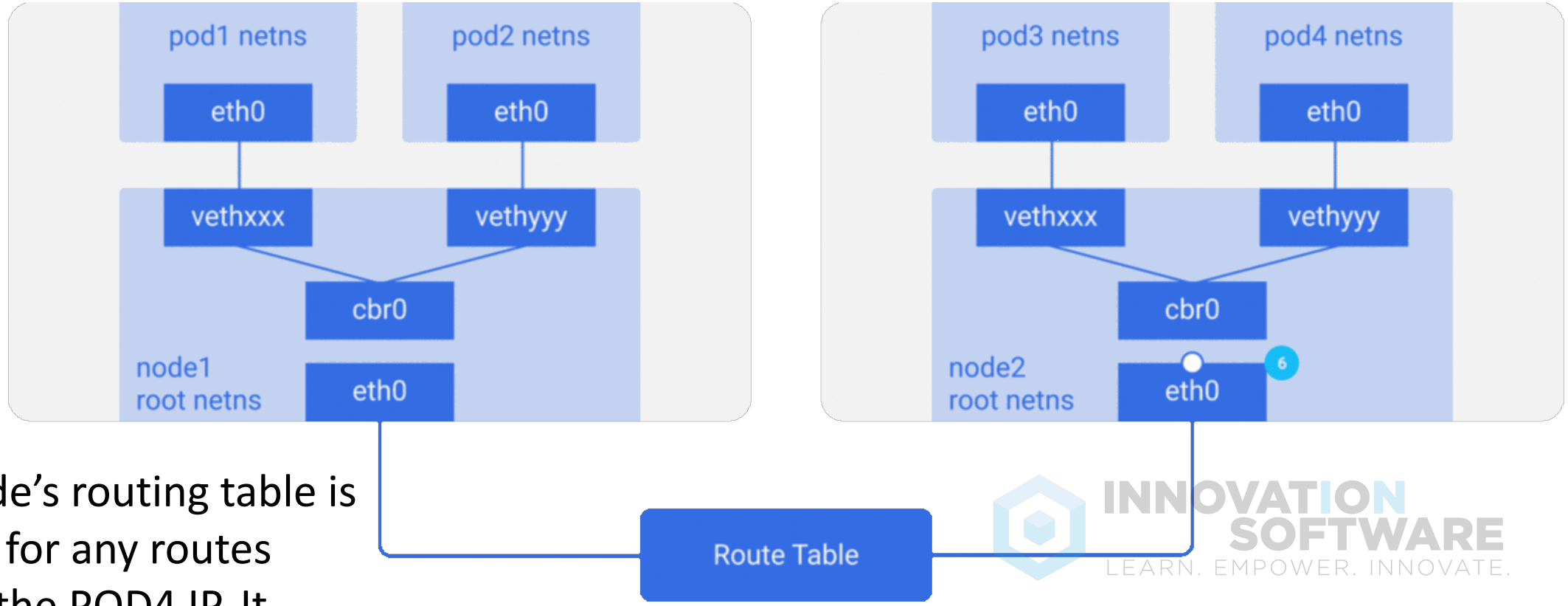
5. The route table has routes setup for each of the node CIDR blocks, and it routes the packet to the node whose CIDR block contains the POD4 IP.

Inter-node Communication



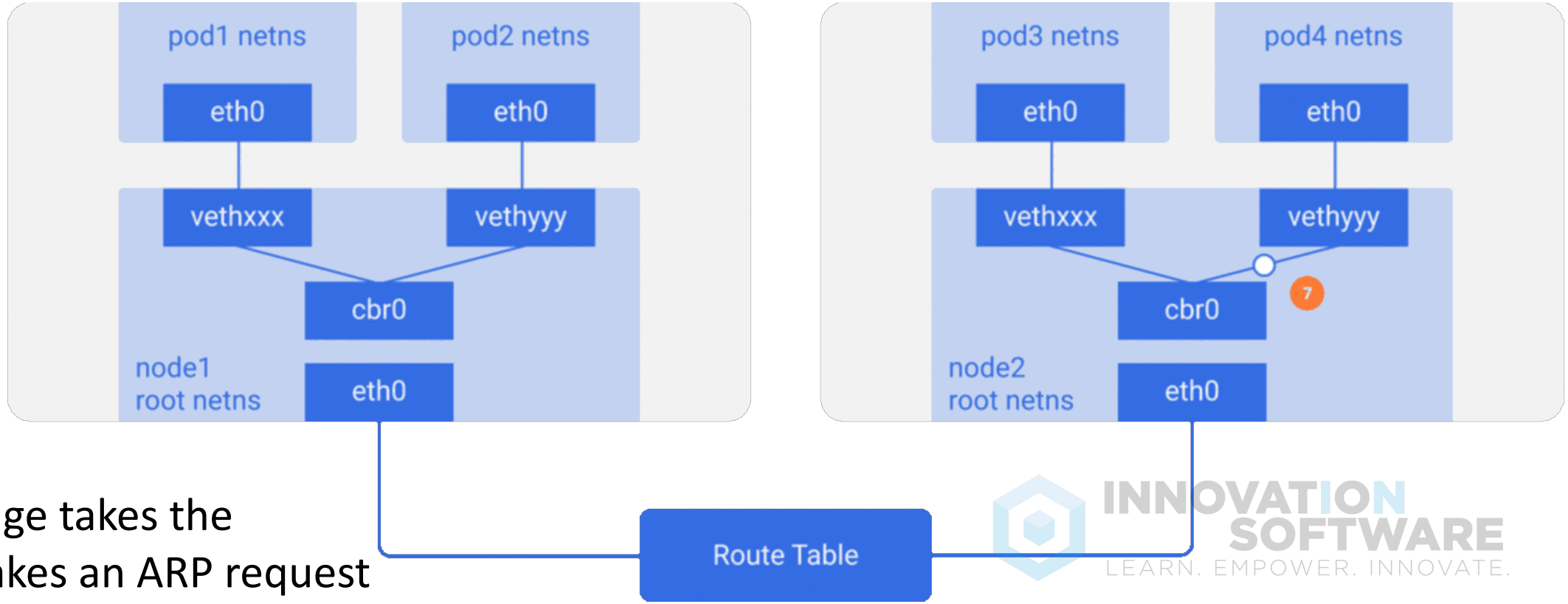
6. Packet arrives at node2 at eth0. POD4 isn't the IP of eth0, the packet is forwarded to cbr0, nodes are configured with IP forwarding enabled.

Inter-node Communication



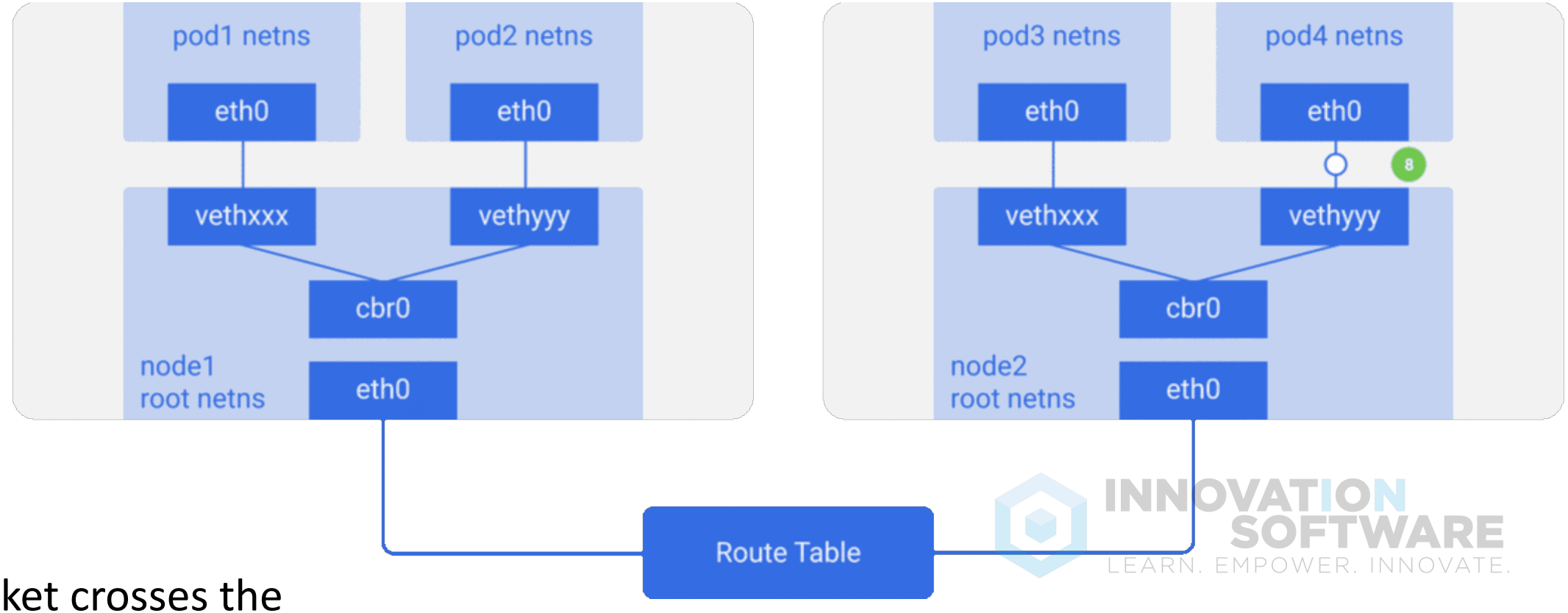
6. The node's routing table is looked up for any routes matching the POD4 IP. It finds cbr0 as the destination for this node's CIDR block.

Inter-node Communication



7. The bridge takes the packet, makes an ARP request and finds out that the IP belongs to vethyyy.

Inter-node Communication



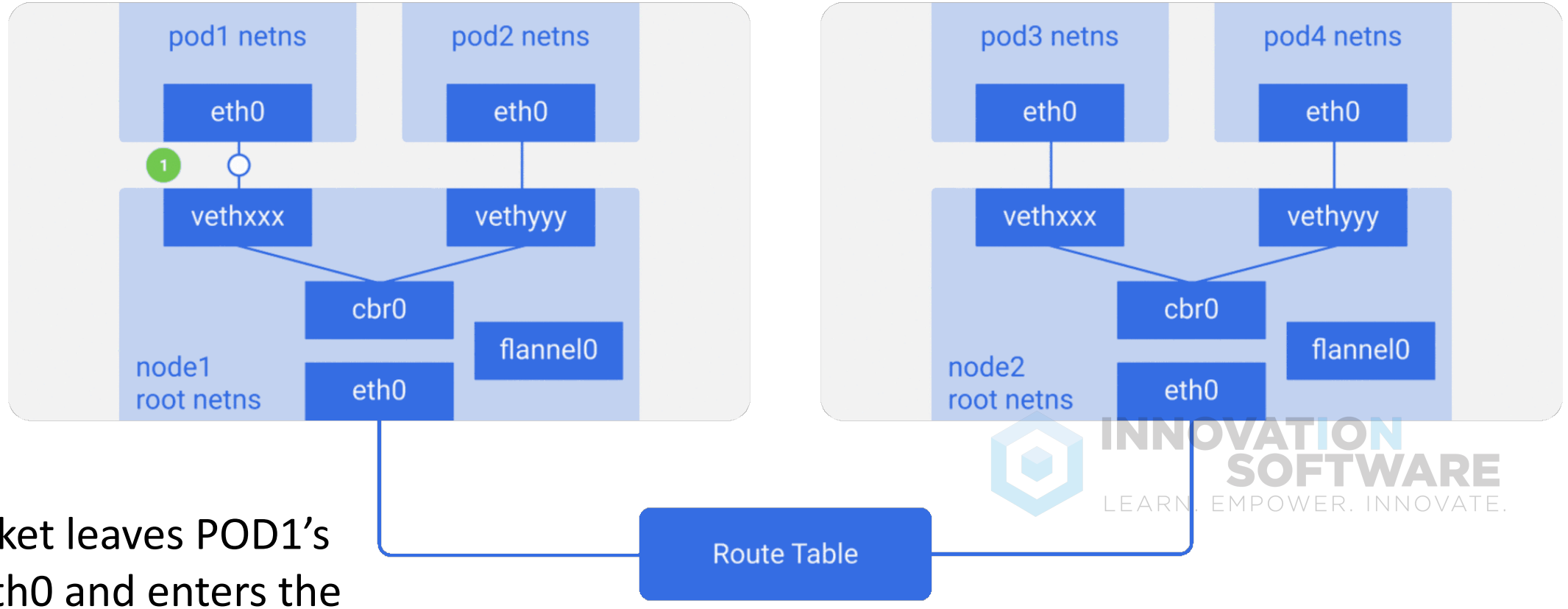
8. The packet crosses the pipe-pair and reaches POD4

Kubernetes Overlay Networking

Overlay Networking

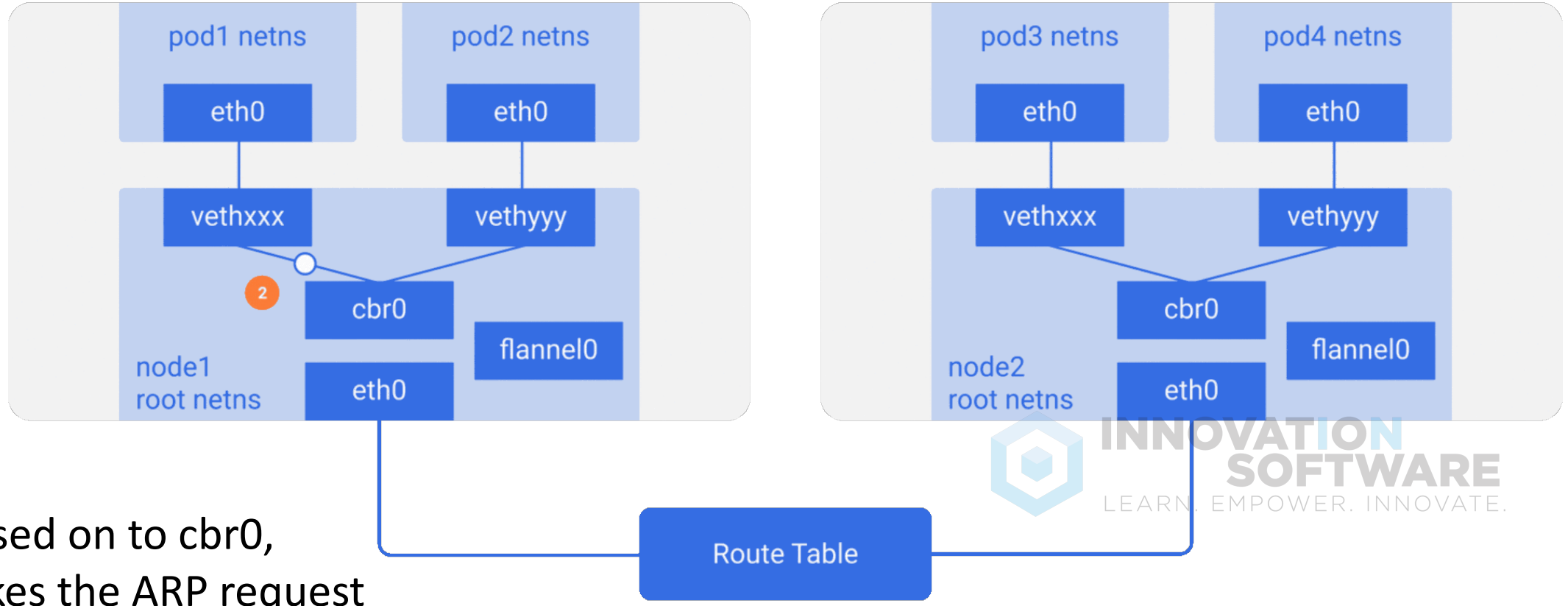
- Not required but very common
- Provide virtual IP space
- Avoid route limits (Public Cloud)
- Encapsulating a packet-in-packet which traverses the native network across nodes.
- Can reduce throughput

Flannel Overlay Networking



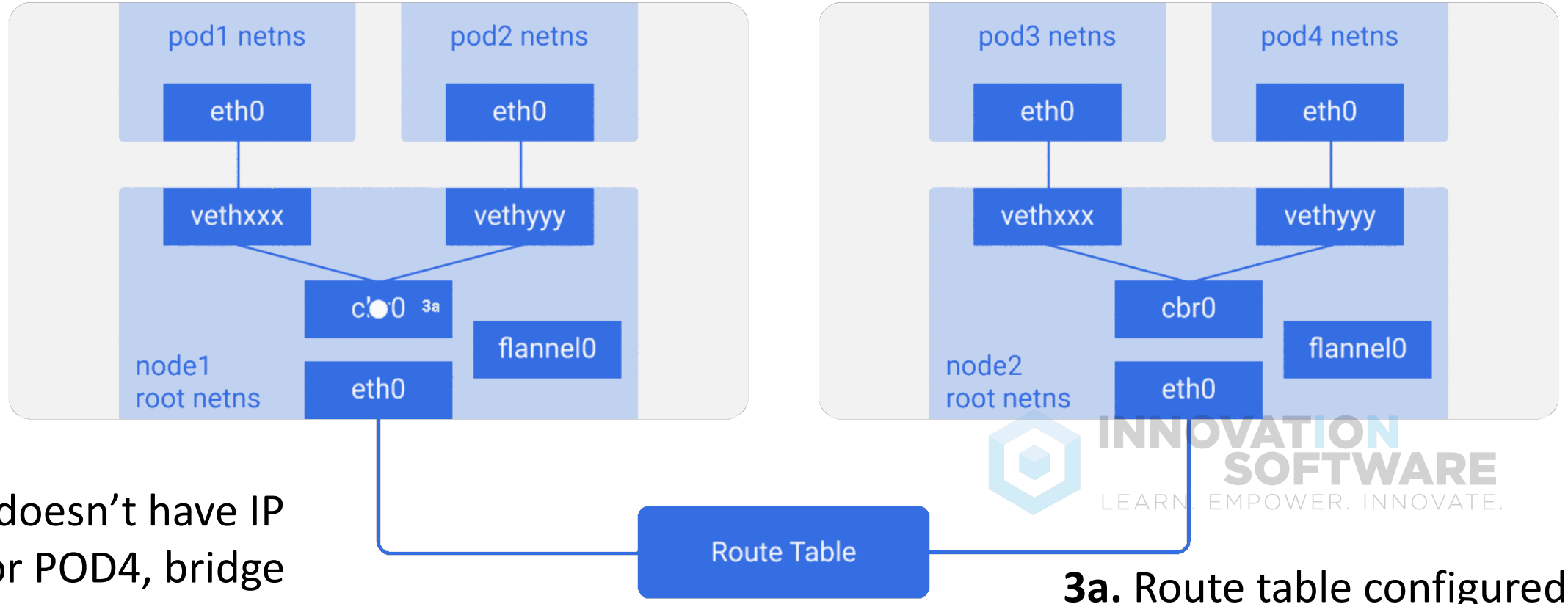
1. The packet leaves POD1's netns at eth0 and enters the root netns at vethxxx.

Flannel Overlay Networking



2. It's passed on to cbr0, which makes the ARP request to find the destination.

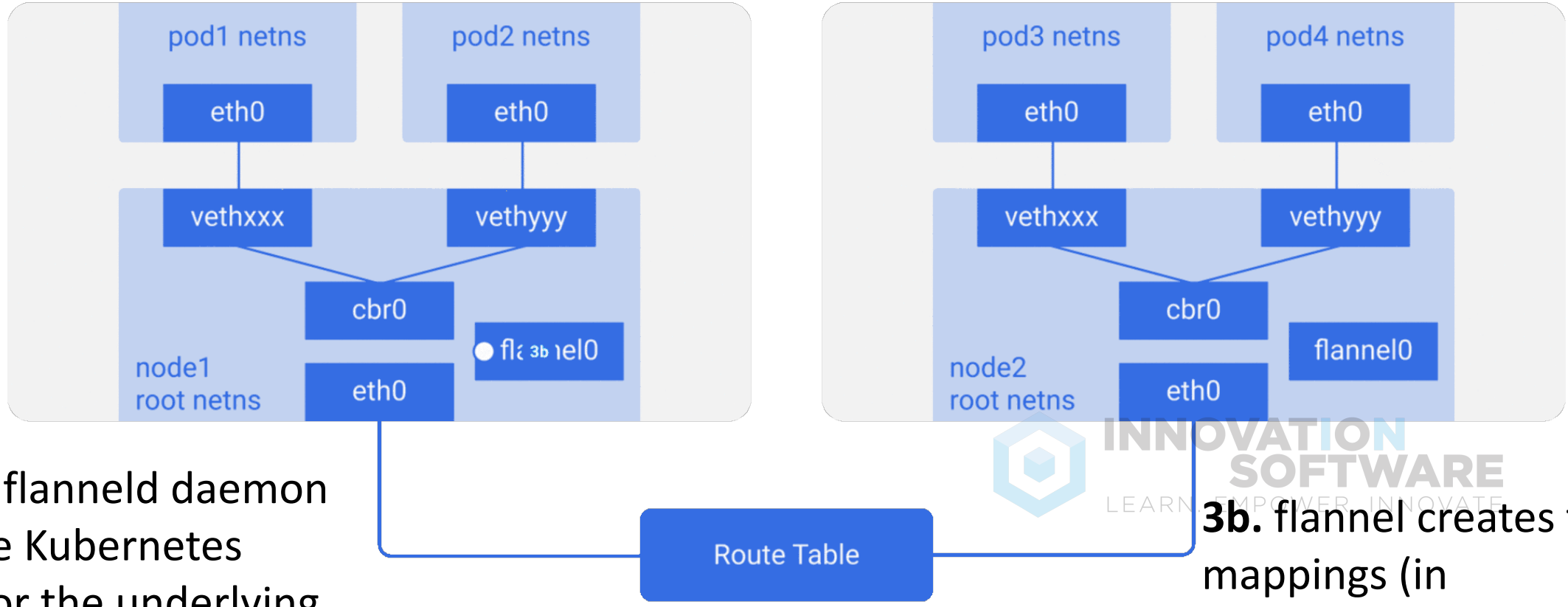
Flannel Overlay Networking



3a. Node doesn't have IP address for POD4, bridge sends to flannel0.

3a. Route table configured with flannel0 as the target for the pod network range .

Flannel Overlay Networking

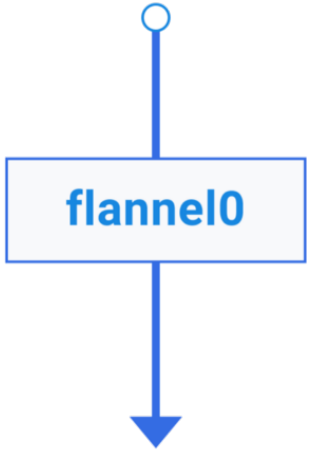


3b. As the flanneld daemon talks to the Kubernetes apiserver or the underlying etcd, it knows about all the pod IPs, what nodes they're on.

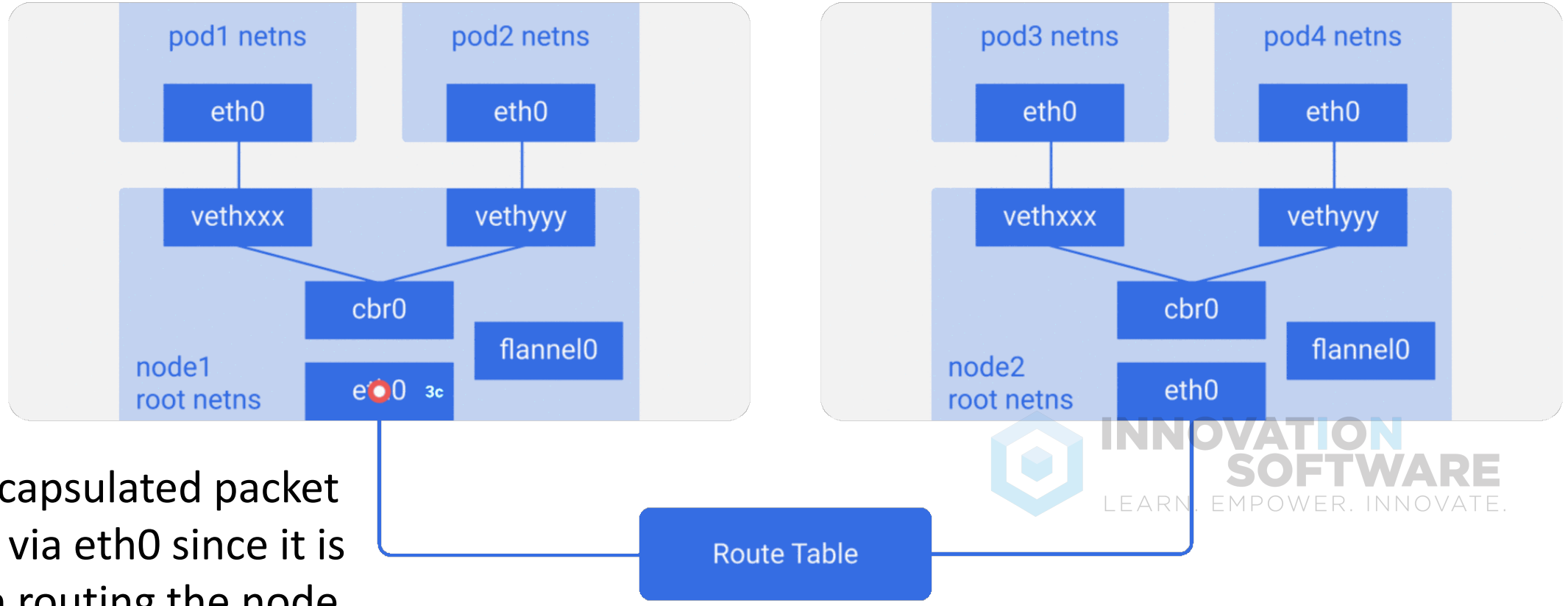
3b. flannel creates the mappings (in userspace) for pods IPs to node IPs.

Flannel Overlay Networking

flannel0 takes this packet and wraps it in a UDP packet with extra headers changing the source and destinations IPs to the respective nodes, and sends it to a special vxlan port (generally 8472).

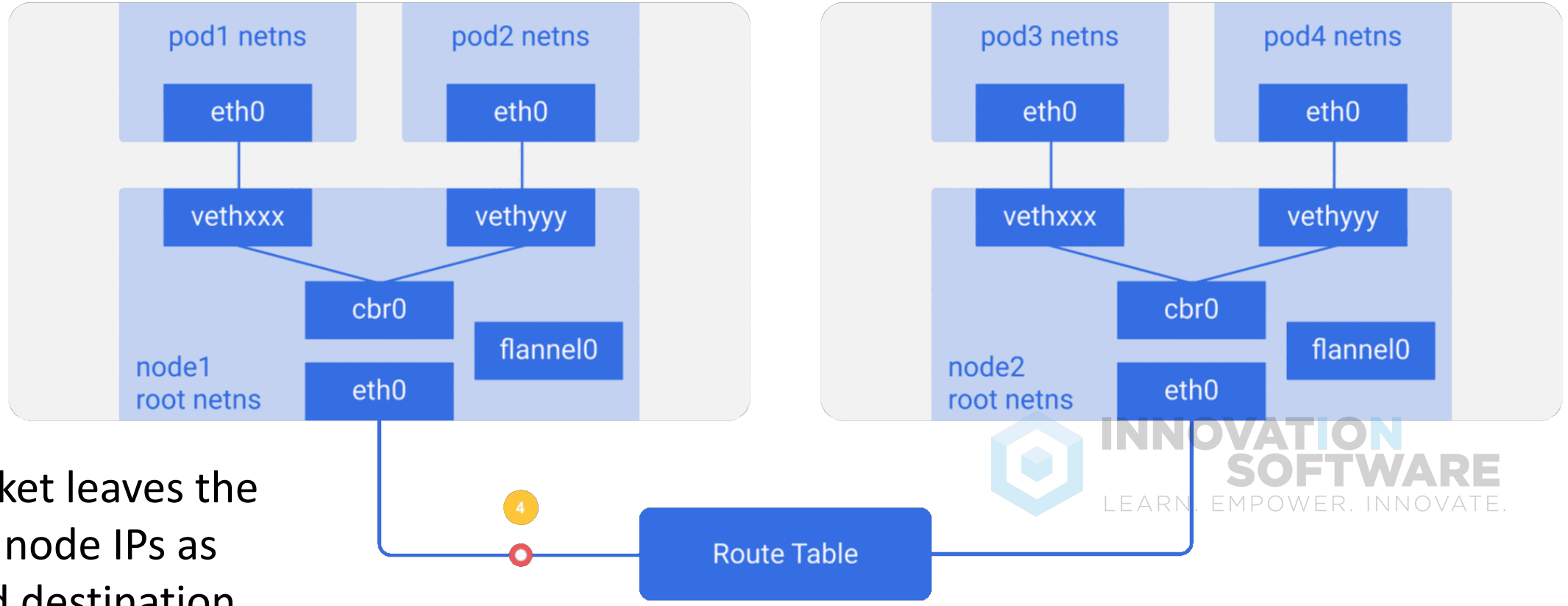


Flannel Overlay Networking



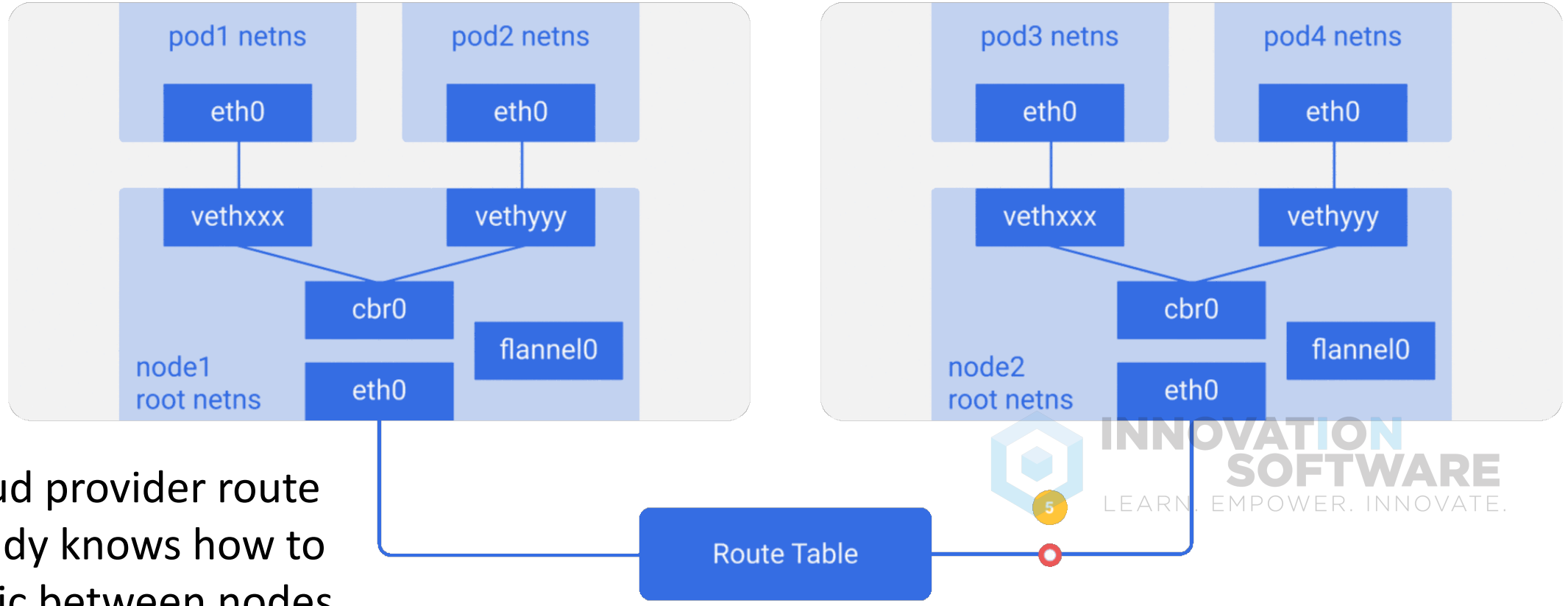
3c. The encapsulated packet is sent out via eth0 since it is involved in routing the node traffic.

Flannel Overlay Networking



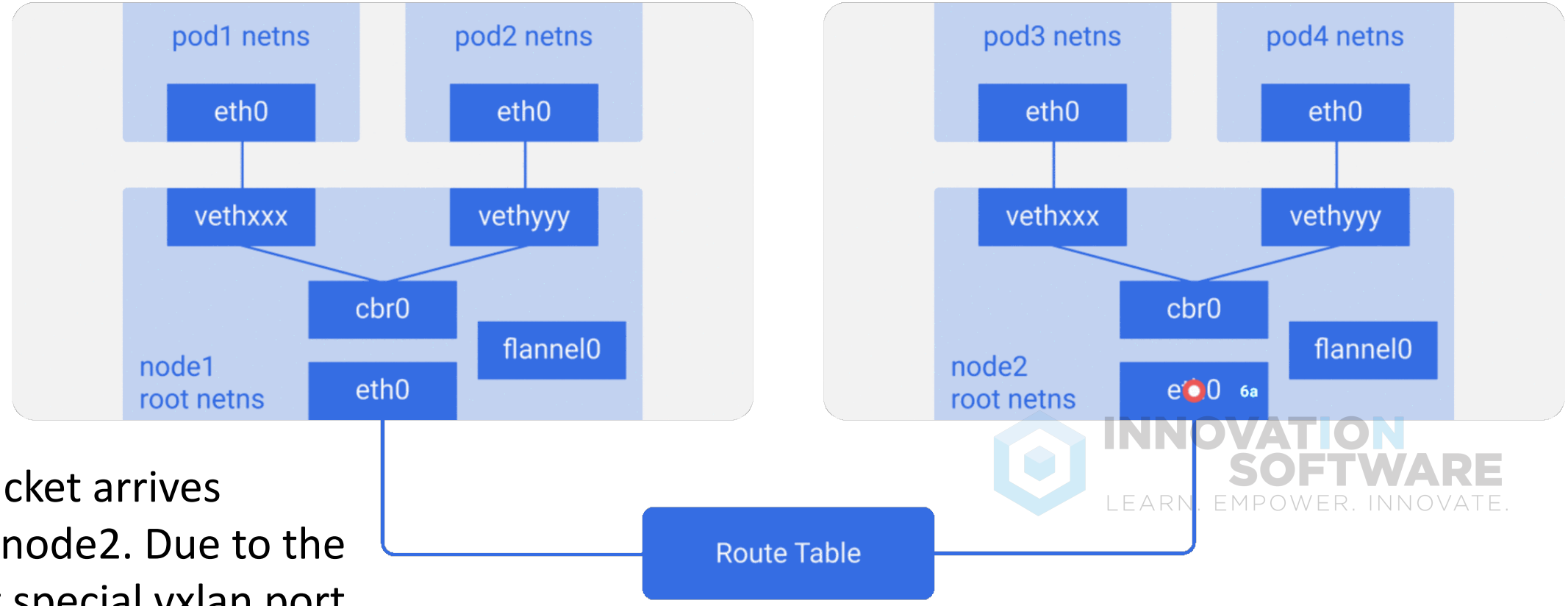
4. The packet leaves the node with node IPs as source and destination.

Flannel Overlay Networking



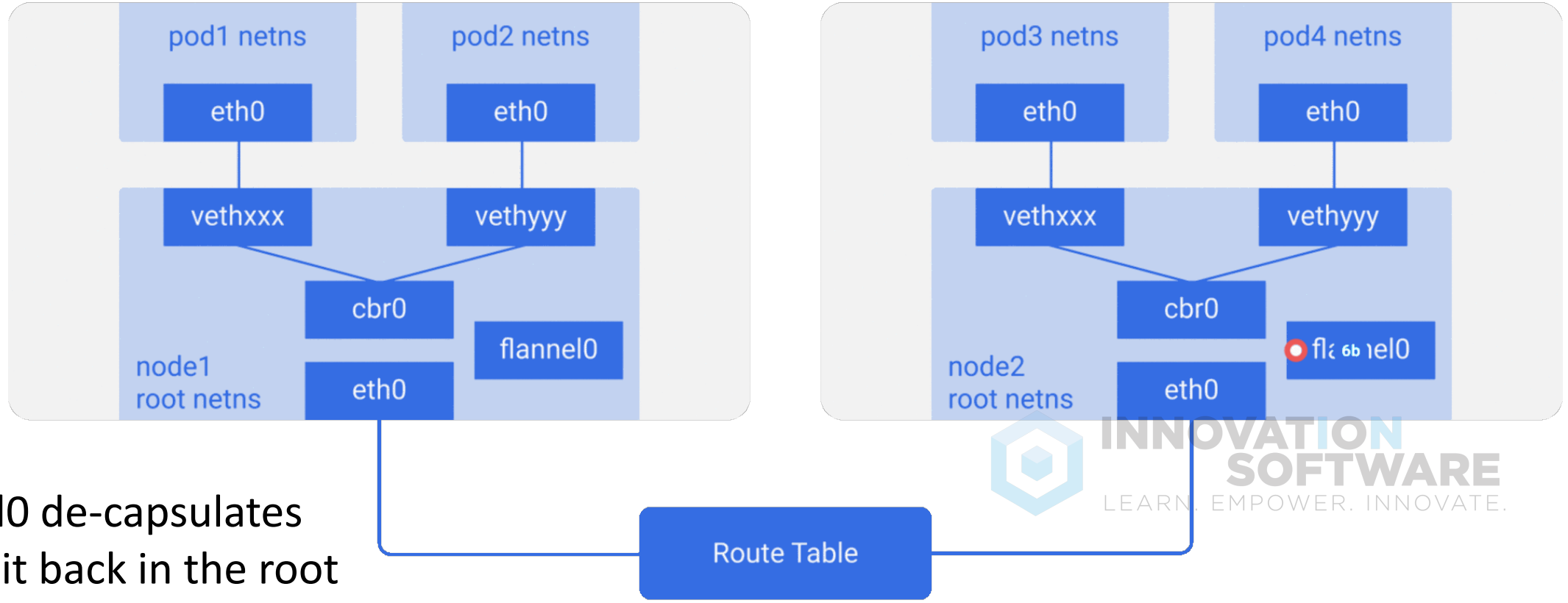
5. The cloud provider route table already knows how to route traffic between nodes, so it sends the packet to destination node2.

Flannel Overlay Networking



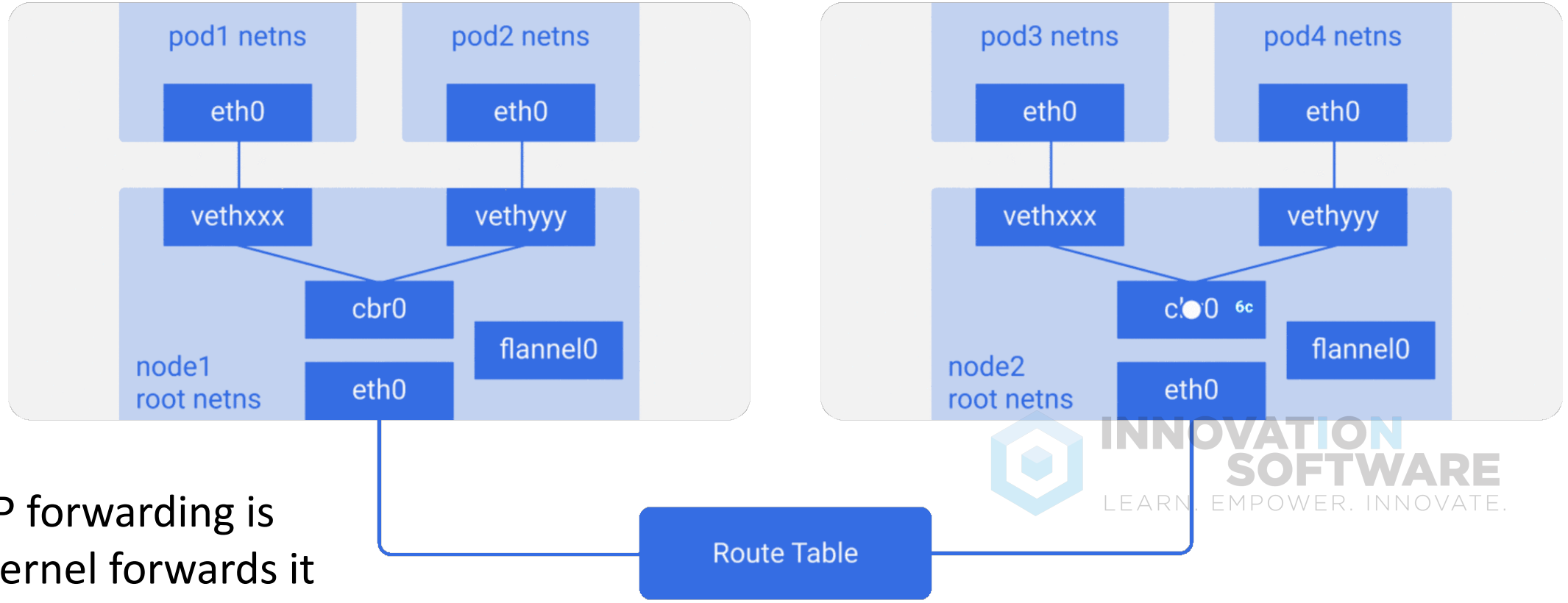
6a. The packet arrives at eth0 of node2. Due to the port being special vxlan port, kernel sends the packet to flannel0.

Flannel Overlay Networking



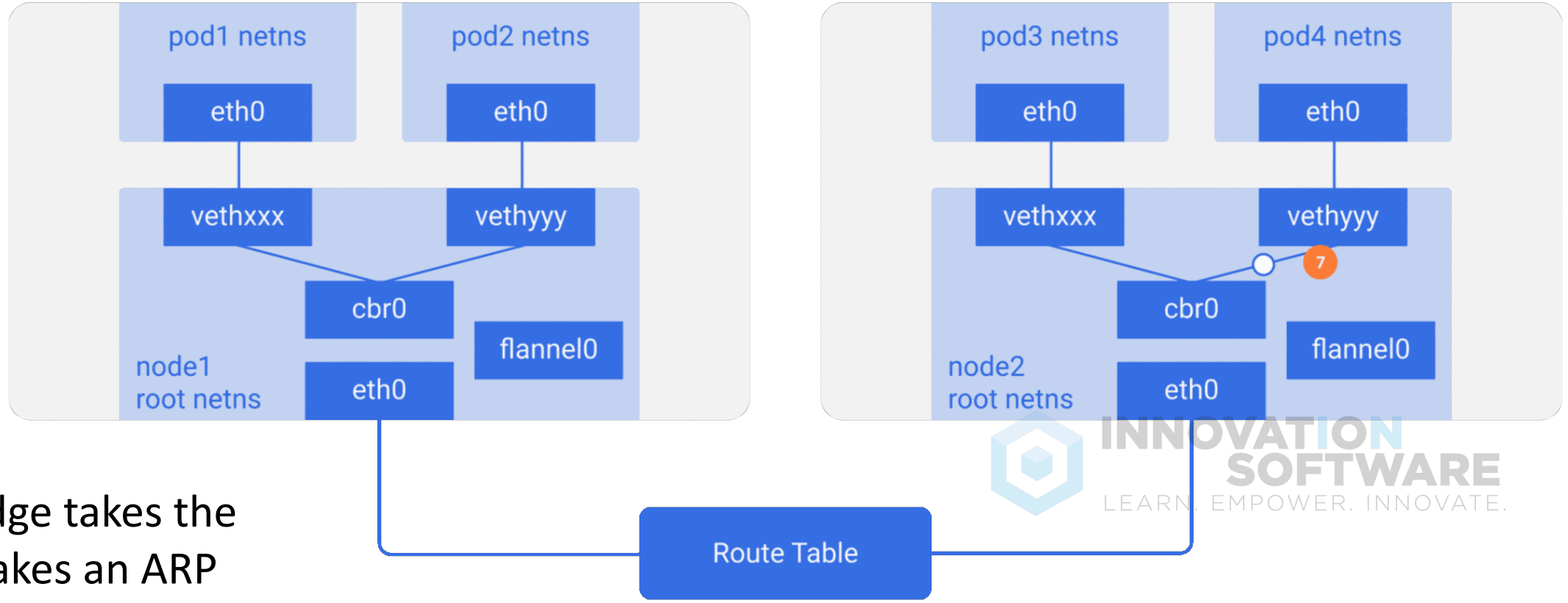
6b. flannel0 de-capsulates and emits it back in the root network namespace.

Flannel Overlay Networking



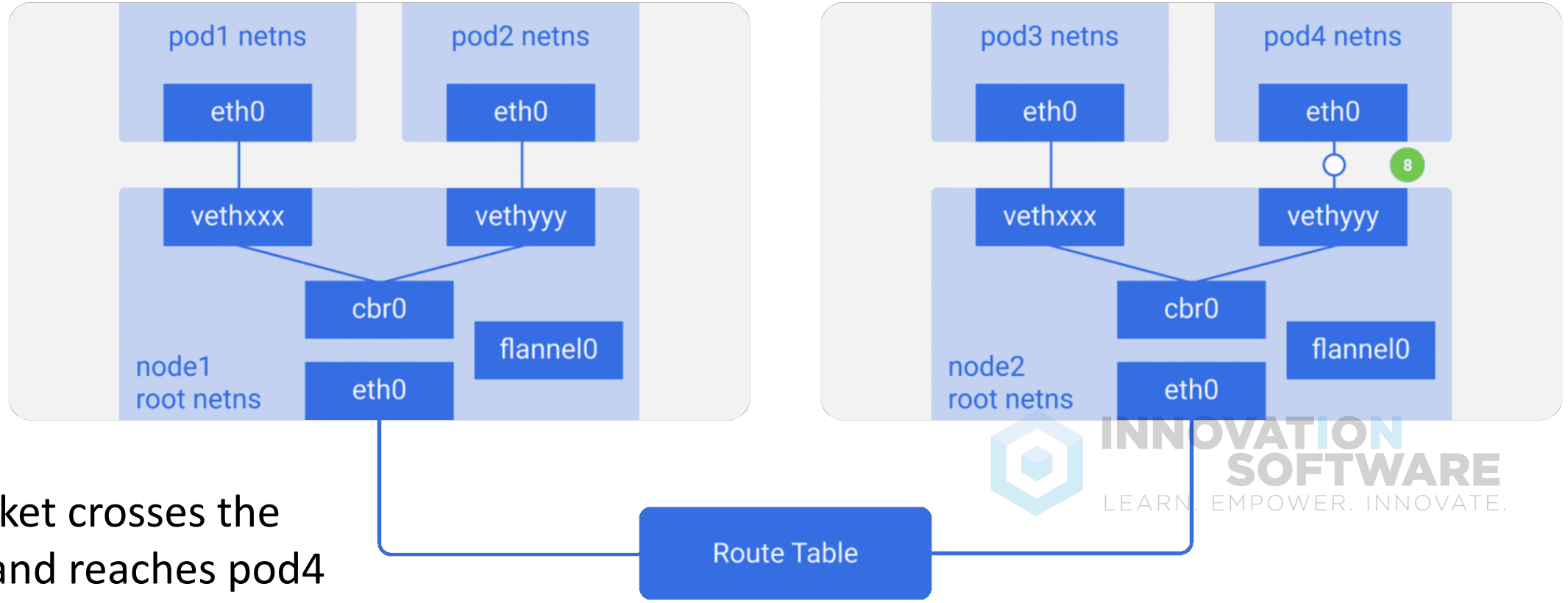
6c. Since IP forwarding is enabled, kernel forwards it to cbr0 as per the route tables.

Flannel Overlay Networking



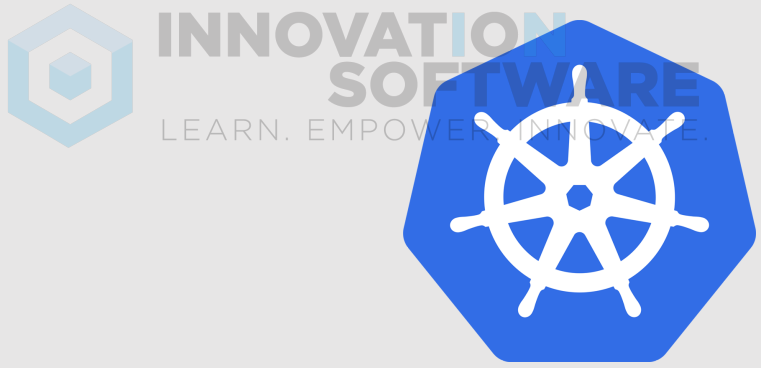
7. The bridge takes the packet, makes an ARP request and finds out that the IP belongs to vethyyy.

Flannel Overlay Networking



8. The packet crosses the pipe-pair and reaches pod4

Deployments



What is a Deployment?

Kubernetes controller optimal for stateless applications

- Deployments allow you to declaratively manage pods, including replication
- Deployments support
  - Creating, rolling out, and rolling back changes to homogeneous set of pods
  - Scaling set of pods out and back declaratively
- Deployments include
  - Implicit Replica Set controller to handle pod replicas
  - Template spec of pods to be created and managed – no need to separately create pods
- Deployments used for web applications, mobile back-ends, API's

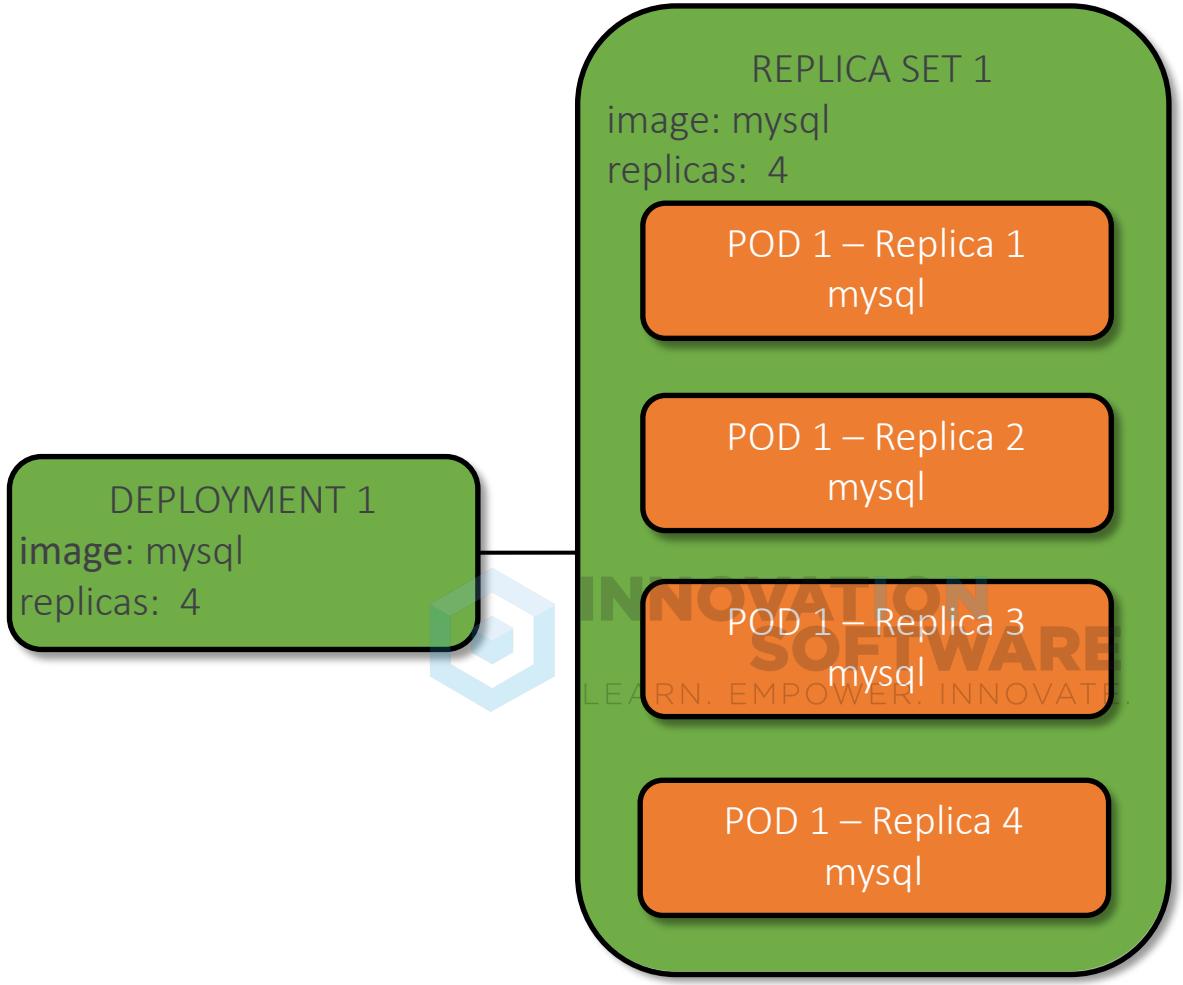
What if my Application isn't Stateless?

- Kubernetes provides other controller objects for applications that need different deployment schemes
- **StatefulSets** (previously PetSets) control deployment of pods for applications that need more stable deployment contexts
  - Pods in StatefulSets have unique ordinal, stable network identity and stable storage using persistent volumes
  - When pods are deployed, they are created in sequence of ordinals 1..N
  - Pod N must be running and ready before Pod N+1 is deployed
  - When pods are destroyed, they are terminated in reverse sequence N..1
- **DaemonSets** ensure that a replica of a specified pod is running on every node (or every selected node) in the cluster
- **Jobs** manage sets of pods where N must run to successful completion

Deployments Control ReplicaSet Controllers

Definition of how many replicated Pods should exist

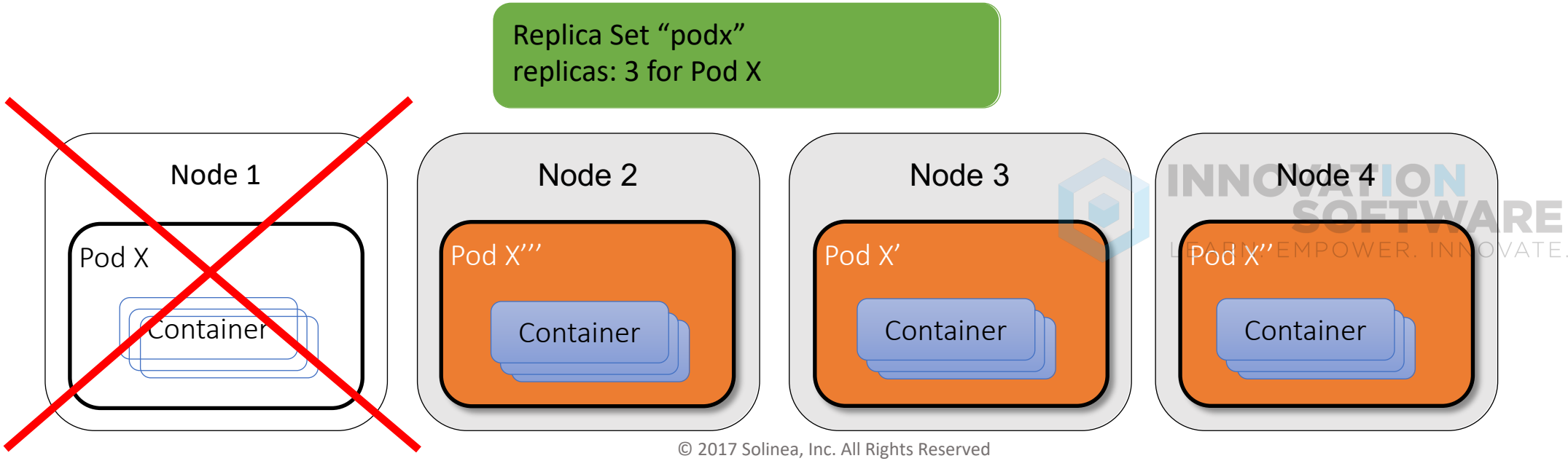
- Deployment creates and manages a Replica Set that manages a set of pods
- Replica count can be adjusted as needed to scale the Replica Set out and back
- Replica Set successor to the ReplicationController object



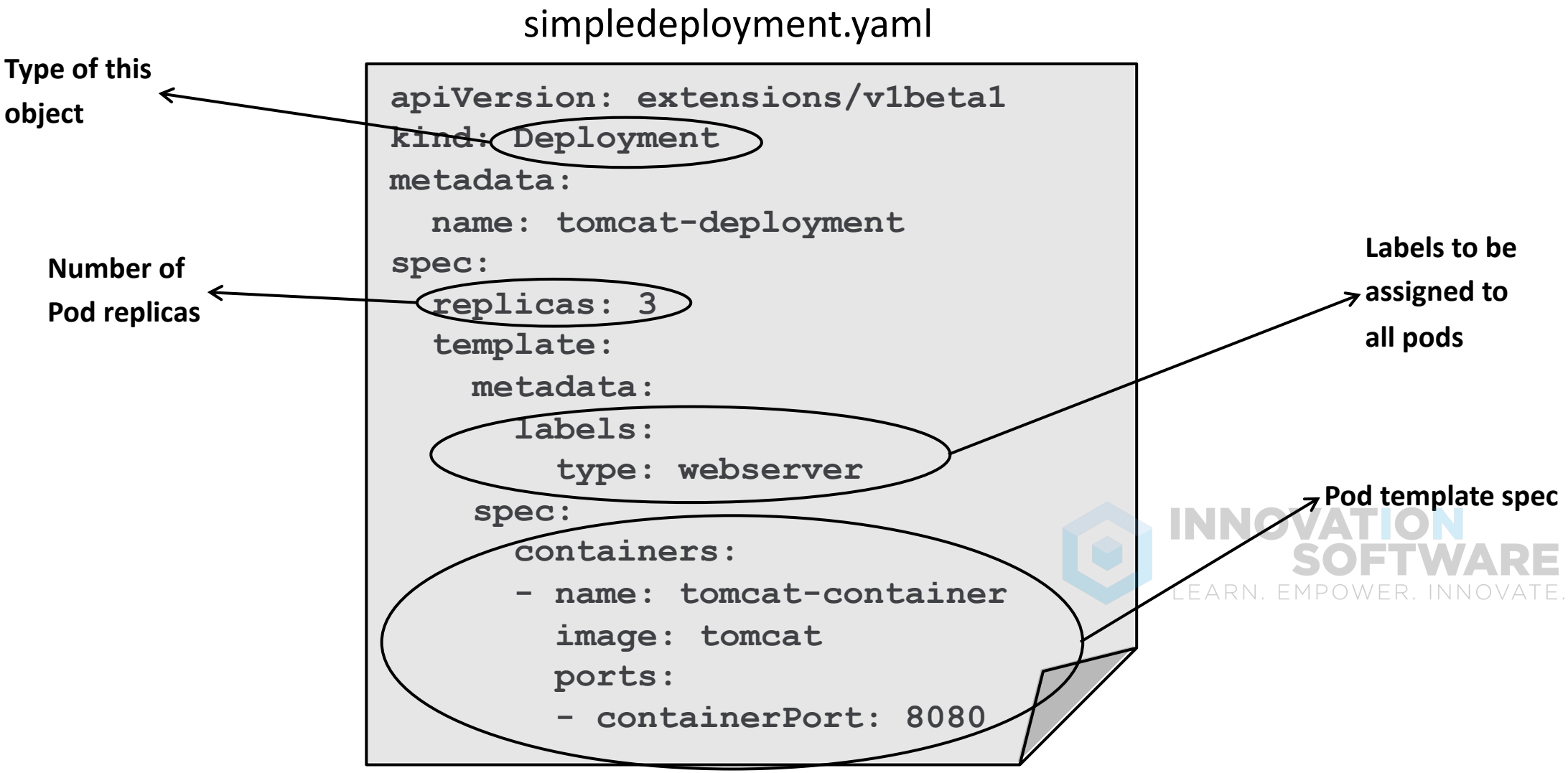
What is a Replica Set?

Provides scaling and high availability

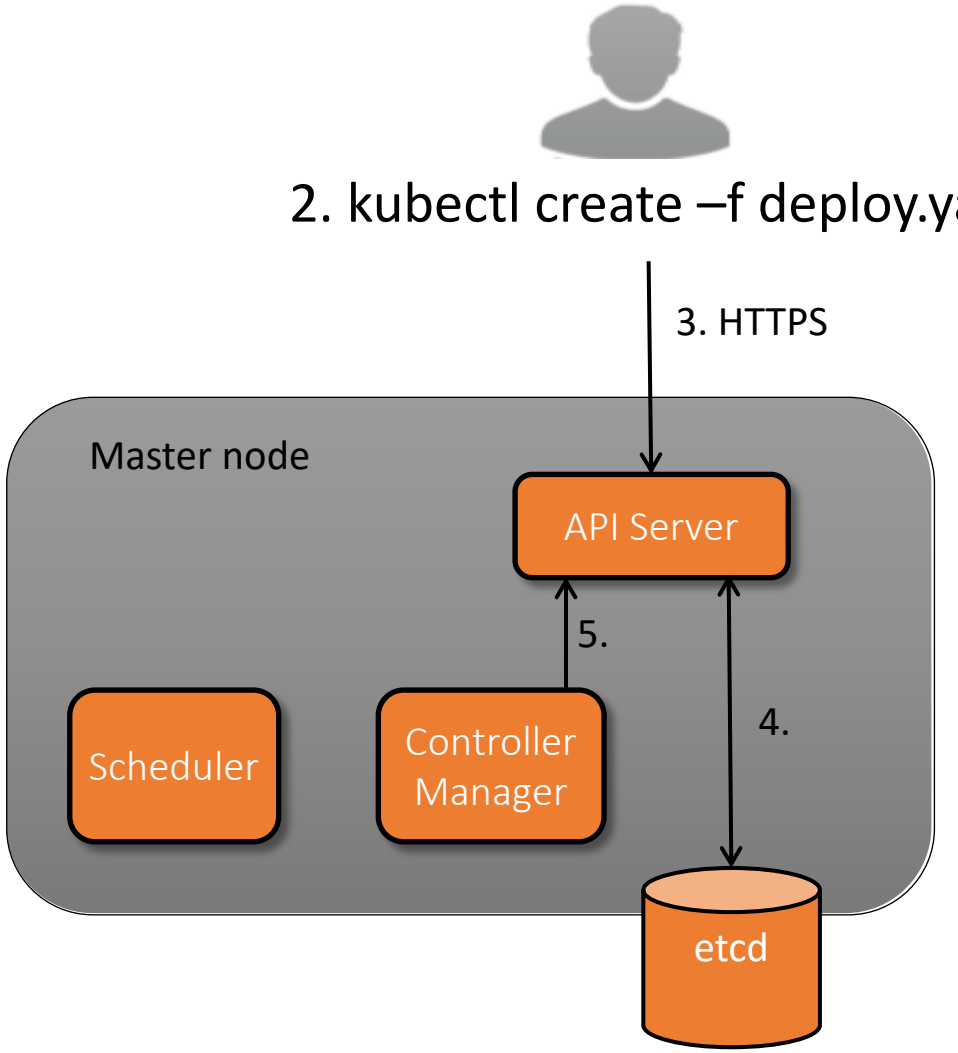
- Replica count can be changed to provide scaling on demand as needed
- If the node hosting a pod fails, the Kubernetes cluster will recreate the pod elsewhere to achieve the target number of replicas



Examining a Deployment Manifest File

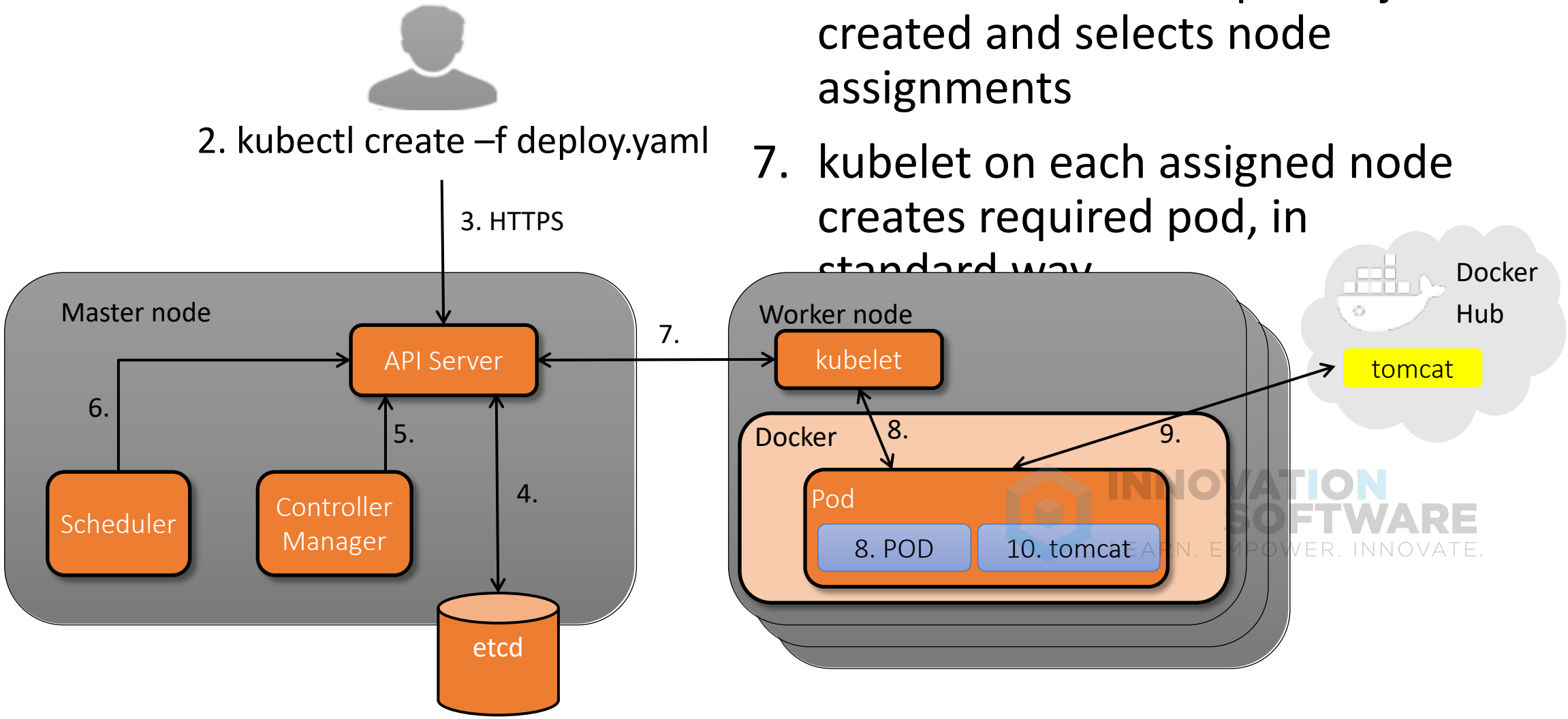


Deployment Creation Process



1. User writes a deployment manifest file
2. User requests creation of deployment from manifest via CLI
3. CLI tool marshals parameters into K8s RESTful API request (HTTP POST)
4. kube-apiserver creates new deployment object record in etcd, and new Replica Set object
5. kube-controller-manager sees new Replica Set and
   a. Evaluates state of existing vs. required replicas
   b. Submits pod creation requests to API to create required number of replicas

Deployment Creation Process

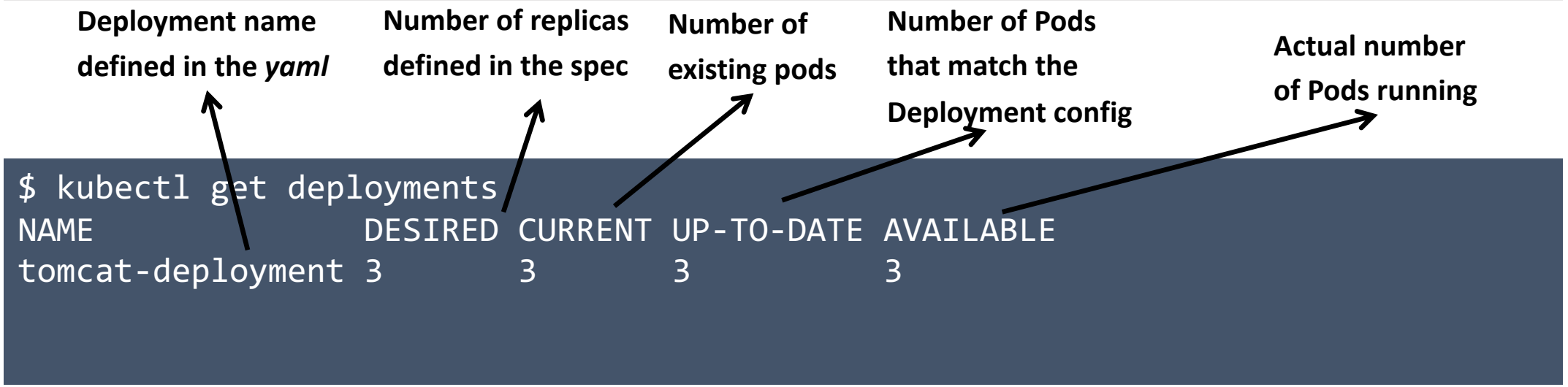


6. Scheduler sees new pod objects created and selects node assignments
7. kubelet on each assigned node creates required pod, in standard way

Deployments Management

Deployments Control ReplicaSets

The deployment creates a ReplicaSet that controls pod creation



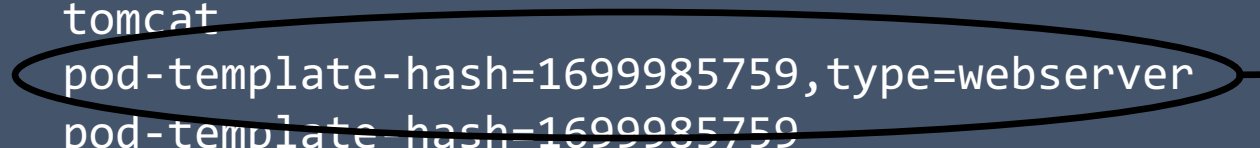

```
$ kubectl get deployments
NAME                DESIRED CURRENT UP-TO-DATE AVAILABLE
tomcat-deployment 3       3       3          3
```

```
$ kubectl get rs
NAME                           DESIRED CURRENT UP-TO-DATE AVAILABLE AGE
tomcat-deployment-1699985759 3       3       3          3         2m
```

Replica Set Details

Replica Set name is <Deployment name>-<pod template hash value>

```
$ kubectl describe replicaset tomcat-deployment-1699985759
Name:           tomcat-deployment-1699985759
Namespace:      default
Image(s):       tomcat
Selector:       pod-template-hash=1699985759,type=webserver
Labels:         pod-template-hash=1699985759
                type=webserver
Replicas:       3 current / 3 desired
Pods Status:    3 Running / 0 Waiting / 0 Succeeded / 0 Failed
...
```



Selector uses labels from pod template and template hash

Pod Naming

Pod name is <Replica Set name>-<pod unique random string>

```
$ kubectl get pods
NAME                                READY   STATUS
tomcat-deployment-1699985759-h11sz 0/1     ContainerCreating
tomcat-deployment-1699985759-ka13j 0/1     ContainerCreating
tomcat-deployment-1699985759-u03b5 1/1     Running

$ kubectl get pods
NAME                                READY   STATUS
tomcat-deployment-1699985759-h11sz 1/1     Running
tomcat-deployment-1699985759-ka13j 1/1     Running
tomcat-deployment-1699985759-u03b5 1/1     Running
```


Pod name based on Replica Set name

Random string to differentiate Pods

Status of Pods

Modifying a Deployment to Trigger a Rollout

Multiple ways to change a Deployment configuration

- Change the manifest file and apply it via *kubectl apply*
- Change specific Deployment attribute via *kubectl set*
- Edit the Deployment config in the cluster via *kubectl edit*
- **Any changes to the Pod template will trigger a rollout of the Deployment to create and replicate new Pods with the new template**
  - **This means any changes – even things like pod labels!**

Pausing a Deployment

Pause a Deployment to temporarily halt rollout of updated pods

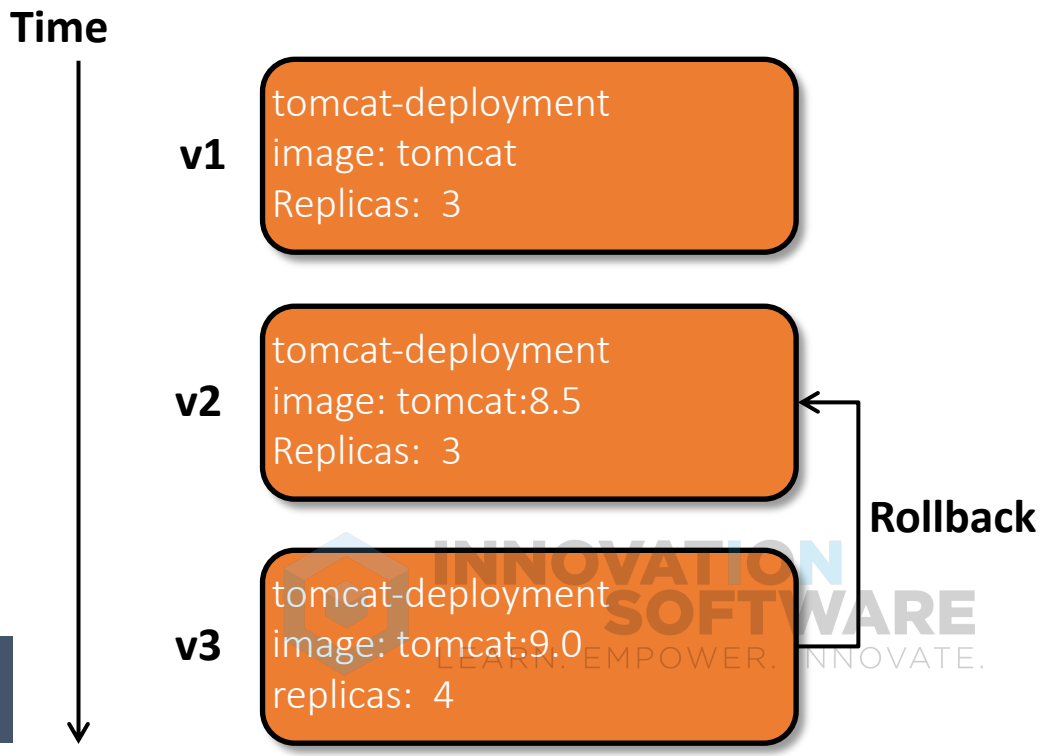
```
$ kubectl set image deployment/tomcat-deployment tomcat-container=tomcat:8.5.5;
kubectl rollout pause deployment/tomcat-deployment
deployment "tomcat-deployment" image updated
deployment "nginx-deployment" paused

$ kubectl rollout resume deployment/tomcat
deployment "tomcat-deployment" resumed

kubectl rollout status deployment/tomcat-deployment
deployment "tomcat-deployment" successfully rolled out
```

Checking Deployment Rollout History

Kubernetes tracks revisions made to a Deployment

- Users can query history of a deployment and see how many versions existed, and what change was made
  - Need to use *–record* flag on kubectl to record details of change commands
- History allows you to roll back state of a Deployment to a previous version

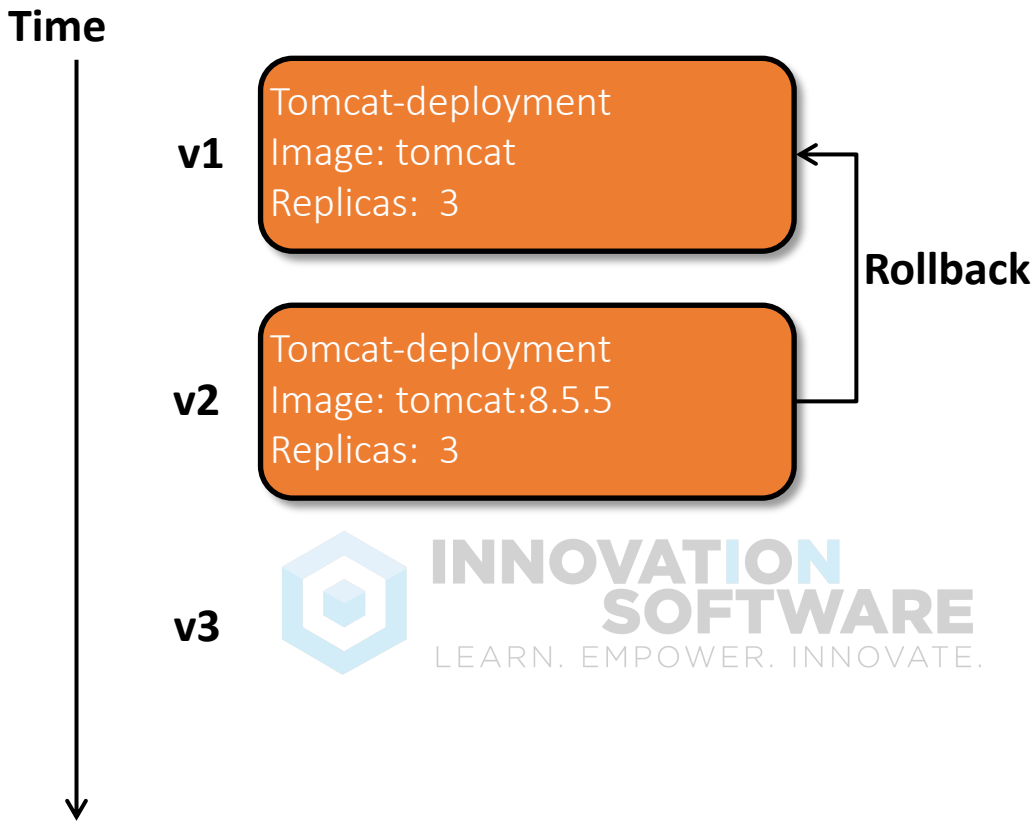
```
$ kubectl rollout history deploy/<deployment>
```



Rolling back a Deployment

Undoing Deployment changes via rollback operation

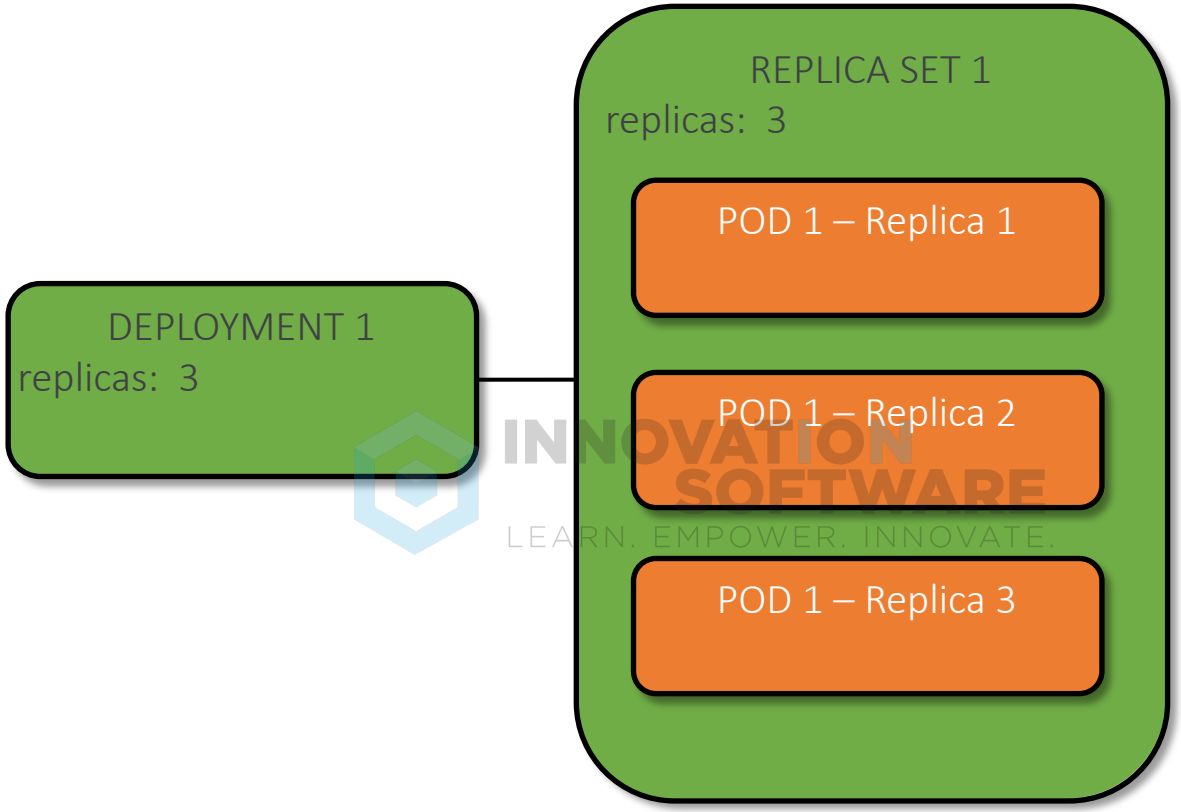
- You can undo the last change or roll back to a specific version
- The revision order will be changed to reflect the change
  - In this example, revision v1 will become the new revision v3
  - Version numbers increase monotonically
- Revision state stored in the corresponding Replica Sets



Deleting a Deployment

Deleting a Deployment will delete its Replica Set and all its Pods

- By default, when Deployment is deleted, its Replica Sets are deleted
- Deletion of Replica Set cascades to deletion of pods managed by the rs
- Any Replica Sets reflecting previous versions of the Deployment will also be deleted

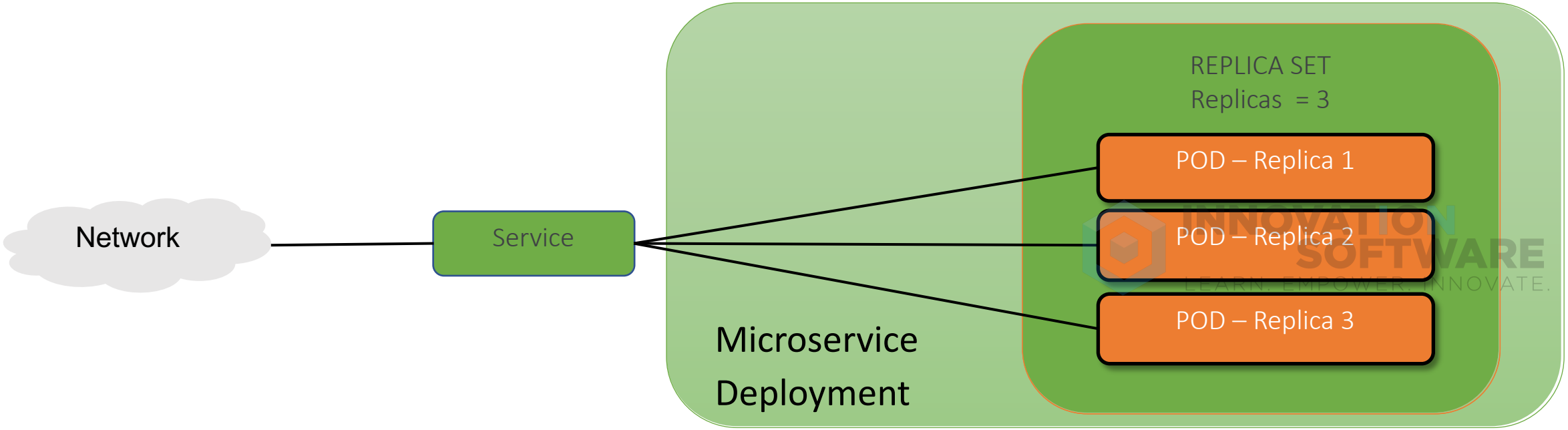


Scaling Deployments

Kubernetes Deployments for Microservices

Kubernetes is perfect for Microservices management

- Applications built as services or collections of microservices easily modeled using Kubernetes Deployment and Service resources
- Key property is that application or component can be scaled horizontally



Application Scaling Strategies

Several ways to achieve scalability

- **Pre-defined application scale**: application deployed with a predefined, static number of resources => not the Kubernetes way
- **Manual scaling**: deployment scale reconfiguration driven by operator
- **Auto-scaling**: automatic scaling of resources based on a defined trigger (number of hits, CPU usage, etc)

Application Scaling Strategies

Manual scaling

- K8s supports manual scaling of Deployment to adjust replica count
- Operator just needs to adjust declaration of how many replicas are desired, and K8s system will manage to that number
  - Pod creation and placement completely automatic
  - Pods automatically re-created if nodes fail

```
$ kubectl scale --replicas=2 deployment/tomcat

$ kubectl scale --replicas=8 deployment/tomcat

$ kubectl scale --replicas=4 deployment/tomcat
```

```
$ kubectl edit deployment/tomcat
```



```
$ kubectl apply –f simpledeployment.yaml
```

Application Scaling Strategies

Auto-scaling in Kubernetes

- Kubernetes has a controller object for automatic scaling of Deployments (or Replica Sets or ReplicationControllers)
- HorizontalPodAutoscaler is control loop to adjust scale of pod set depending on one or more metrics, evaluated at configurable interval (default 30s)
  - Requires Heapster to be deployed on the cluster to provide metric data
  - Metrics include CPU and RAM utilization for pods
- Typical scenario: increase Deployment replica count when average Pod CPU utilization is above threshold value for specified period of time
- Note: application must support horizontal scaling!

Automatic Scaling of a Deployment

Creating a HorizontalPodAutoscaler resource

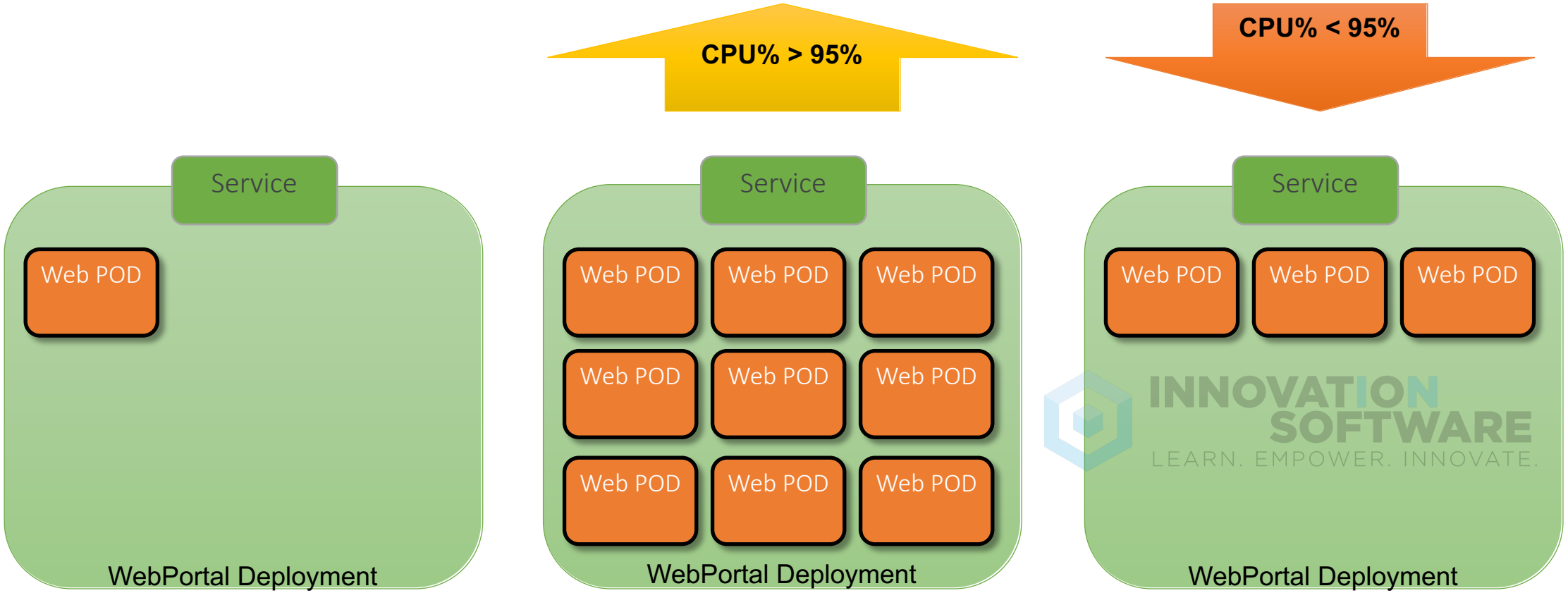
- The hpa is created similarly to any other Kubernetes resource
  - Use a manifest file for source tracking
  - Can create directly with *kubectl*
- 30 seconds is the default for considering the threshold
- Scaling is metrics-driven, either resource metrics from Heapster or custom metrics API

```
apiVersion: autoscaling/v1
kind: HorizontalPodAutoscaler
metadata:
  name: tomcat-autoscaler
spec:
  maxReplicas: 10
  minReplicas: 2
  scaleTargetRef:
    kind: Deployment
    name: tomcat-deployment
  targetCPUUtilizationPercentage: 75
```


simplescaler.yaml

Auto-Scaling of a Deployment

HorizontalPodAutoscaler with a 95% CPU usage threshold



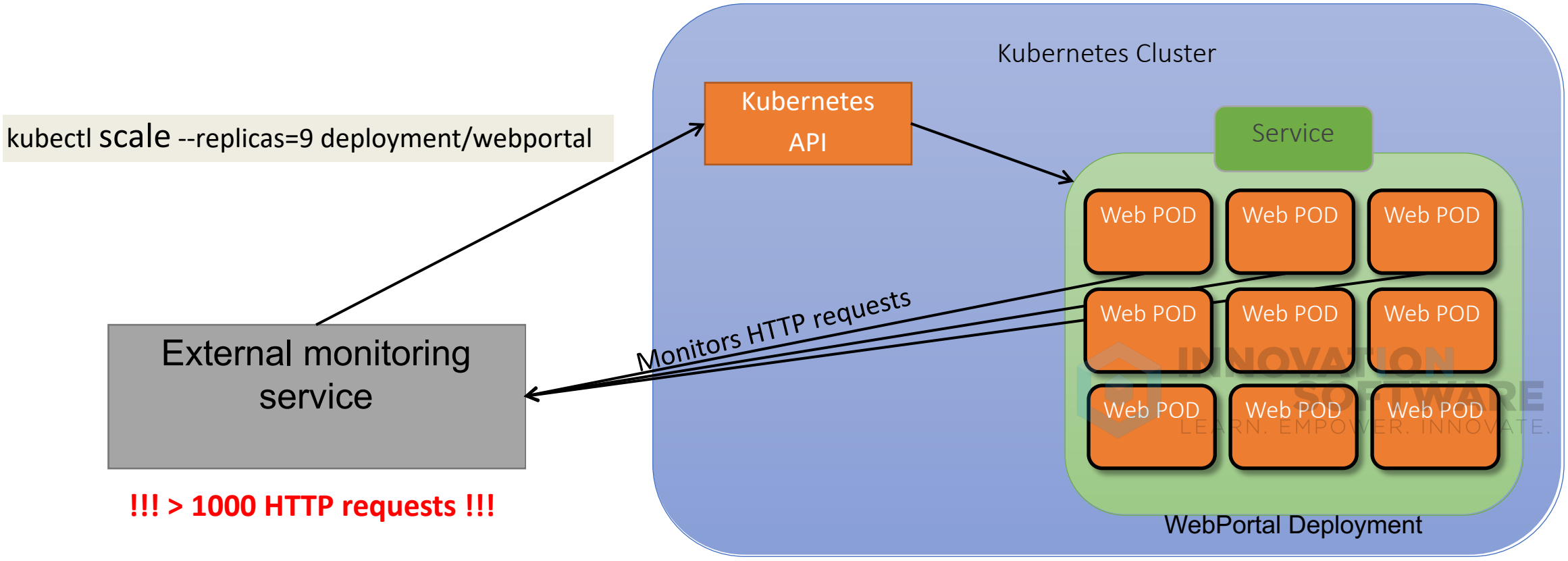
Application Scaling Strategies

Externally-driven auto-scaling

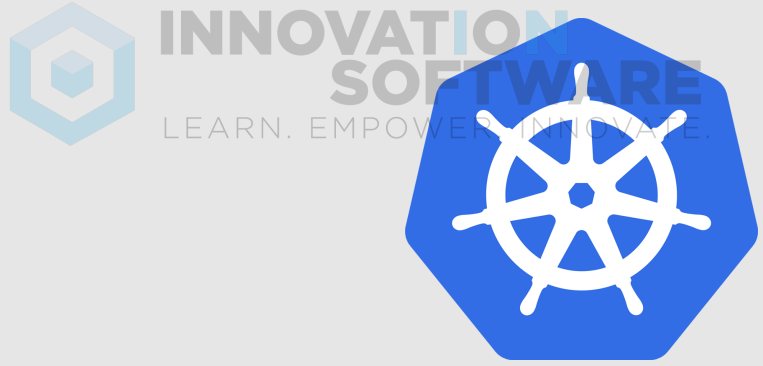
- Kubernetes API can be used to change Deployment replica counts remotely
- Any monitoring application that can send REST calls (e.g. Nagios) could be used to drive automatic scaling externally
- Very flexible approach, but more complex to implement
- **Needs robust testing before going into production**

Application Scaling Strategies

Auto-scaling driven by external system



Deployment Strategies Overview



What is a Deployment Strategy?

Approaches to manage risks on updating Deployments

- On each Deployment update/change, all pods in the deployment will be deleted and recreated
- Recreation process can have service impacts, especially for large Deployments
- A Deployment strategy defines how this rebuild process is done, to minimize downtime due to application failures or malfunctions

Types of Deployment Strategies

Kubernetes supports two basic strategies, but users can also leverage multiple Deployments when applying changes

- Strategies for single Deployments
  - Recreate
  - RollingUpdate
- Strategic approaches using two Deployments with a Service
  - Canary deployments
  - Blue/Green deployments

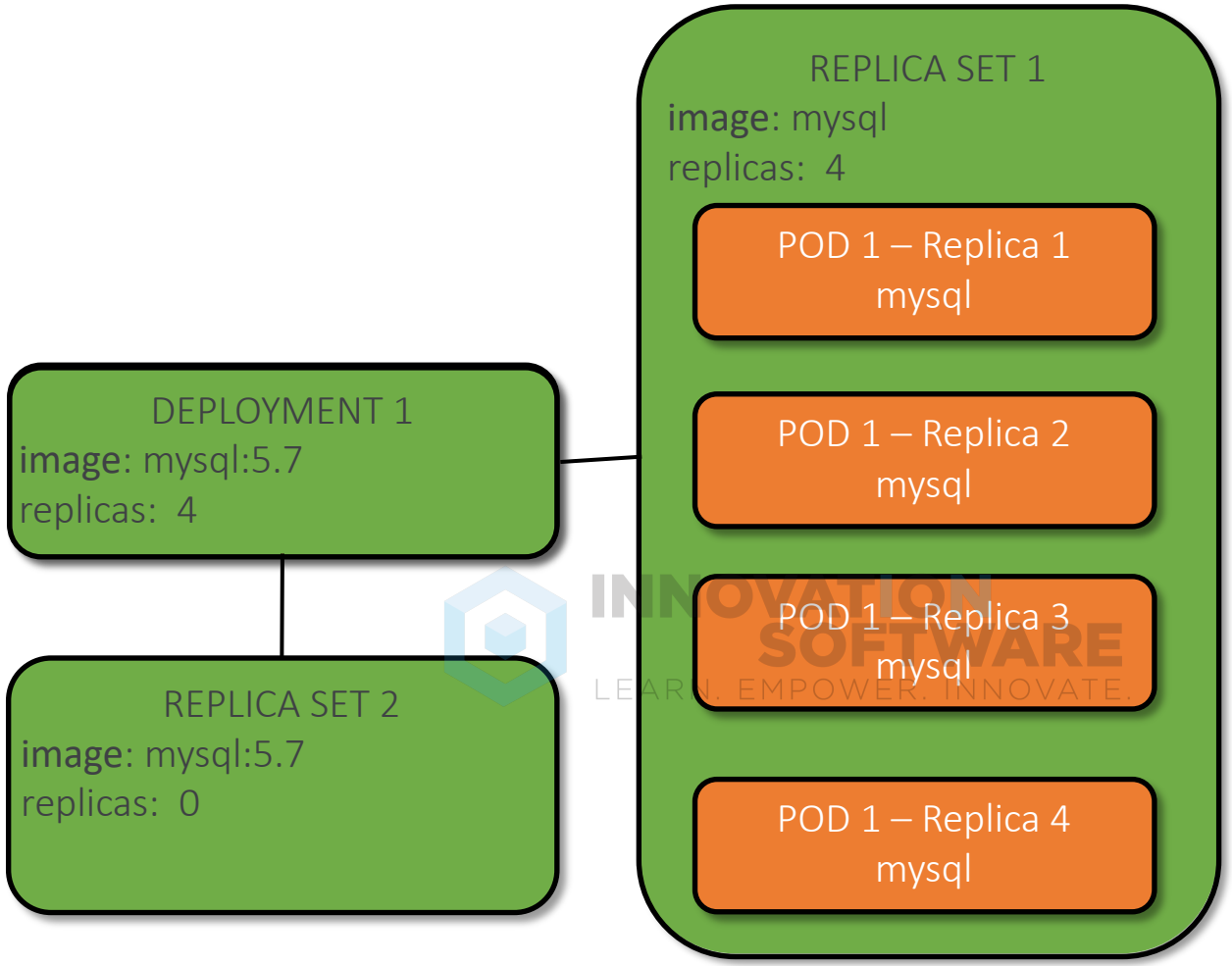
Each approach has a specific behavior and advantages/disadvantages.

Deployment Strategy: Recreate

Deployment Strategy: Recreate

Simplest strategy for deployments

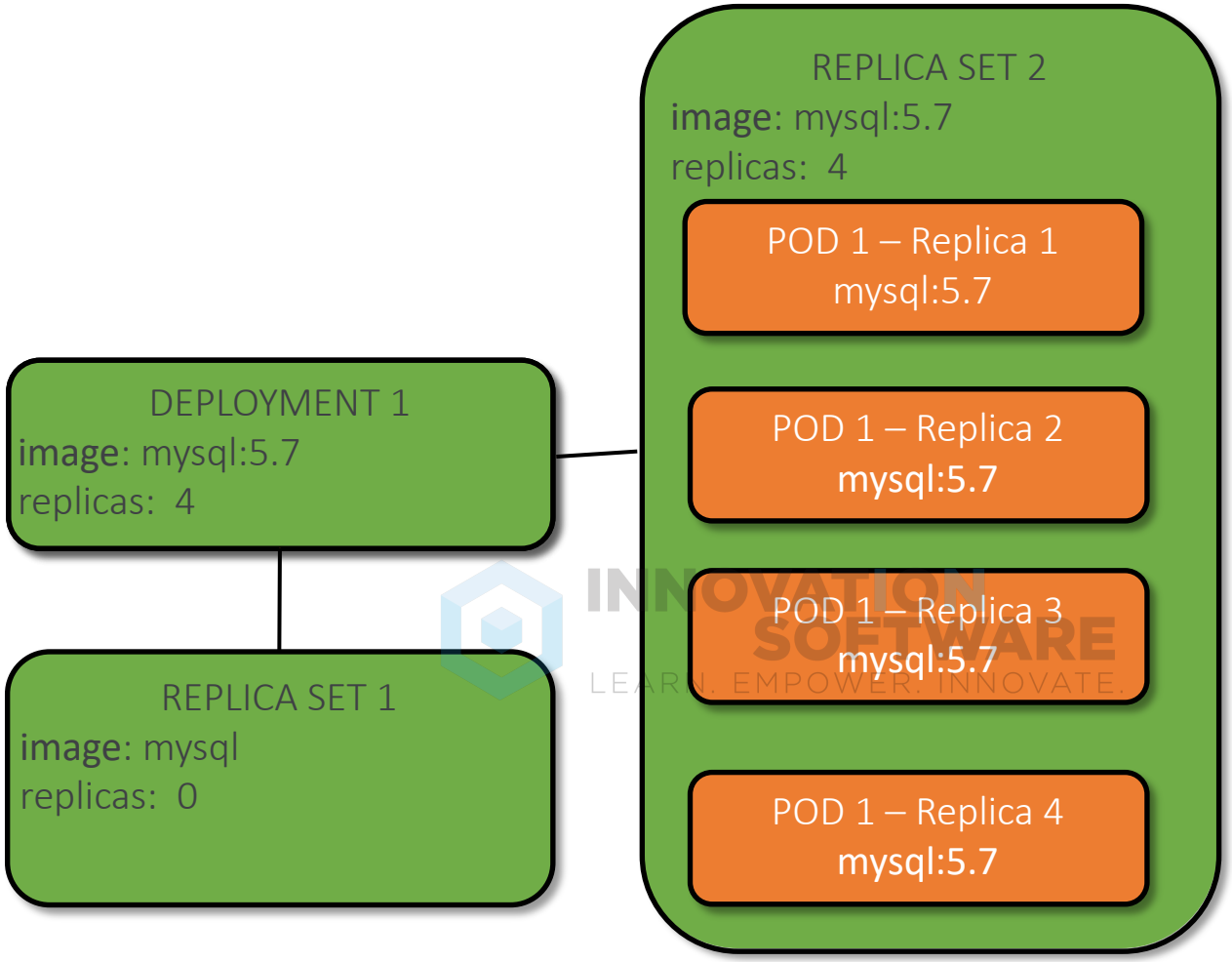
- When a change is made to a Deployment's spec, all Pods are removed and then recreated
  - Old Replica Set pods are killed
  - Then, new Replica Set starts pods
- May lead to downtime during the process while new pods are started



Deployment Strategy: Recreate

Simplest strategy for deployment updates

- When a change is made to a Deployment's template, all Pods are removed and then recreated
  - Old Replica Set pods are killed
  - New Replica Set starts pods
- May cause downtime due to delay between old pods terminating and new pods becoming available



Deployment Strategy: Recreate

Strategies are defined in the spec of a Deployment

- **strategy** parameter in Deployment spec sets the strategy to be used for updates
- If no parameter value is set, the default is **RollingUpdate**

```
apiVersion: extensions/v1beta1
kind: Deployment
metadata:
  name: tomcat-deployment
spec:
  replicas: 3
  strategy:
    type: Recreate
  template:
    metadata:
      labels:
        type: webserver
    spec:
      containers:
      - name: tomcat-container
        image: tomcat
        ports:
        - containerPort: 8080
```

Deployment Strategy: RollingUpdate

Deployment Strategy: RollingUpdate

RollingUpdate is DEFAULT strategy for Deployments

- When a change is made to the Deployment, the old Replica Set pods are scaled down as new pods are created by the new Replica Set
- A minimum number of running Pods is specified, so the Deployment will never be totally out of Pods to respond to service requests
- During the update process, the requested replica count may be temporarily exceeded

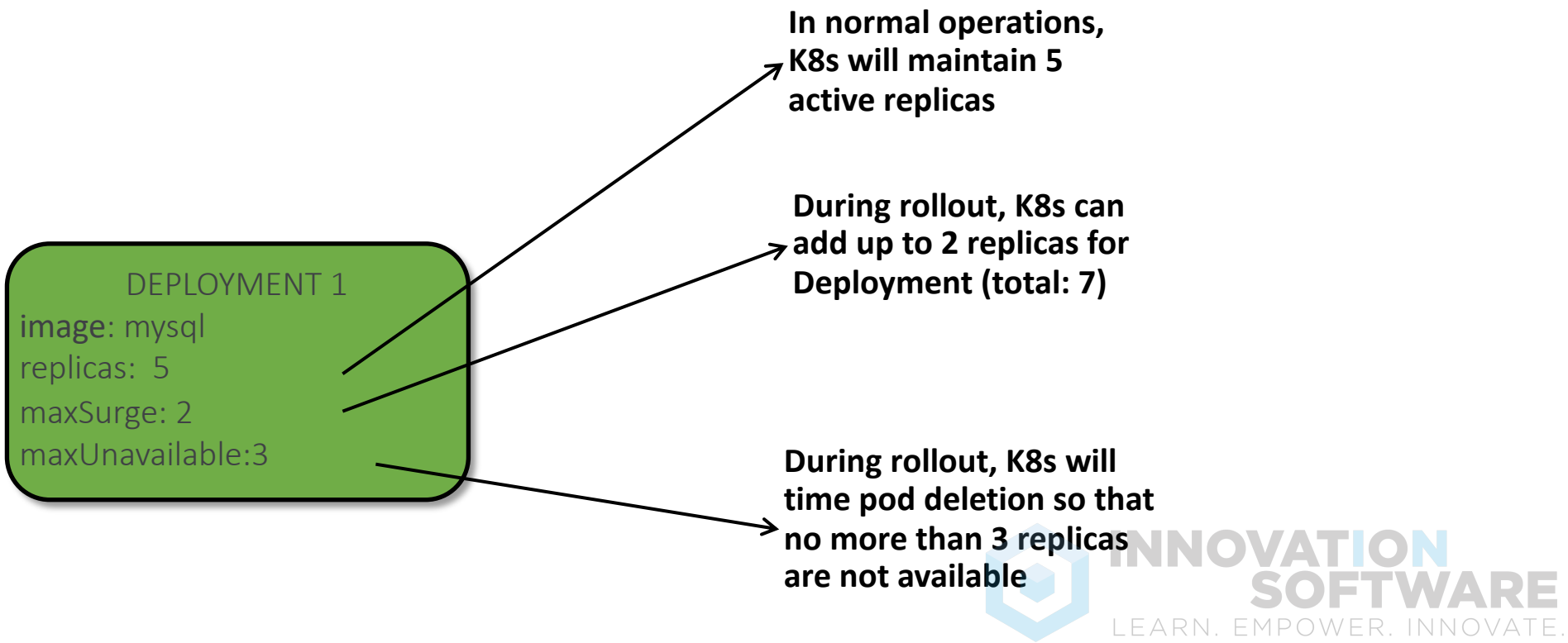
Deployment Strategy: RollingUpdate

Configure parameters to control the update process

```
...
metadata:
  name: tomcat-deployment
spec:
  replicas: 3
  strategy:
    type: RollingUpdate
    rollingUpdate:
      maxSurge: 25%
      maxUnavailable:10%
template:
    metadata:
      labels:
        type: webserver
...
```

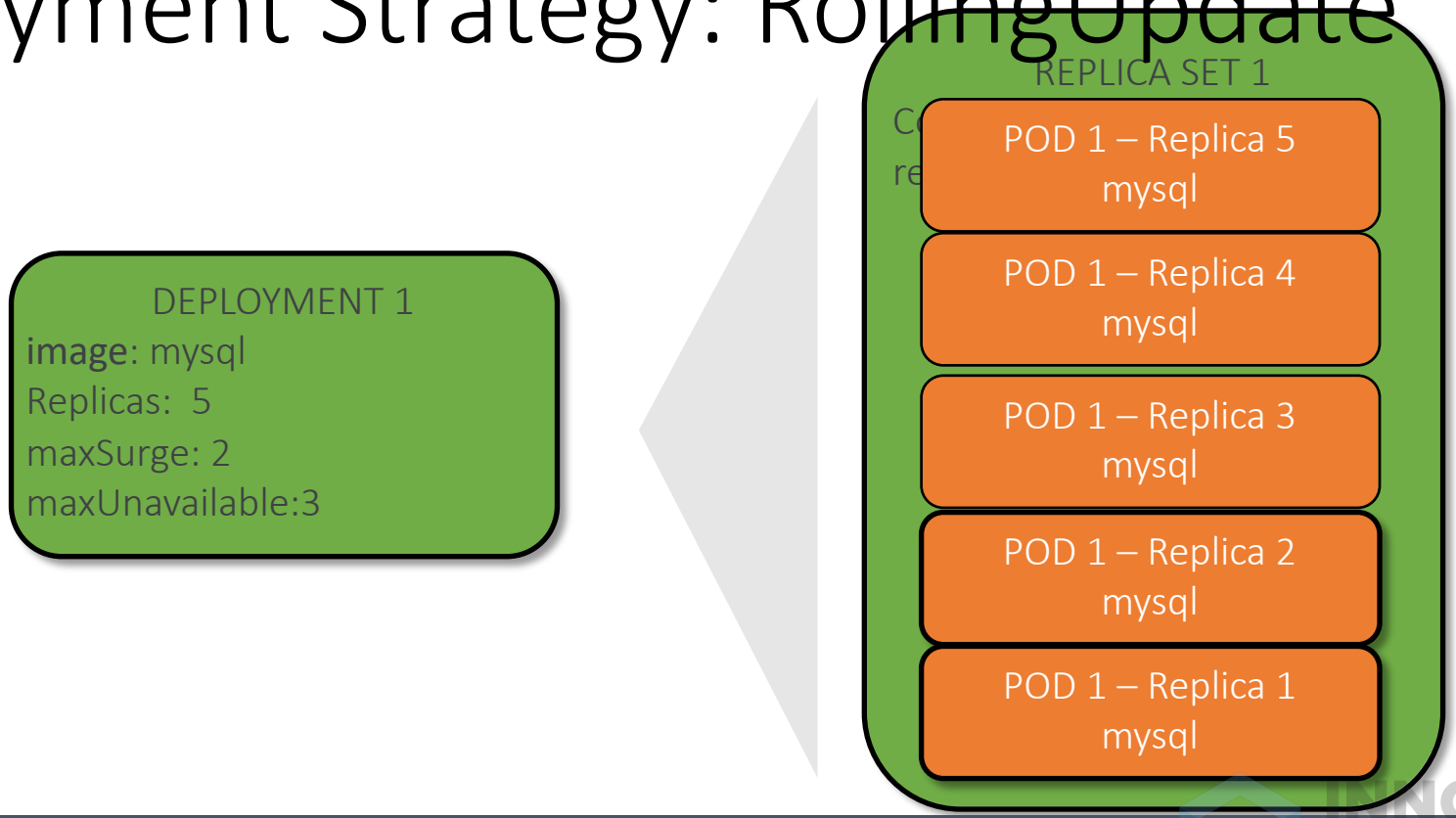
- **maxSurge**: number or percentage of additional Pods that can be created exceeding the replica count during update
  - Default value of 25%
- **maxUnavailable**: number of Pods that can be unavailable during the update
  - Default value of 25%

Deployment Strategy: RollingUpdate



Deployment Strategy: RollingUpdate

Initial State

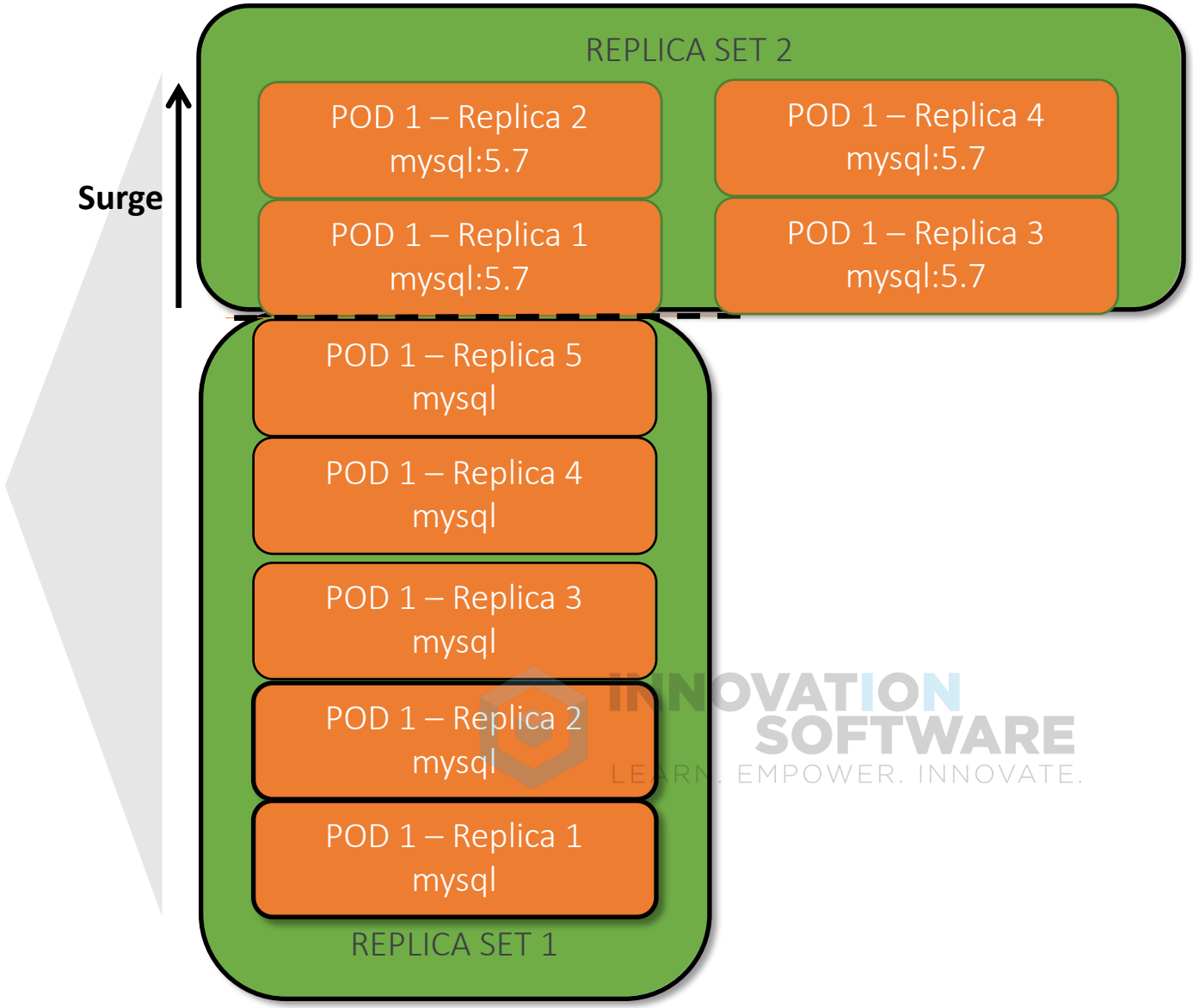



```
$ vi simpledeployment.yaml
...
    image: mysql:5.7
...
$ kubectl apply -f simpledeployment.yaml
```

Deployment Strategy: RollingUpdate

Rollout in progress

DEPLOYMENT 1
image: mysql:5.7
Replicas: 5
maxSurge: 2
maxUnavailable:3



- Initial surge of new pods on new Replica Set
- Original Replica Set scaled back as new RS scaled out

Deployment Strategy: RollingUpdate

Rollout complete

DEPLOYMENT 1
image: mysql:5.7
replicas: 5
maxSurge: 2
maxUnavailable:3

REPLICA SET 2
image: mysql:5.7
replicas: 5

- POD 1 – Replica 5 mysql:5.7
- POD 1 – Replica 4 mysql:5.7
- POD 1 – Replica 3 mysql:5.7
- POD 1 – Replica 2 mysql:5.7
- POD 1 – Replica 1 mysql:5.7

REPLICA SET 1
image: mysql
replicas: 0

- By default, old, inactive Replica Set saved – previous version of the Deployment

Updating Using Multiple Deployments

RollingUpdate using Multiple Deployments

Controlled testing of new versions in production

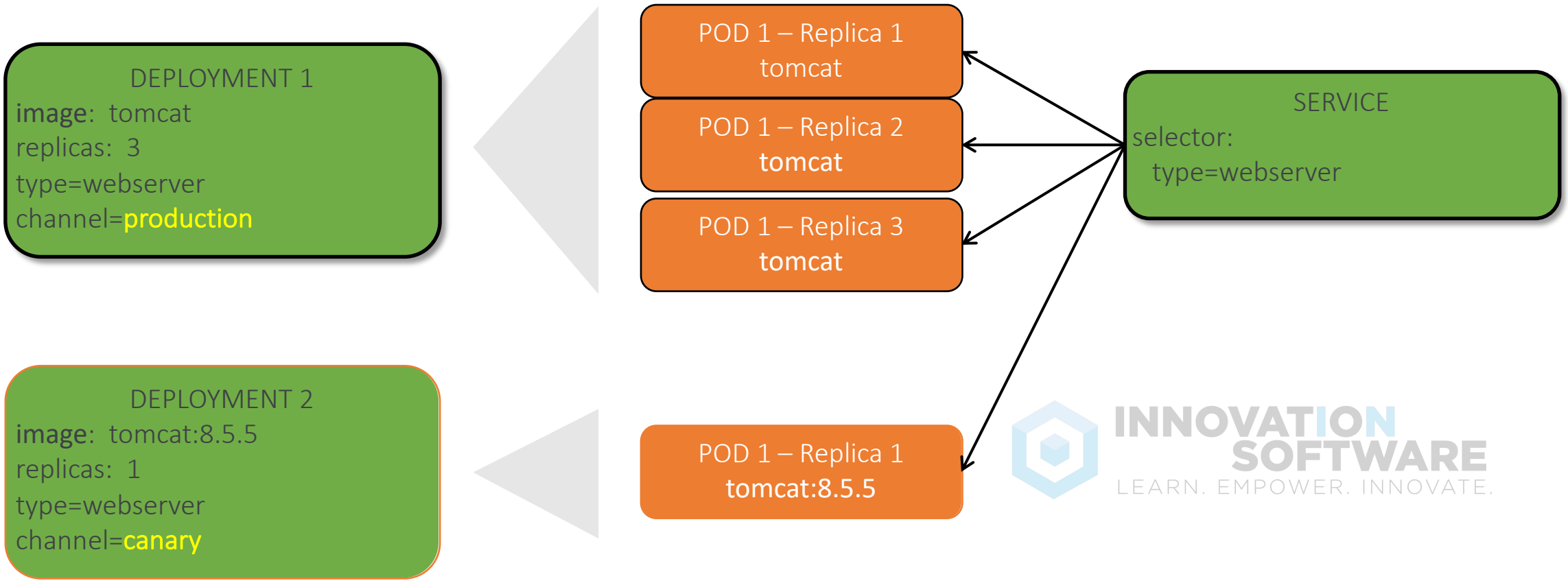
- Assume an application running as a Deployment, exposed as a Service
- To apply a new application version in production, a second Deployment can be used using labels in common with the first Deployment
  - Canary deployment allows for limited testing of new version in production
  - Blue/green deployment

Strategic Approach: Canary Deployment

Controlled testing of the update on production

- Consider a Service selecting pods from a Deployment of application pods
- In a canary deployment, a second Deployment (Canary Deployment) is created with pods for the new version, with labels matching the Service's selector
- Service directs some requests to pods on the Canary, allowing testing of changes in production
- If a malfunction is detected, it will only impact a small portion of the Pods and can be undone.

Strategic Approach: Canary Deployment



Strategic Approach: Canary Deployment

Decisions after running the canary Deployment in production

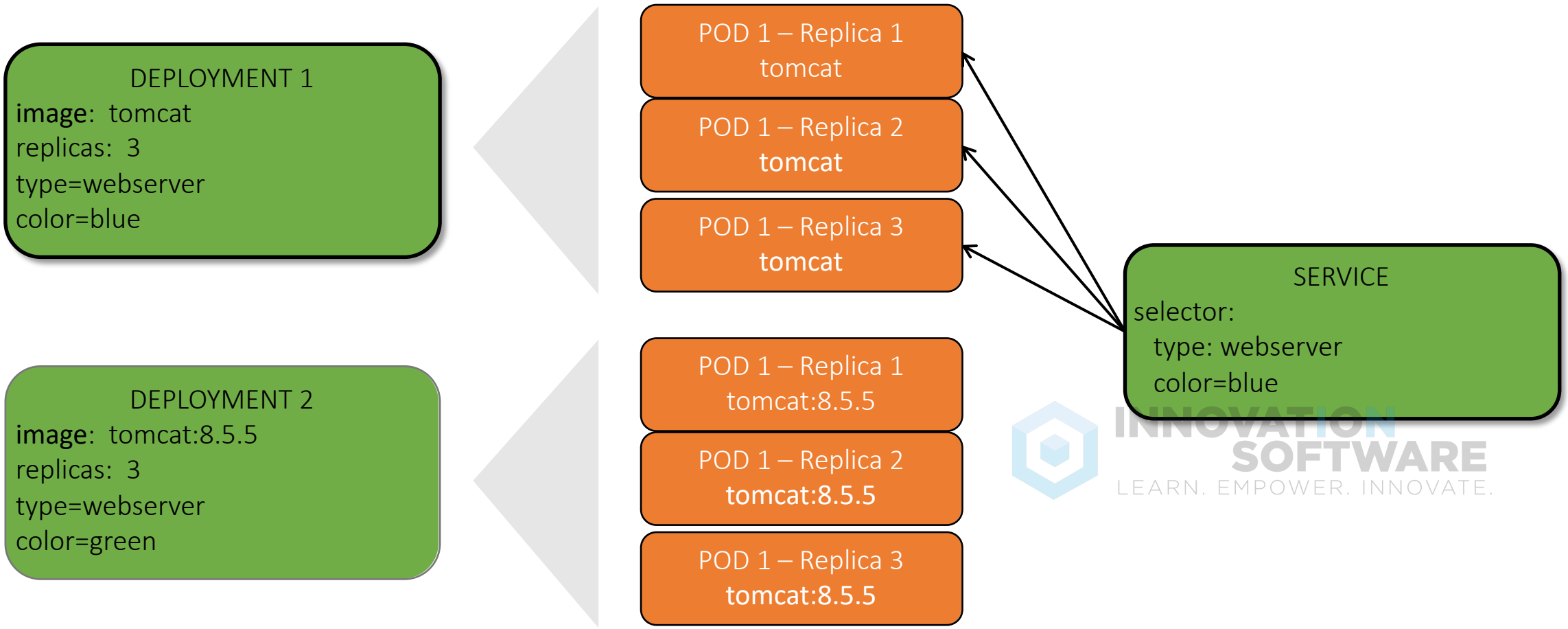
- If the application error rate is not increasing and Canary Deployment is stable:
  - The main Deployment can be updated to the newer version (using Rolling Update for example) and then the Canary can be discarded; OR
  - The Canary can be scaled up and reconfigured and the old Deployment can be discarded.
- If the test results in failure, the Canary deployment can be deleted

Strategic Approach: Blue/Green Deployment

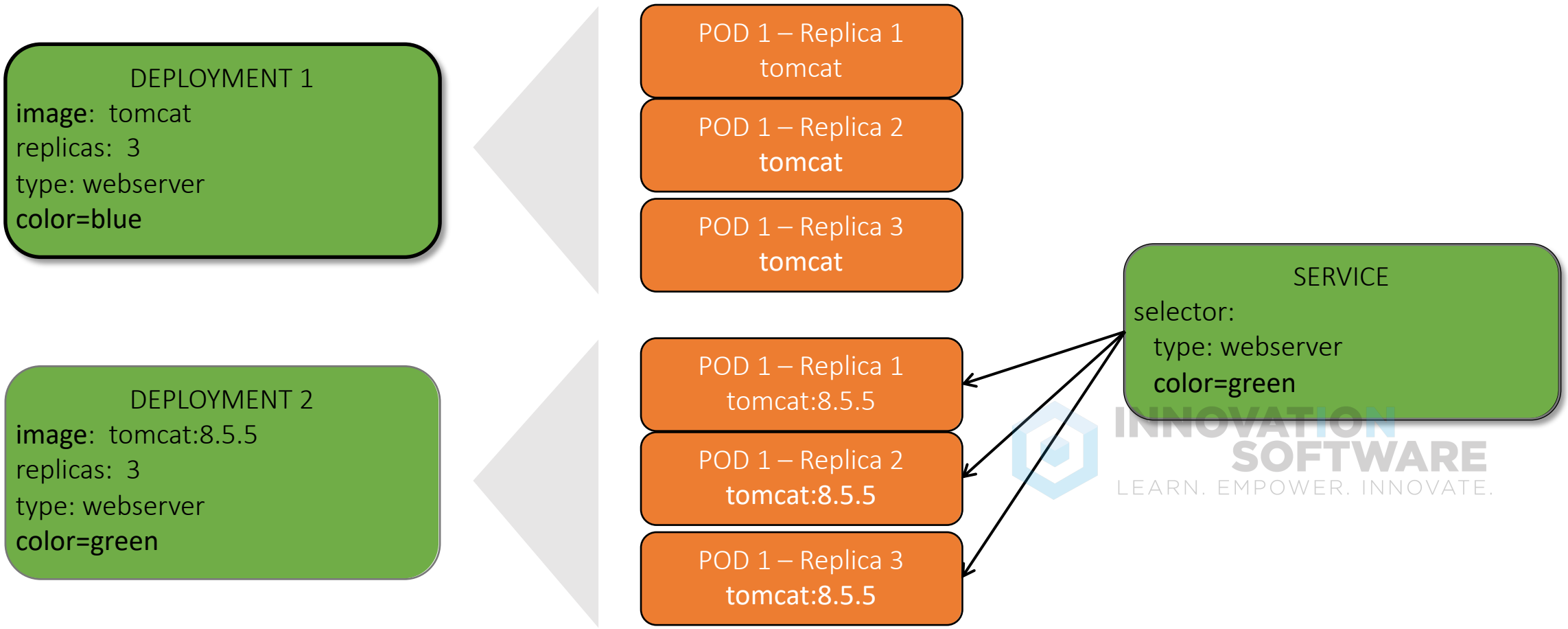
Complete environment switch from one version to another

- With a Blue/Green deployment, you create a new full-scale Deployment in addition to the current production Deployment
- Reconfiguring the pod label selector on the application's Service allows choice of directing requests to old Deployment or new Deployment
- Similar to effect of Replace strategy without application downtime

Strategic Approach: Blue/Green Deployment



Strategic Approach: Blue/Green Deployment



Kubernetes Services

Services

- Persistent way to access logical set of PODs
- Set of PODs (usually) determined by a Label Selector
- Kubernetes-native apps: Kubernetes offers a simple Endpoints API that is updated whenever the set of Pods in a Service changes.
- Non-native apps: Kubernetes offers a virtual-IP-based bridge to Services which redirects to the backend Pods.

Service Definition

```
kind: Service
apiVersion: v1
metadata:
    name: my-service
spec:
   selector:
     app: MyApp
   ports:
   - protocol: TCP
     port: 80
     targetPort: 9376
```


INNOVATION SOFTWARE
LEARN. EMPOWER. INNOVATE.

Types of Services

- ClusterIP
- NodePort
- LoadBalancer
- Headless

- Ingress is not a service

ClusterIP

- Virtual IP that every node can route to

NodePort

- Same port open on every node (default range: 30000-32767)

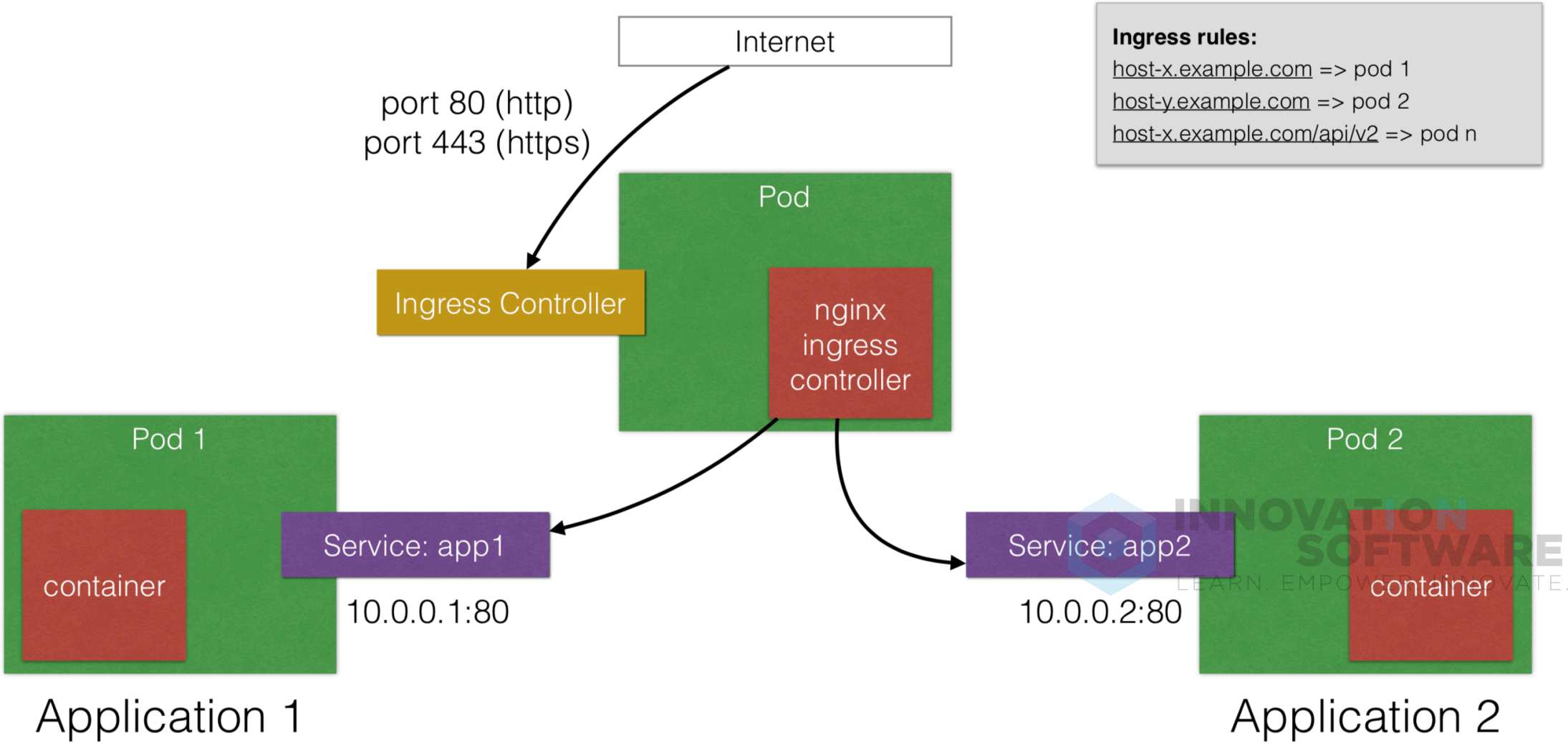
LoadBalancer

- External L4 network load balancer
- Requires cloud / IaaS coordination

Ingress

- L7 (instead of L4)
- HTTP (instead of tcp/udp)
- Ingress can route paths differently:
  - /api/app1 -> app1 pods
  - /api/app2 -> app2 pods
- Requires ingress provider (might be cloud, might be in-cluster)

Ingress


Internet
port 80 (http)
port 443 (https)
Ingress rules:
host-x.example.com => pod 1
host-y.example.com => pod 2
host-x.example.com/api/v2 => pod n
Pod
Ingress Controller
nginx ingress controller
Pod 1
container
Service: app1
10.0.0.1:80
Service: app2
10.0.0.2:80
Pod 2
container
Application 1
Application 2

Ingress Definition

```
apiVersion: extensions/v1beta1
kind: Ingress
metadata:
  name: helloworld-rules
spec:
  rules:
  - host: helloworld-v1.example.com
    http:
      paths:
      - path: /
        backend:
          serviceName: helloworld-v1
          servicePort: 80
  - host: helloworld-v2.example.com
    http:
      paths:
      - path: /
        backend:
          serviceName: helloworld-v2
          servicePort: 80
```

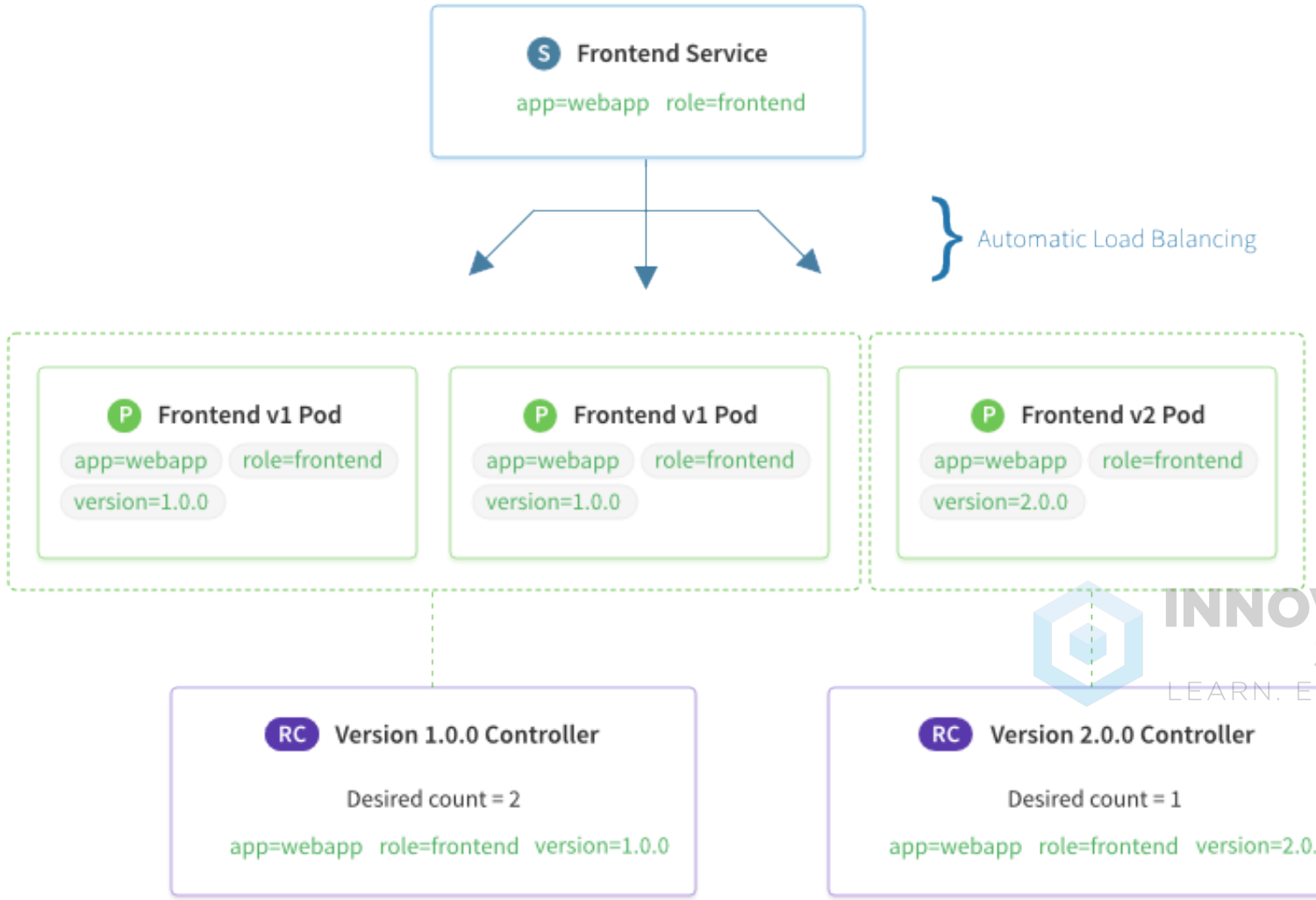
Services

my-service

app=MyApp

Port=80

targetPort=9276



Services

- Services can map incoming port to any targetPort
- By default the targetPort will be set to the same value as the port field.
- NOTE: targetPort can be a string, referring to the name of a port in the backend Pods.
- Services support TCP and UDP for protocols. The default is TCP.

Services mapping string

Deployment Specification

```
apiVersion: apps/v1beta2
kind: Deployment
metadata:
   name: nginx
spec:
   selector:
      matchLabels:
           app: nginx
   replicas: 3
   template:
      metadata:
           labels:
              app: nginx
      spec:
         containers:
         - name: nginx
           image: nginx
           ports:
           - containerPort: 8080
             name: http-web
             protocol: TCP
```

Services targetPort mapped to string

Service specification

```
kind: Service
apiVersion: v1
metadata:
    name: my-service
spec:
   selector:
      app: MyApp
   ports:
     name: http-web
     port: 80
   - protocol: TCP
     targetPort: http-web
```

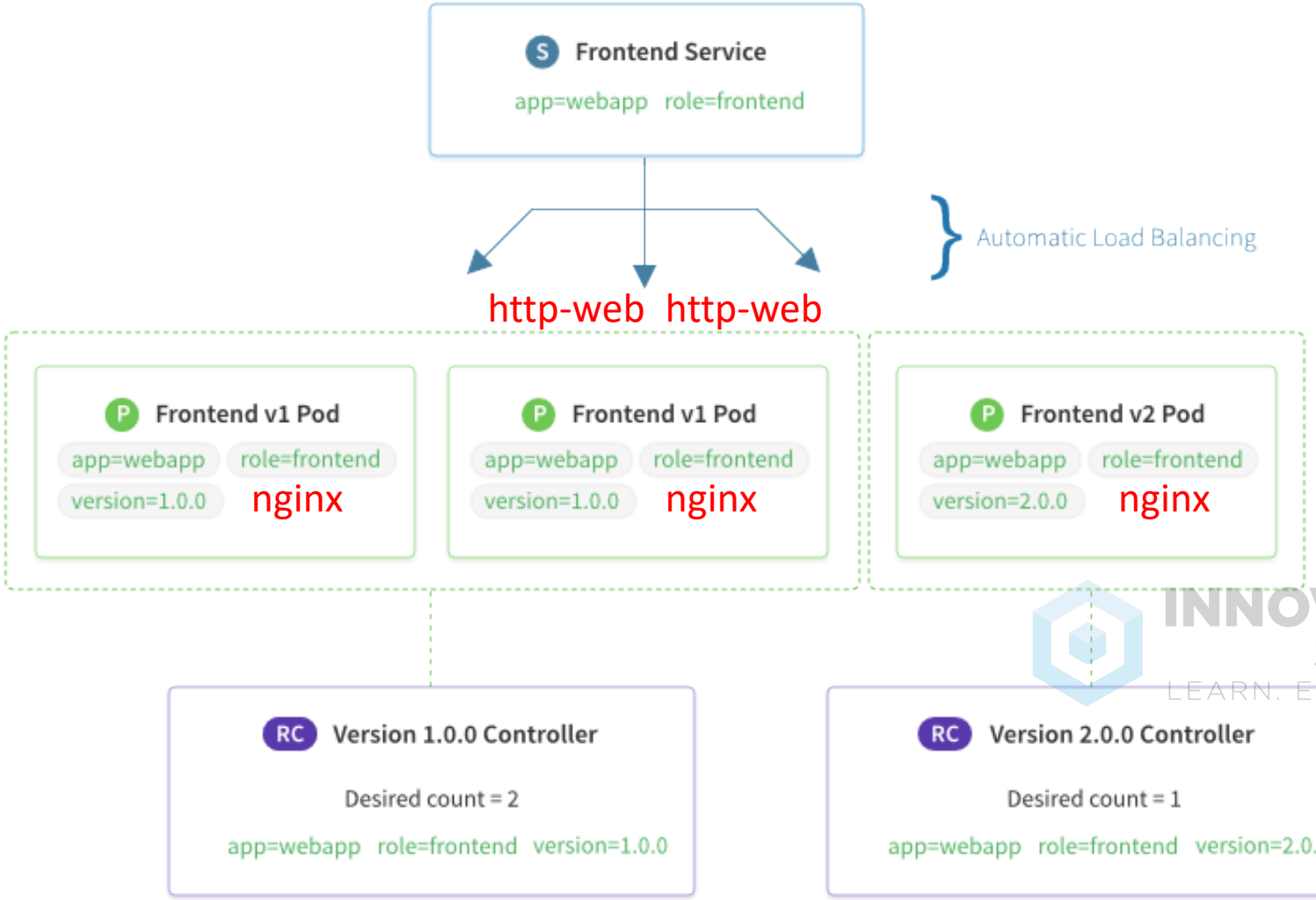
Services diagram mapping string

my-service

app=nginx

Port=80

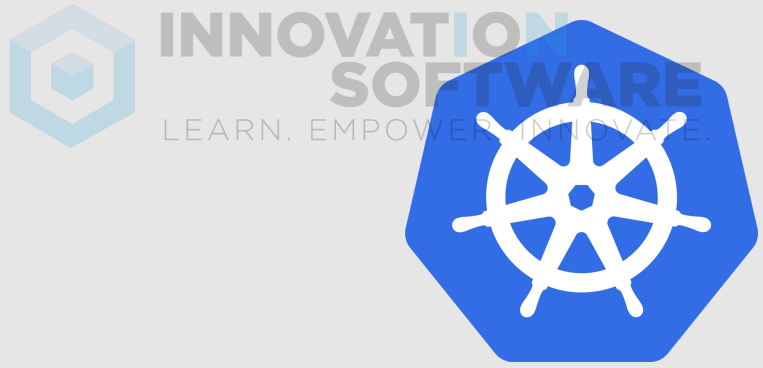
targetPort=http-web



Services without selectors

- Why would you want a Service that’s not mapped to a selector?
- Use an external database cluster in production, but in test you use your own databases.
- Point your service to a service in another namespace or on another cluster.
- Migrating your workload to Kubernetes and some of your backends run outside of Kubernetes
- More flexibility

Kubernetes DNS



Kubernetes DNS

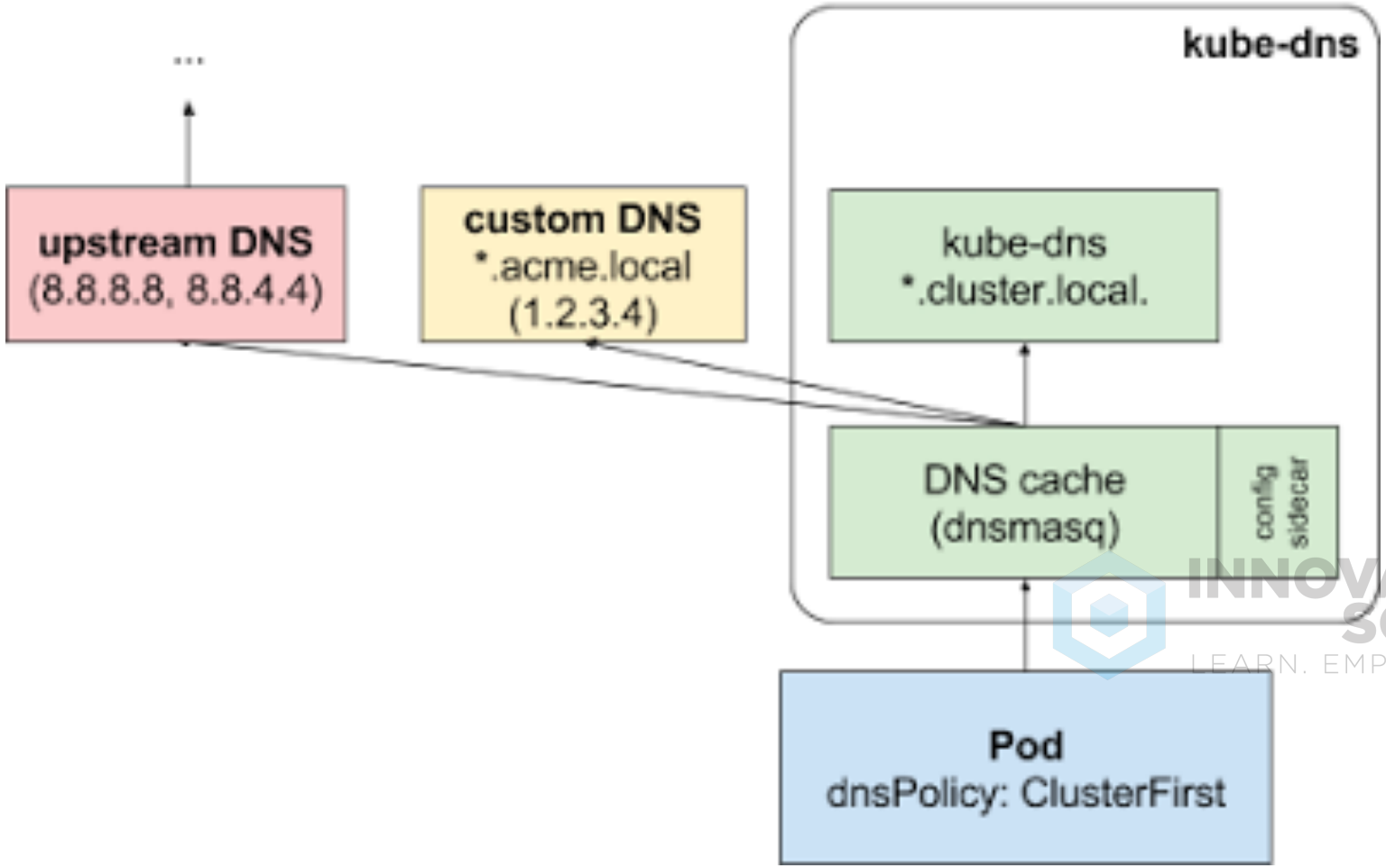
- Kubernetes Schedules a DNS POD, which sits in “Pending” until a network is created.
- Objects that have DNS names:
  - Everything
- DNS enables PODs in different namespaces to communicate easily

Kubernetes DNS

```
apiVersion: v1
kind: Service
metadata:
    name: default-subdomain
spec:
   selector:
      app: MyApp
ports:
   - name: http
     protocol: TCP
     port: 80
     targetPort: 9376
   - name: https
     protocol: TCP
     port: 443
     targetPort: 9377
```

```
apiVersion: v1
kind: Pod
metadata:
    name: busybox1
    labels:
      name: busybox
spec:
   hostname: busybox-1
   subdomain: default-subdomain
   containers:
   - image: busybox
     command:
       - sleep
       - “3600”
     name: busybox
```

Kubernetes DNS



Kubernetes DNS

- Use a ConfigMap to specify:
  - custom stub domains
  - upstream nameservers

```
apiVersion: v1
kind: ConfigMap
metadata:
     name: kube-dns
     namespace: kube-system
data:
    stubDomains: |
      {"acme.local": ["1.2.3.4"]}
    upstreamNameservers: |
      ["8.8.8.8", "8.8.4.4"]
```

Debugging DNS

- Simple POD to use for testing
  - YAML file to deploy busybox

```
apiVersion: v1
kind: Pod
metadata:
     name: busybox
     namespace: default
spec:
    containers:
    - name: busybox
      image: busybox
      command:
        - sleep
        - "3600"
      imagePullPolicy: IfNotPresent
    restartPolicy: Always
```

Debugging DNS

- Simple POD to use for testing
  - YAML file to deploy busybox

```
kubectl exec -ti busybox – nslookup kubernetes.default

Server:    10.96.0.10
Address 1: 10.96.0.10 kube-dns.kube-system.svc.cluster.local
Name:      kubernetes.default
Address 1: 10.96.0.1 kubernetes.default.svc.cluster.local
```

Debugging DNS

- If nslookup fails check local DNS config first!
- Check the resolv.conf

```
kubectl exec busybox cat /etc/resolv.conf

nameserver 10.96.0.10
search default.svc.cluster.local svc.cluster.local cluster.local ec2.internaloptions
ndots:5
```


INNOVATION SOFTWARE
LEARN. EMPOWER. INNOVATE.

Debugging DNS

- Problems with kube-dns add-on or associated Services:

```
kubectl exec –ti busybox – nslookup kubernetes.default

Server:        10.0.0.10
Address 1:   10.0.0.10
nslookup: can’t resolve ‘kubernetes.default’
```

Debugging DNS

- Check to make sure DNS pod is running
- Check for errors in kube-dns PODs logs

```
kubectl get pods -n kube-system –l k8s-app=kube-dns
NAME                        READY     STATUS    RESTARTS   AGE
kube-dns-6f4fd4bdf-pr659    3/3       Running   0          6d
```


INNOVATION SOFTWARE
LEARN. EMPOWER. INNOVATE.

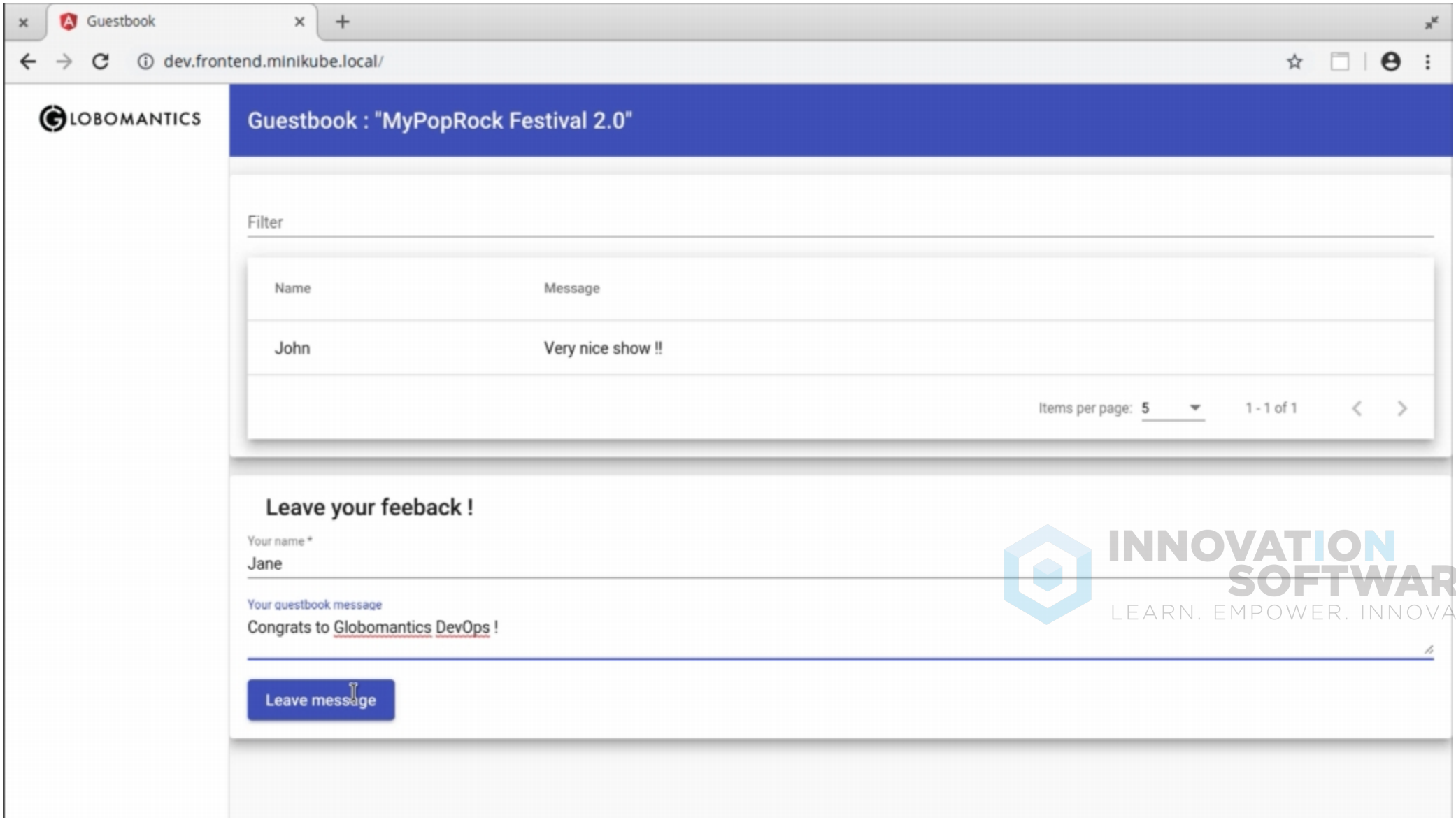
Service Discovery: Env Var

Service Discovery also possible via environment variable:

```
> kubectl run -it --restart=Never --rm busybox --image=busybox env
PATH=/usr/local/sbin:/usr/local/bin:/usr/sbin:/usr/bin:/sbin:/bin
HOSTNAME=busybox
TERM=xterm
SIMPLE_API_PORT_80_TCP_PROTO=tcp
NGINX_DEPLOYMENT_SERVICE_HOST=10.55.246.243
NGINX_DEPLOYMENT_PORT_80_TCP_PORT=80
NGINX_SERVICE_PORT=80
SIMPLE_API_PORT=tcp://10.55.241.109:80
KUBERNETES_PORT_443_TCP=tcp://10.55.240.1:443
NGINX_SERVICE_HOST=10.55.255.228
KUBERNETES_SERVICE_HOST=10.55.240.1
SIMPLE_API_PORT_80_TCP_PORT=80
NGINX_PORT=tcp://10.55.255.228:80
SIMPLE_API_SERVICE_PORT=80
NGINX_DEPLOYMENT_SERVICE_PORT=80
NGINX_DEPLOYMENT_PORT_80_TCP_PROTO=tcp
KUBERNETES_SERVICE_PORT=443
KUBERNETES_PORT_443_TCP_PROTO=tcp
NGINX_PORT_80_TCP=tcp://10.55.255.228:80
SIMPLE_API_PORT_80_TCP=tcp://10.55.241.109:80
KUBERNETES_PORT_443_TCP_PORT=443
SIMPLE_API_SERVICE_HOST=10.55.241.109
```

Helm: Package management

Helm sample application



Sample application components

- ✓ ConfigMap
- ✓ Pod
- ✓ Service
- ✓ Ingress

Frontend

- ✓ Secret
- ✓ Pod
- ✓ Service

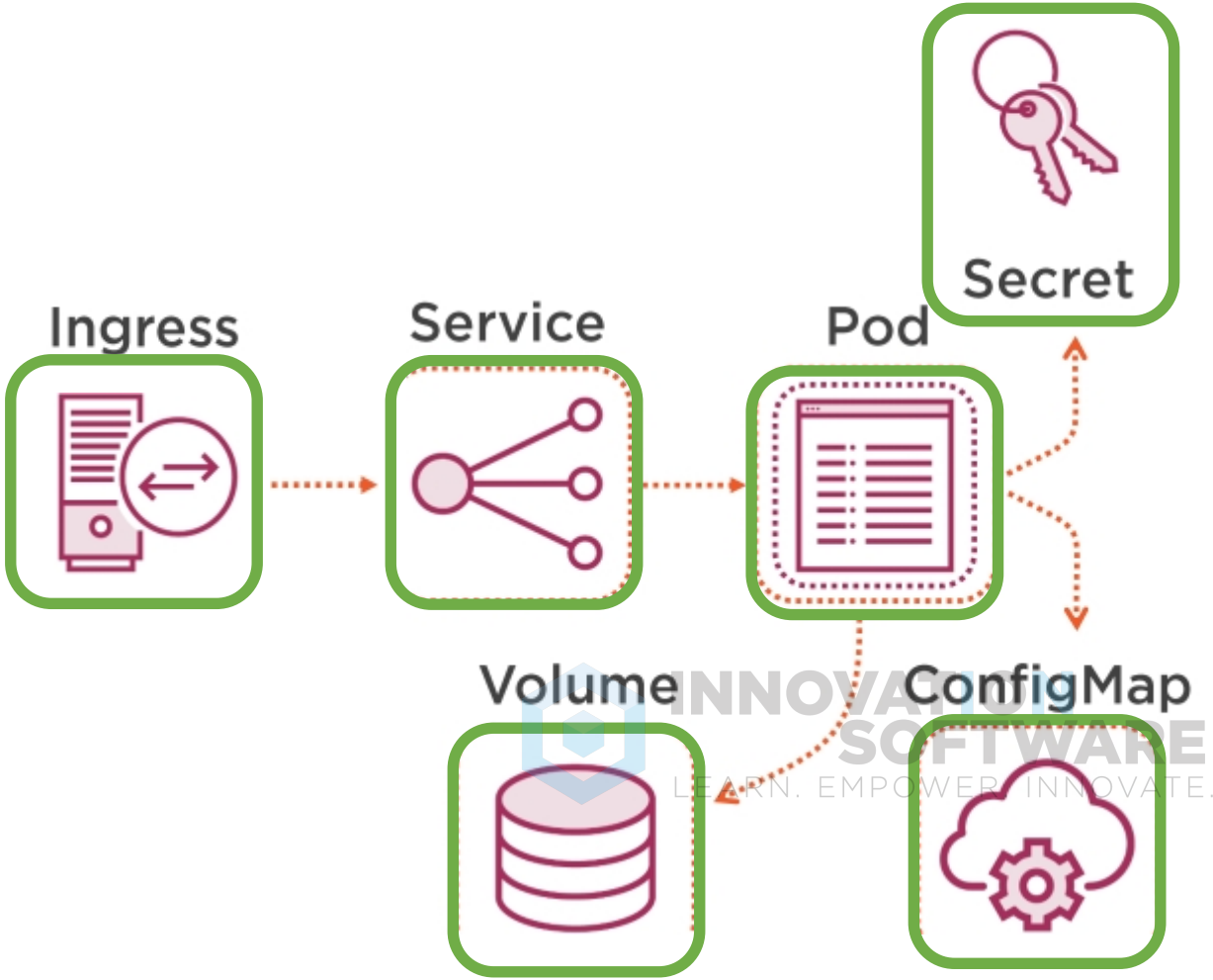
Backend API

- ✓ Secret
- ✓ PV
- ✓ PVC
- ✓ Pod
- ✓ Service

Database

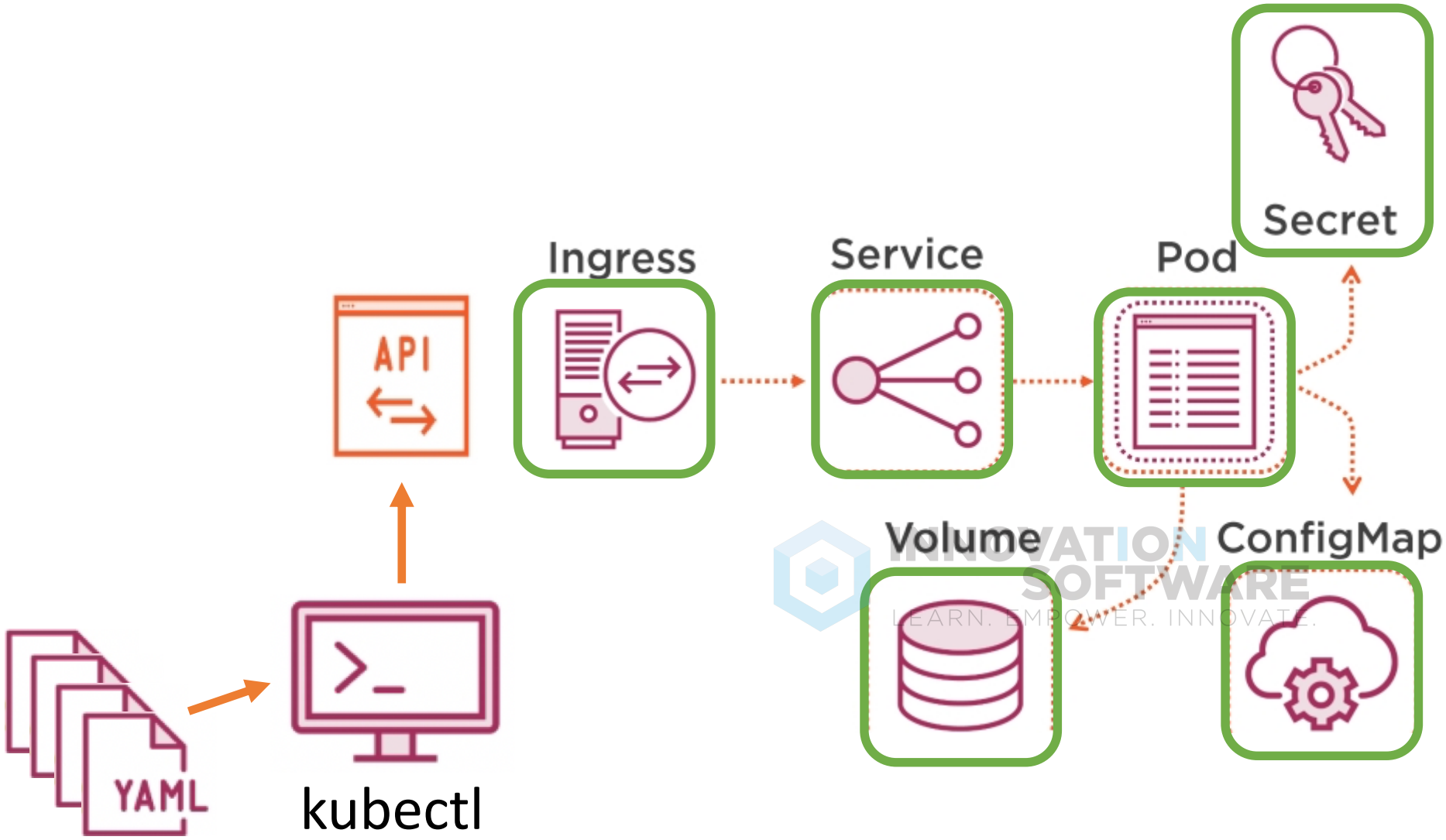
Native Kubernetes way

- Application
- Container
- Pod
- Service
- Ingress
- ConfigMap
- Secrets
- Volumes: PV, PVC, Storage



Native Kubernetes way

- Limitations
  - Packaging
  - Versioning



Guestbook: version 1

- ConfigMap
- Pod
- Service
- Ingress

Frontend

Guestbook: version 2

- ConfigMap
- Pod
- Service
- Ingress

- Secret
- Pod
- Service

- Secret
- PV
- PVC
- Pod
- Service

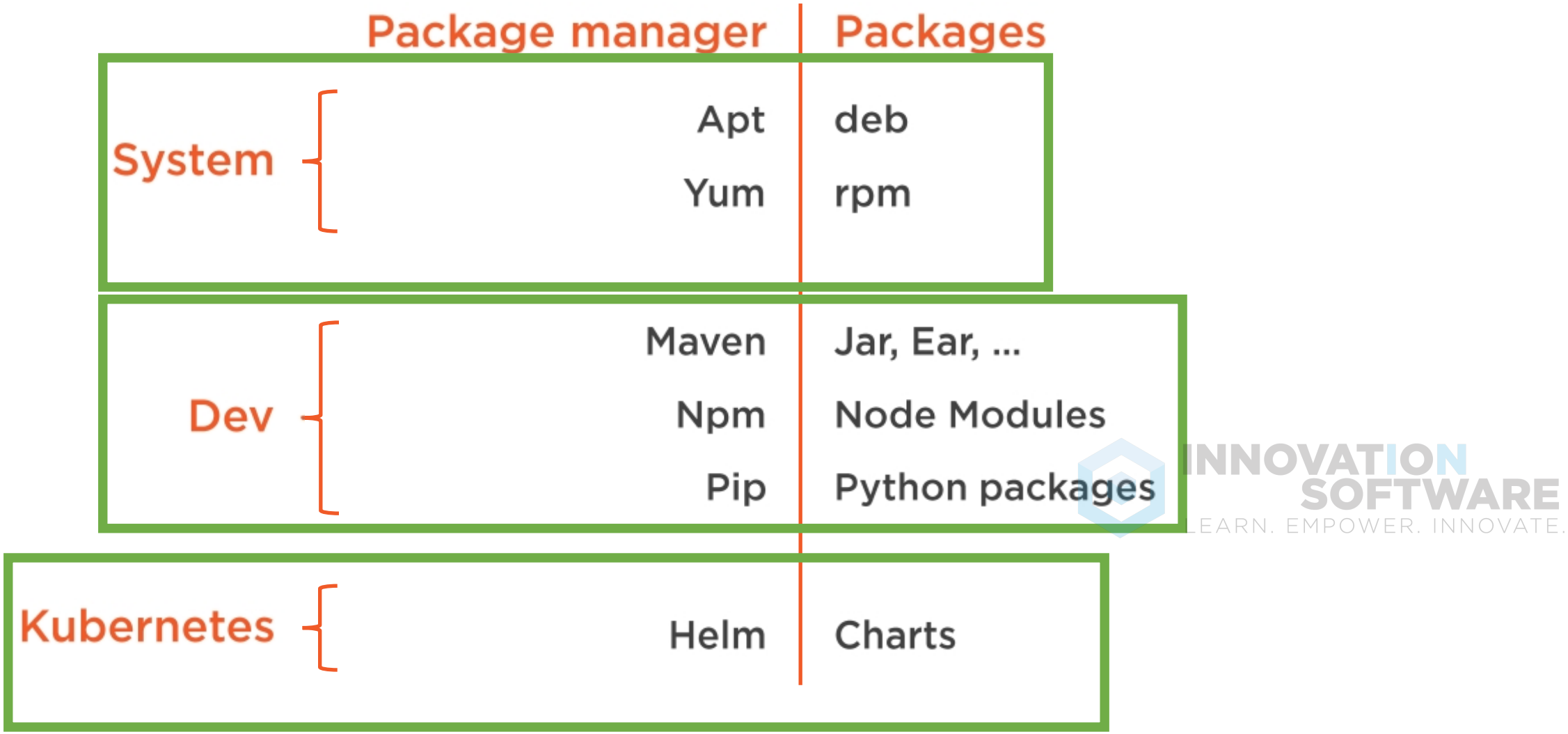
Frontend

Backend

Database

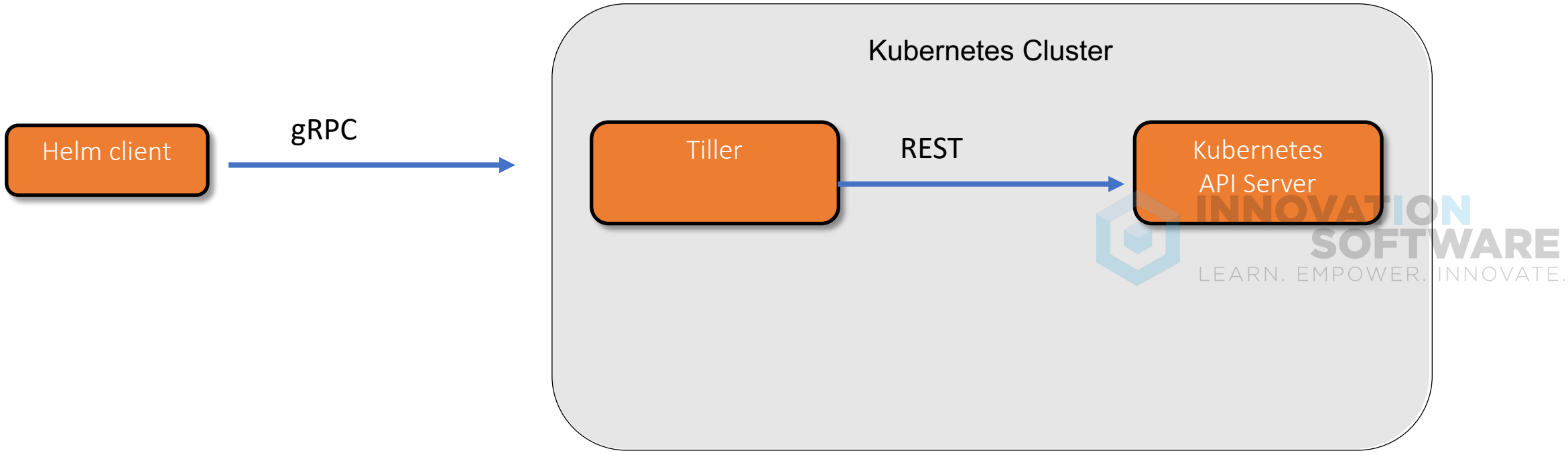
Painful to manage

Helm features



Helm architecture

- Helm client
  - command-line
  - Interacts with Tiller
  - Local chart development
- Tiller
  - In-cluster
  - Listens to Helm client
  - Interacts with Kube API
  - Manages lifecycle



Helm features

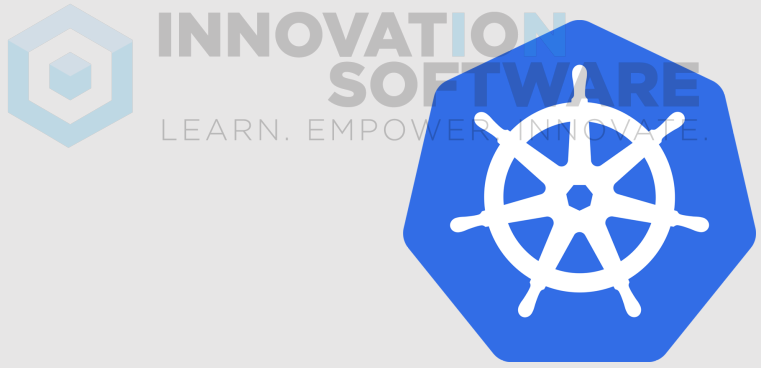
Charts

Templates

Dependencies

Repositories

Helm Chart Structure



Helm Chart structure

- nginx-demo
  - Chart.yaml

- Chart properties
  - name
  - version
  - more..

Helm Chart structure

- nginx-demo
  - Chart.yaml
  - README.md

- Document chart
  - Overrides
  - Maintainer
  - Instructions

Helm Chart structure

- nginx-demo
  - Chart.yaml
  - README.md
- templates
  - deployment.yaml
  - ingress.yaml
  - service.yaml

- Kubernetes object definitions
  - customizable YAML templates

Helm Chart structure

- nginx-demo
  - Chart.yaml
  - README.md
- templates
  - deployment.yaml
  - ingress.yaml
  - service.yaml
- values.yaml

- Kubernetes object definitions
  - customizable YAML templates
    - Provide default values.

Helm Chart structure

- nginx-demo
  - Chart.yaml
  - README.md
- templates
  - deployment.yaml
  - ingress.yaml
  - service.yaml
  - NOTES.txt
- values.yaml

- Provide helpful output after installation
  - How to access application
  - Create user/pass

Helm Chart structure

- nginx-demo
  - Chart.yaml
  - README.md
- templates
  - deployment.yaml
  - ingress.yaml
  - service.yaml
  - NOTES.txt
  - tests
    - test-connection.yaml
- values.yaml

- You can create tests to confirm Chart works as expected.

Helm Chart structure

- nginx-demo
  - Chart.yaml
  - README.md
  - requirements.yaml
- templates
  - deployment.yaml
  - ingress.yaml
  - service.yaml
  - NOTES.txt
  - tests
    - test-connection.yaml
- values.yaml

- Define sub-charts and dependencies

Helm Chart.yaml

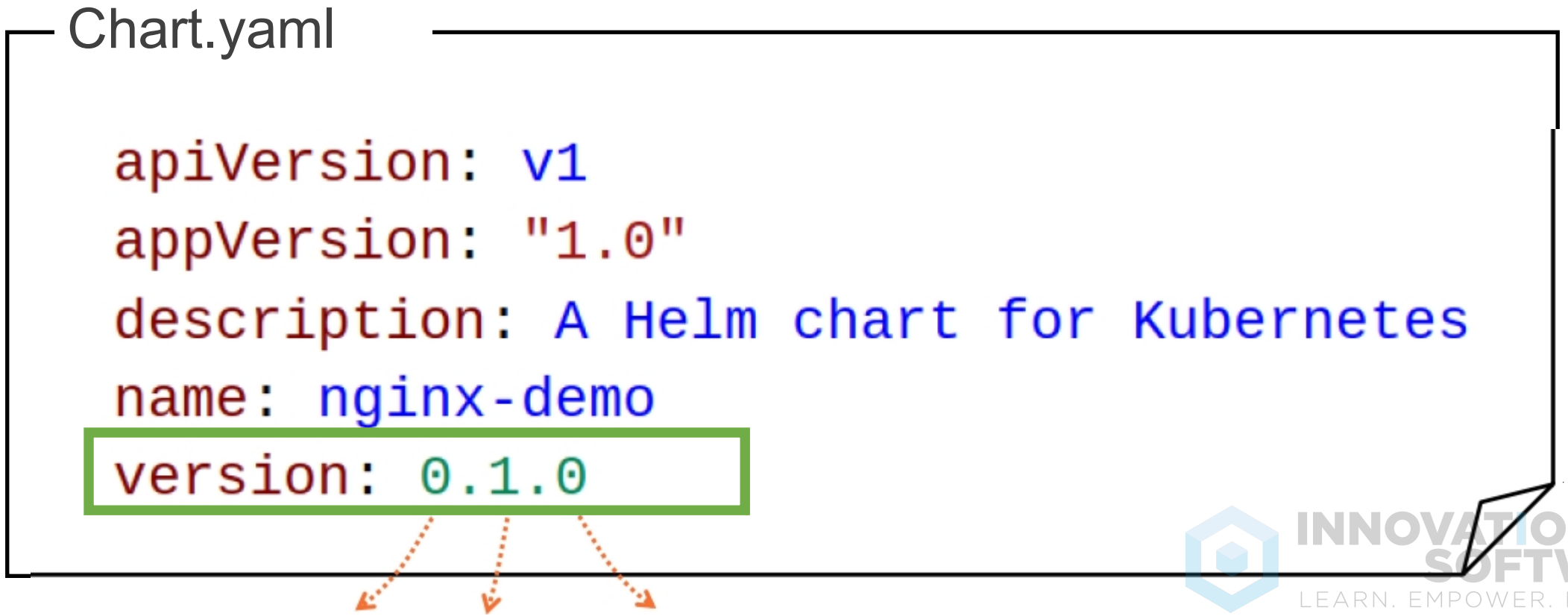
Chart.yaml

```yaml
apiVersion: v1
appVersion: "1.0"
description: A Helm chart for Kubernetes
name: nginx-demo
version: 0.1.0
```

Major,Minor,Patch (SemVer 2.0)

- App you are installing

Helm Chart.yaml



Major,Minor,Patch (SemVer 2.0)

- Version of Helm chart

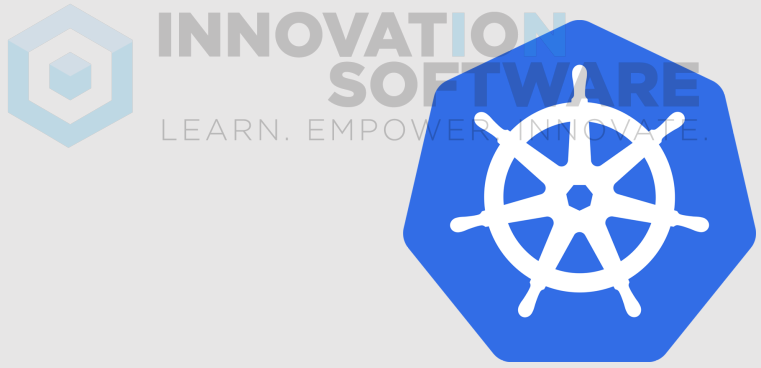
Common Helm commands

Action	Command
Install a Release	`helm install [chart]`
Upgrade a Release revision	`helm upgrade [release] [chart]`
Rollback to a Release revision	`helm rollback [release] [revision]`
Print Release history	`helm history [release]`
Display Release status	`helm status [release]`
Show details of a release	`helm get [release]`
Uninstall a Release	`helm delete [release]`
List Releases	`helm list`

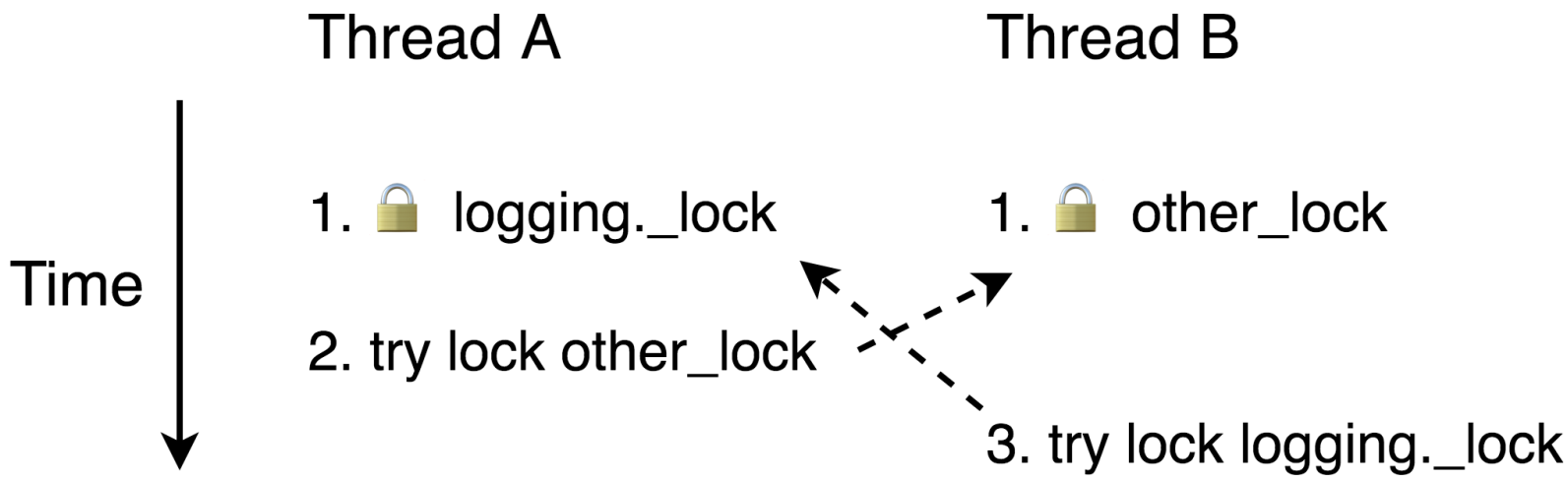
Deploy applications with Helm

- Install Helm
- Create Helm chart
- Deploy application
- Modify Chart
- Upgrade application
- Rollback application

Liveness & Readiness Probes



Health Checks: deadlock



Health Checks

- Simple process health checks are enabled by default.
- Kubelet checks to see if container is responding and if not recreates it.

Go deadlock example code

```
lockOne := sync.Mutex{}
lockTwo := sync.Mutex{}
go func() {
    lockOne.Lock();
    lockTwo.Lock();
    ...
}()
lockTwo.Lock();
lockOne.Lock();
```

Health Checks

Kubernetes provides 3 types of application health checks

- HTTP: Kubelet calls a web hook and looks for return status between 200 and 399 for success.
- Container Exec: Kubelet will execute a command inside your container, exit status=0 is a success
- TCP Socket: Kubelet will attempt to open a socket to your container. If it establishes a connection, the container is considered healthy

In all cases, if the Kubelet discovers a failure the container is restarted.

Health Checks

Kubernetes refers to it’s application health checks as:

- Liveness Probe: Check to confirm application is running as expected
- Readiness Probe: Check to confirm application has completed startup configuration

Health Checks

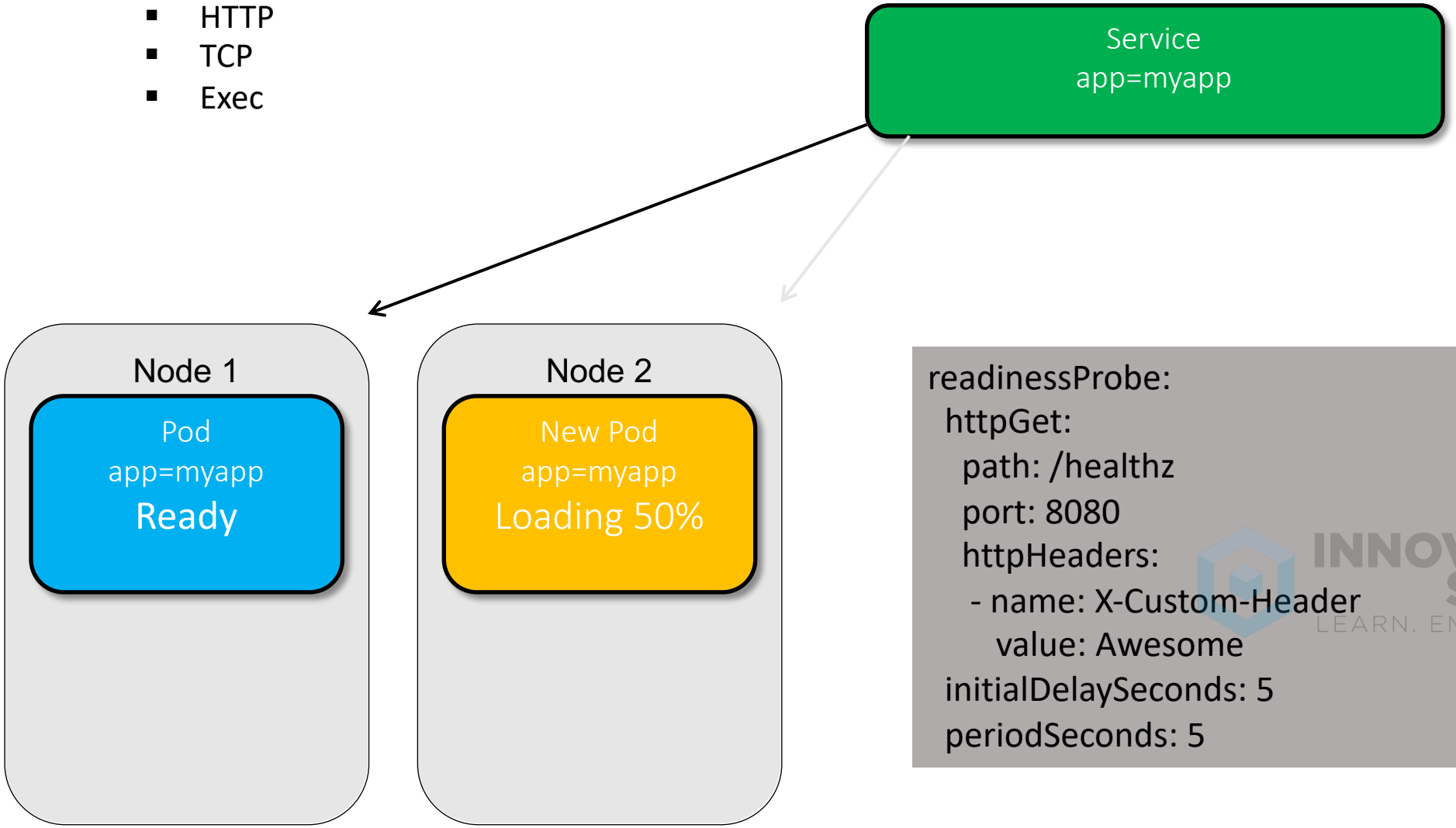
- Execute command to check if application is responding
- Set delay in seconds
  - How long before performing first check
- Set period in seconds.
  - How often it should run

livenessProbe example

```
livenessProbe:
  exec:
    command:
     - cat
     - /tmp/healthy
  initialDelaySeconds: 5
  periodSeconds: 5
```

Health Checks: livenessProbe

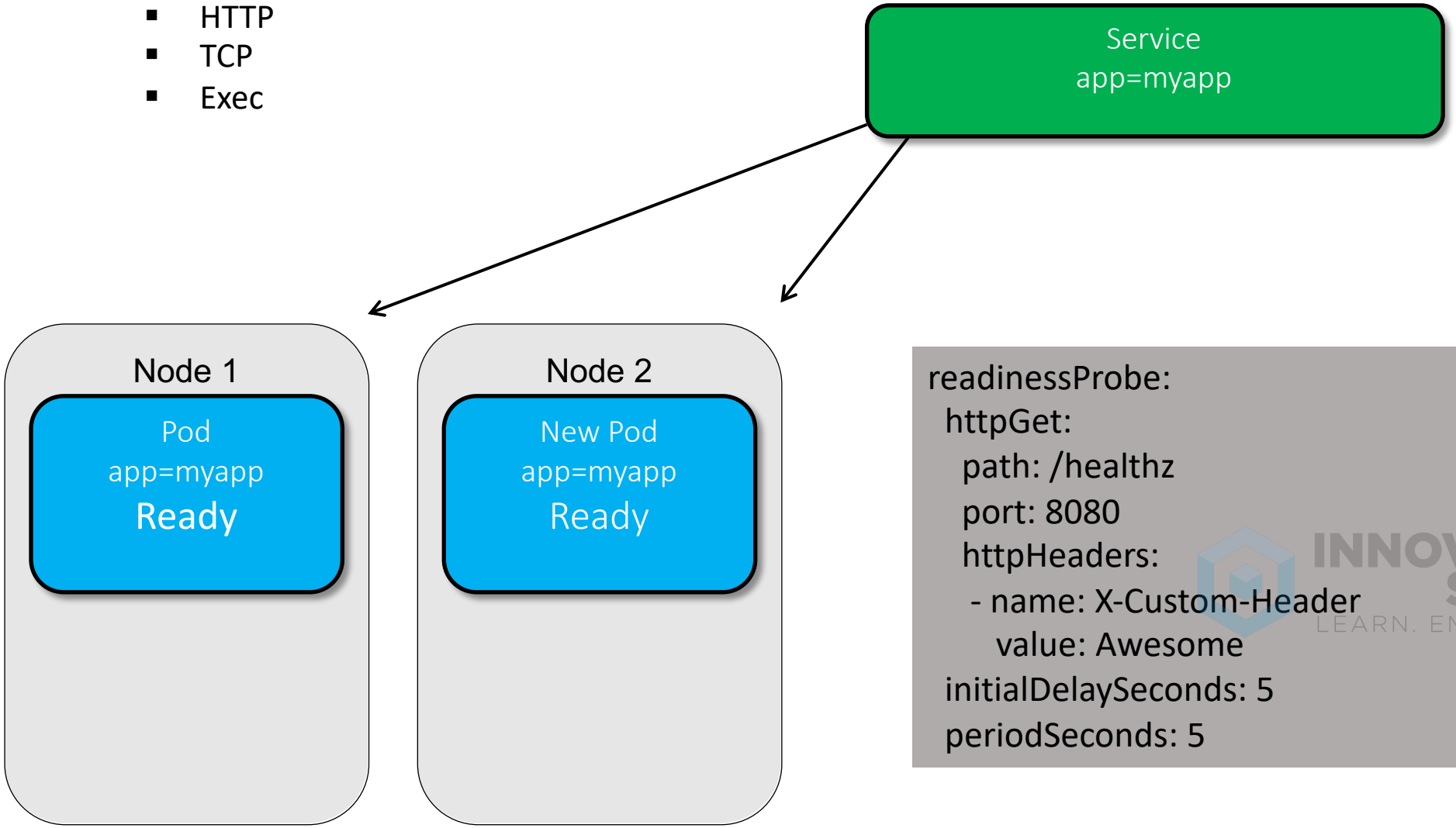
- Do not send traffic to Pod until passes.
  - HTTP
  - TCP
  - Exec




```
readinessProbe:
  httpGet:
    path: /healthz
    port: 8080
    httpHeaders:
     - name: X-Custom-Header
       value: Awesome
  initialDelaySeconds: 5
  periodSeconds: 5
```

Health Checks: livenessProbe

- Do not send traffic to Pod until passes.
  - HTTP
  - TCP
  - Exec




```
readinessProbe:
  httpGet:
    path: /healthz
    port: 8080
    httpHeaders:
     - name: X-Custom-Header
       value: Awesome
  initialDelaySeconds: 5
  periodSeconds: 5
```

Health Checks

- Same as livenessProbe but traffic won't be sent to it if probe fails.

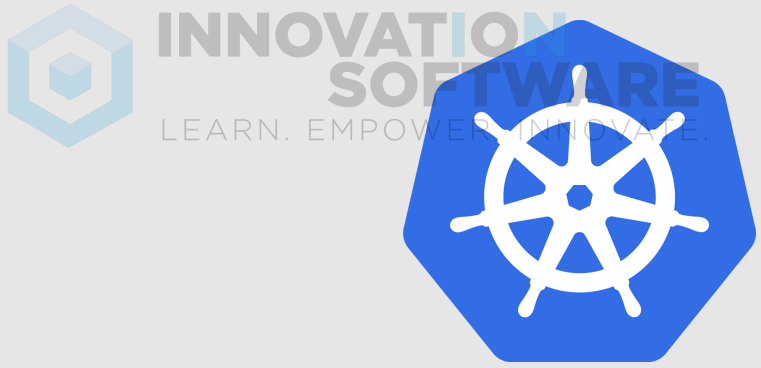
readinessProbe example

```
readinessProbe:
  httpGet:
    path: /healthz
    port: 8080
    httpHeaders:
     - name: X-Custom-Header
       value: Awesome
  initialDelaySeconds: 5
  periodSeconds: 5
```

Health Check Lab

- Create POD with liveness check
- Verify check is working as expected
- Create POD with HTTP liveness check
- Confirm HTTP liveness probes are working correctly
- Create deployment with liveness and readiness probe
- Confirm checks are working

Role Based Access Controls



RBAC

- Considered stable in Kubernetes 1.8 and later
- To enable start apiserver with
  - --authorization-mode=RBAC
  - This allows for more fine-grained control of access permissions

RBAC Roles

- Role used to grant access to resources in a single namespace

```
kind: Role
apiVersion: rbac.authorization.k8s.io/v1
metadata:
  namespace: default
  name: pod-reader
rules:
-   apiGroups: [""] # "" indicates the core API group
    resources: ["pods"]
    verbs: ["get", "watch", "list"]
```

RBAC ClusterRole

- ClusterRole used to grant access to resources that are cluster specific, not namespace specific

```
kind: ClusterRole
apiVersion: rbac.authorization.k8s.io/v1
metadata:
  # "namespace" omitted since ClusterRoles are not namespaced
  name: secret-reader
rules:
- apiGroups: [""]
  resources: ["secrets"]
  verbs: ["get", "watch", "list"]
```

RBAC RoleBinding

- Grant permissions defined in a role to user or set of users

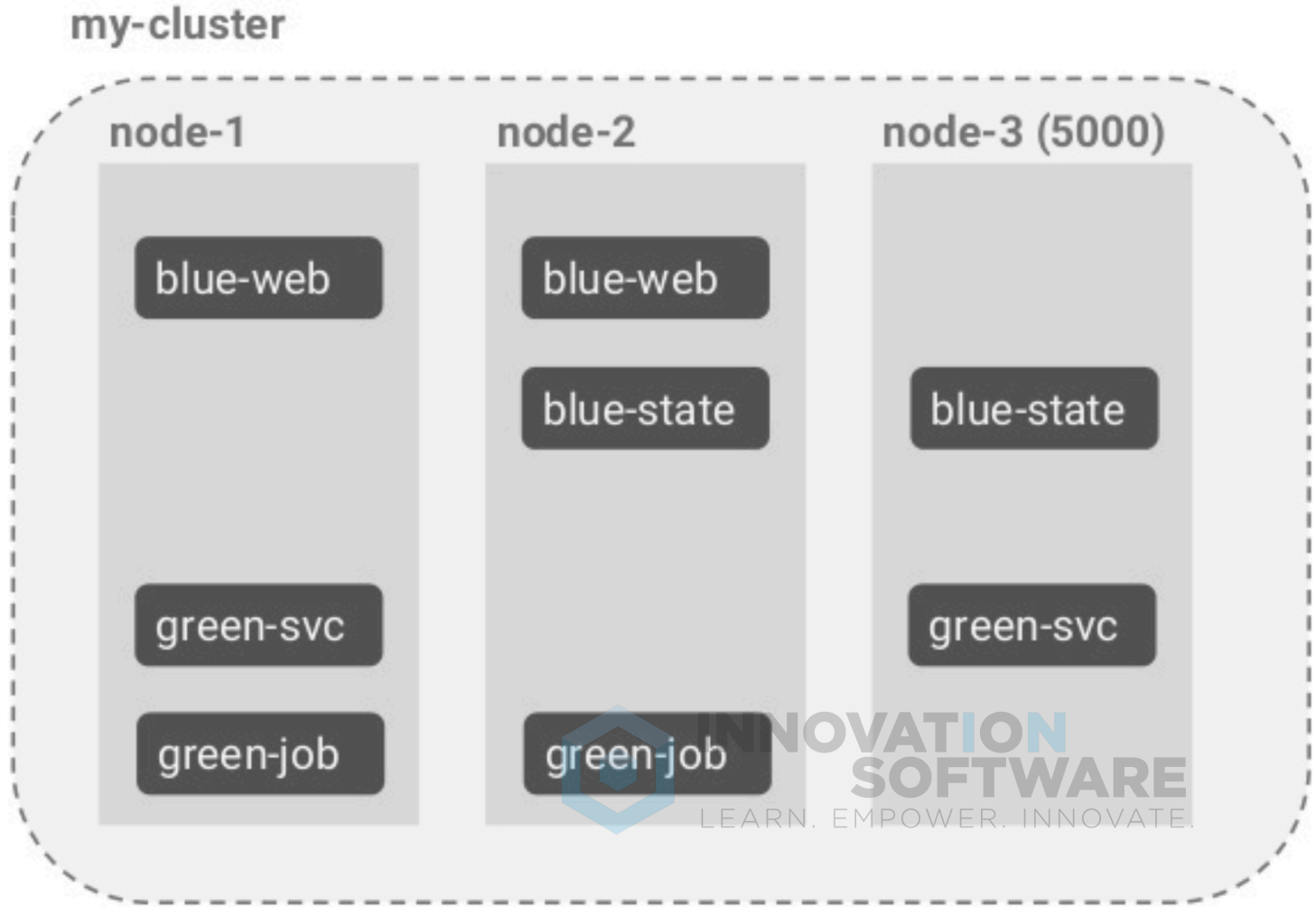
```
# This role binding allows "jane" to read pods in the "default" namespace.
kind: RoleBinding
apiVersion: rbac.authorization.k8s.io/v1
metadata:
  name: read-pods
  namespace: default
subjects:
- kind: User
  name: jane
  apiGroup: rbac.authorization.k8s.io
roleRef:
   kind: Role
   name: pod-reader
   apiGroup: rbac.authorization.k8s.io
```

Without fine-grained Access:

- Authorization at cluster level
- All pods have same authorization

Without controlled scheduling:

- Lack flexibility for multi-workload

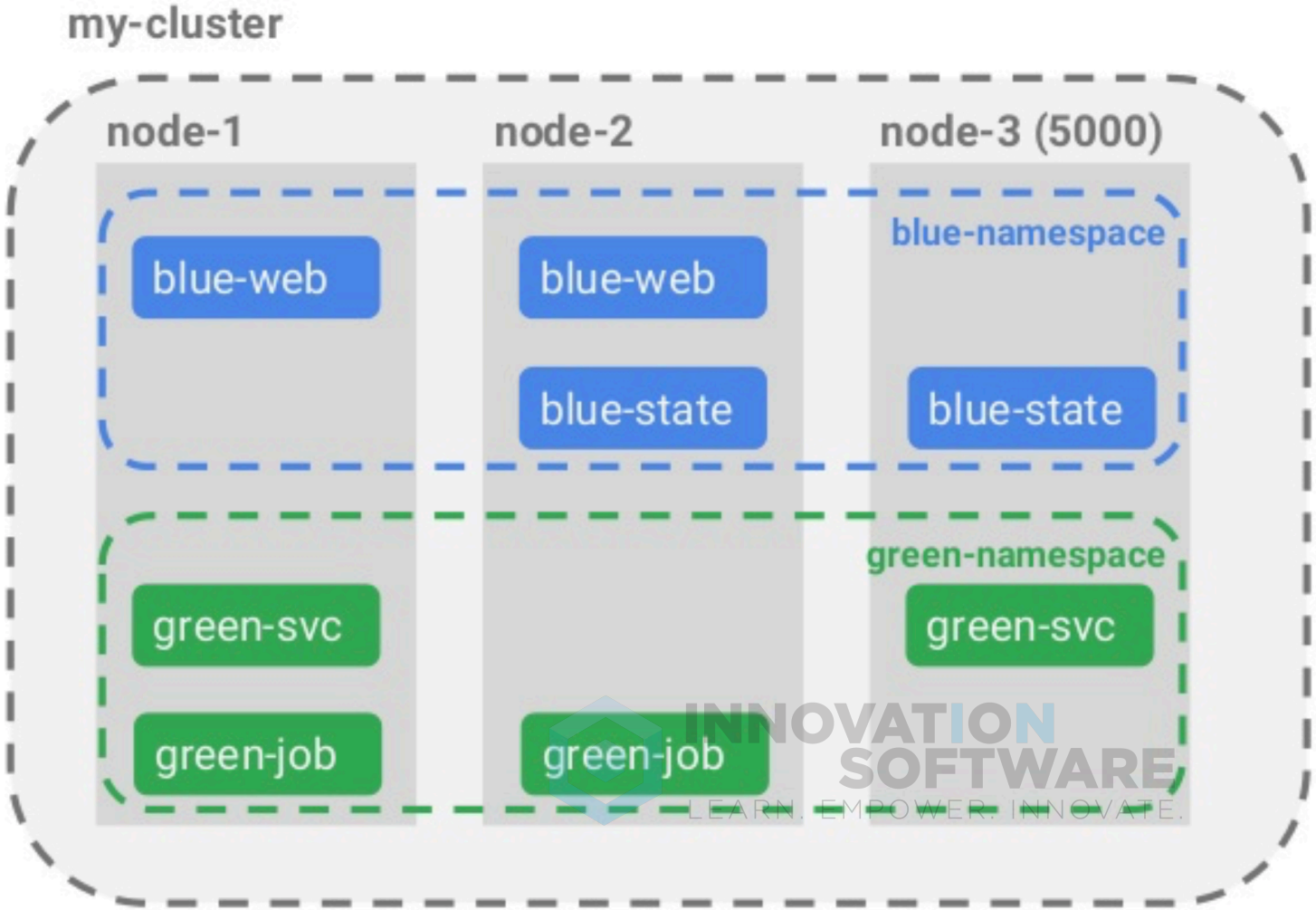


Introducing RBAC:

- Per-namespace/ resource, role, action

Examples:

- **Alice** can list **Eng** services, but not **HR**
- **Bob** can create Pods in **Test** namespace, but not in **Prod**
- **Scheduler** can read **Pods** but not **Secrets**



RBAC lab

- Create user
- Generate SSL credentials for new user
- Create RBAC Role and RoleBinding
- Assign correct permissions to user
- Confirm RBAC is working as expected

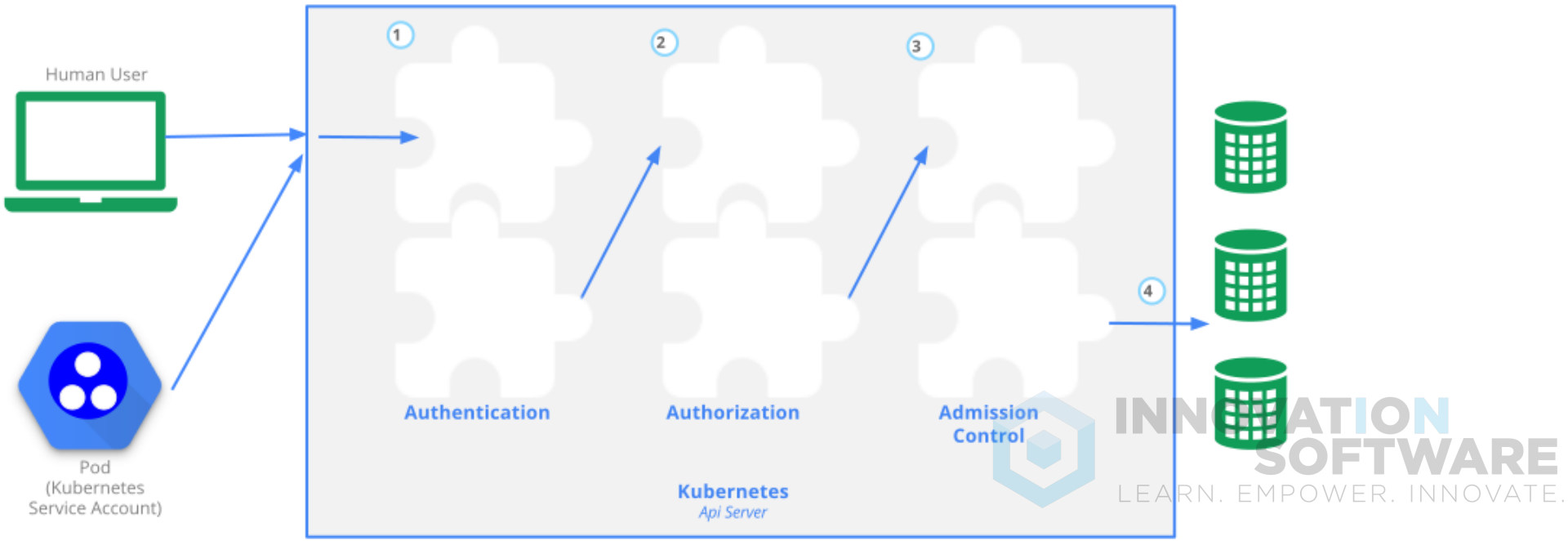
Deployments lab

- Deploy Redis master
  - Deployment/Service
- Deploy Redis slaves
  - Deployment/Service
- Deploy Frontend
  - Deployment/Service

NOTE: Investigate YAML files to see how DNS is being used between services.

Kubernetes API & Security

API Authorization Flow



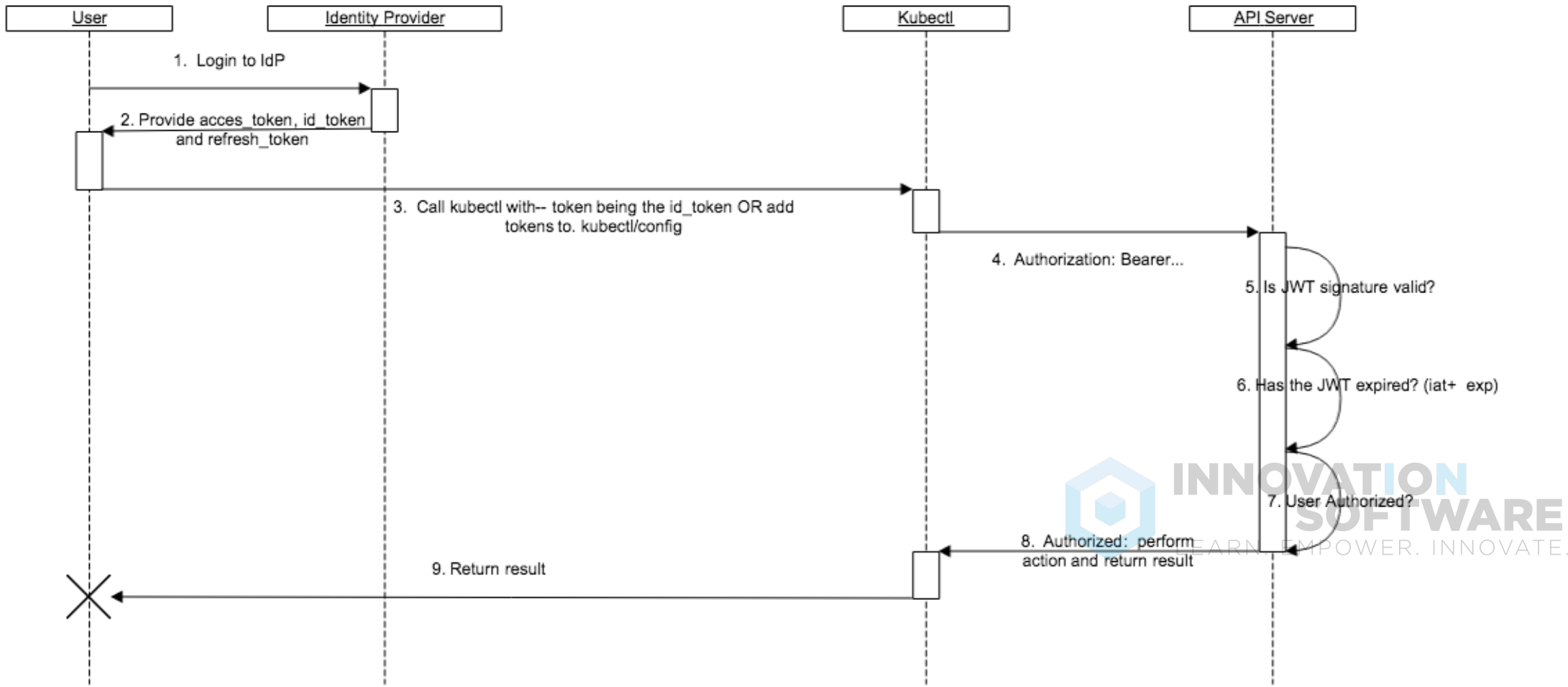
API Authentication

- In a typical Kubernetes cluster, the API serves on port 443
- Typically **$USER/.kube/config** contains the root certificate
- If request cannot be authenticated it's rejected with HTTP status code 401
- Kubernetes can use "usernames" for access control decisions and in request logging, it does not have a user object nor does it store usernames or other information about users in its object store.

API Authentication

- types: user, service account
- users are managed by independent service, not kubernetes cluster
- service accounts are managed by kubernetes api
- Authentication modules include Client Certificates, Password, and Plain Tokens, Bootstrap Tokens, and JWT Tokens (used for service accounts).

API Auth with Identity Provider



API Authorization

Request must include:

- username
- action
- object affected by action

API Authorization

- Example of policy for Bob

```
{
    "apiVersion": "abac.authorization.kubernetes.io/v1beta1",
    "kind": "Policy",
    "spec": {
          "user": "bob",
          "namespace": "projectCaribou",
          "resource": "pods",
         "readonly": true
    }
}
```

API Authorization

This request will be authorized for Bob

```
{
  "apiVersion": "authorization.k8s.io/v1beta1",
  "kind": "SubjectAccessReview",
  "spec": {
    "resourceAttributes": {
      "namespace": "projectCaribou",
      "verb": "get",
      "group": "unicorn.example.org",
      "resource": "pods"
    }
  }
}
```

API Access (kubectl proxy)

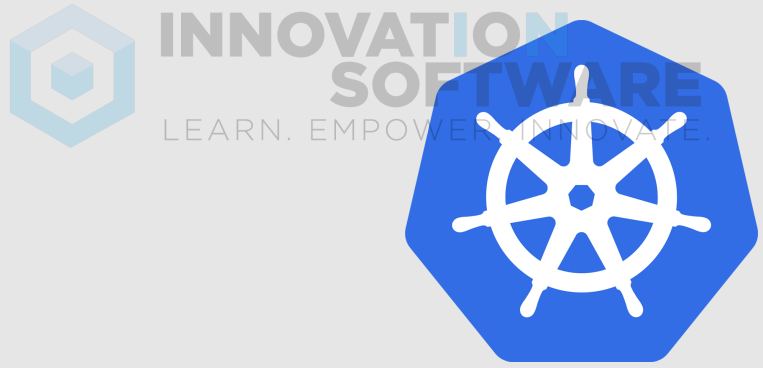
- kubectl proxy creates a tunnel from local machine to API endpoint

Admission Controllers

- Additional custom security modules which may reject the request
- Must be enabled on the api server when kube-apiserver is started
- Examples:
  - AlwaysPullImages
    - Security enhancement (checks image access every time new Pod created)
  - NameSpaceAutoProvision
  - Priority
    - Checks priorityClassName field, fails if not listed
  - many more!

Additional info: https://kubernetes.io/docs/reference/access-authn-authz/admission-controllers/

Monitoring



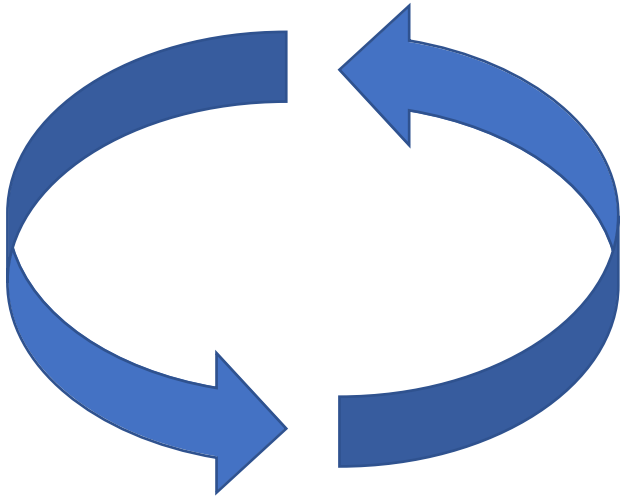
Monitoring

Why monitor?


HYUNDAI FORTUNE
PANAMA
HYUNDAI

Monitoring

Quality Assurance



Continuous Improvement

Monitoring

Not about collecting data

- Why vs How

INNOVATION SOFTWARE

LEARN. EMPOWER. INNOVATE.

Monitoring

Why monitor?

- Know when things go wrong
- Debug and learn from issues
- Historical view/Trends
- Drive technical/business decisions
- Feed into other systems/processes (QA, Security, automation)

Monitoring

Challenges

- Monitoring tools are limited
  - Technically
  - Conceptually
- Tools don’t scale well and are difficult to manage
- Operational practices don’t align with business needs

Monitoring

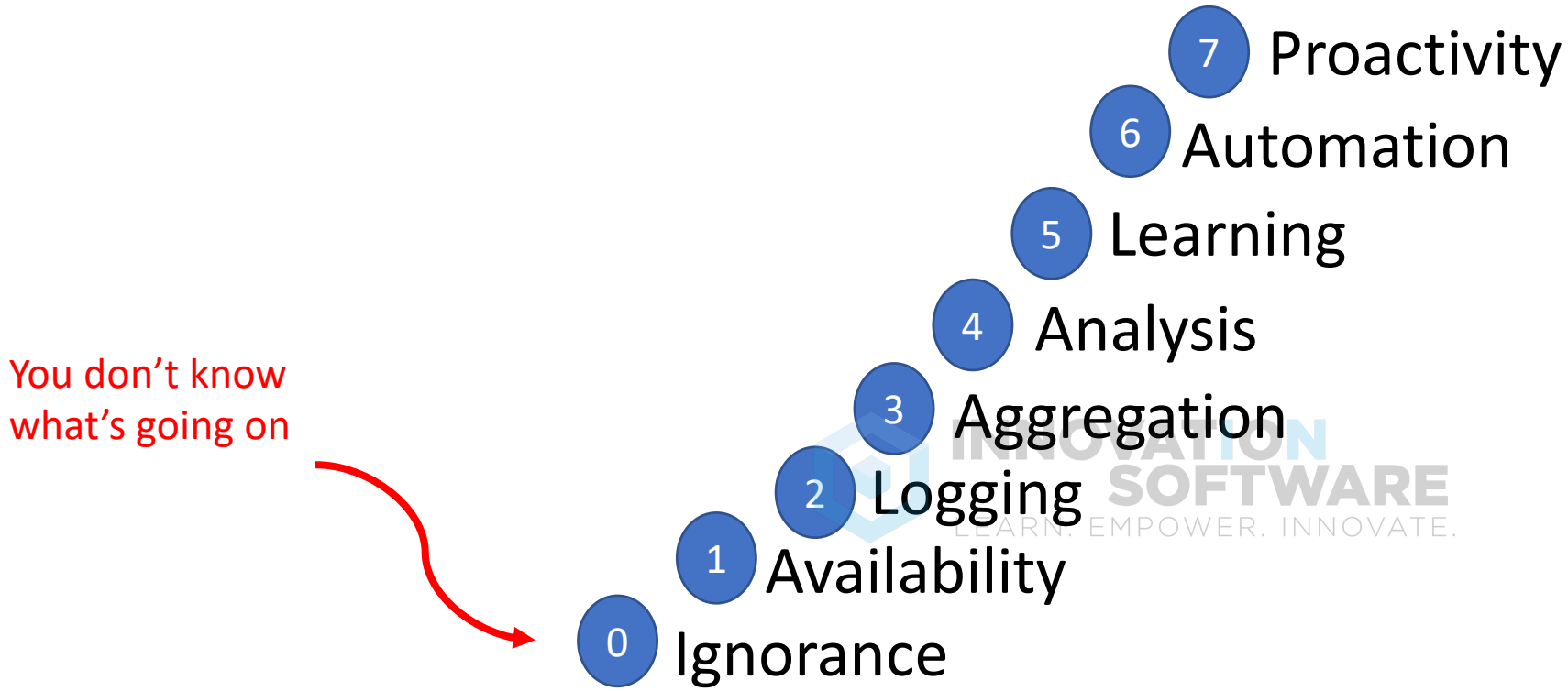
Challenges

Example:

Customers care about increased latency and it’s in your SLAs. Monitoring only supports alerting on individual machines performance and not the entire clusters.

Result: Engineers get a bunch of non critical/false-positive alerts and are woken up for non-issues. This leads to fatigue and ignoring alerts.

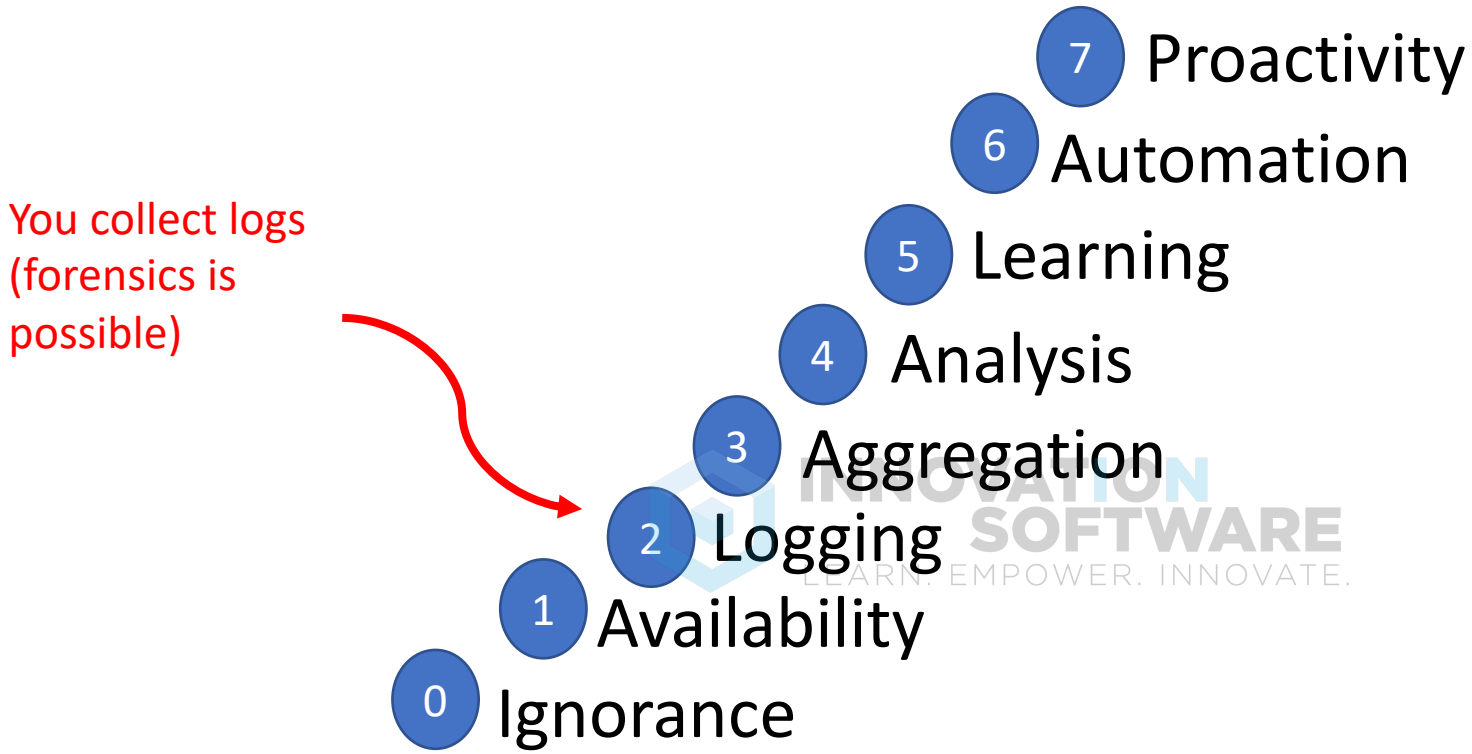
Monitoring


You don't know what's going on
0 Ignorance
1 Availability
2 Logging
3 Aggregation
4 Analysis
5 Learning
6 Automation
7 Proactivity

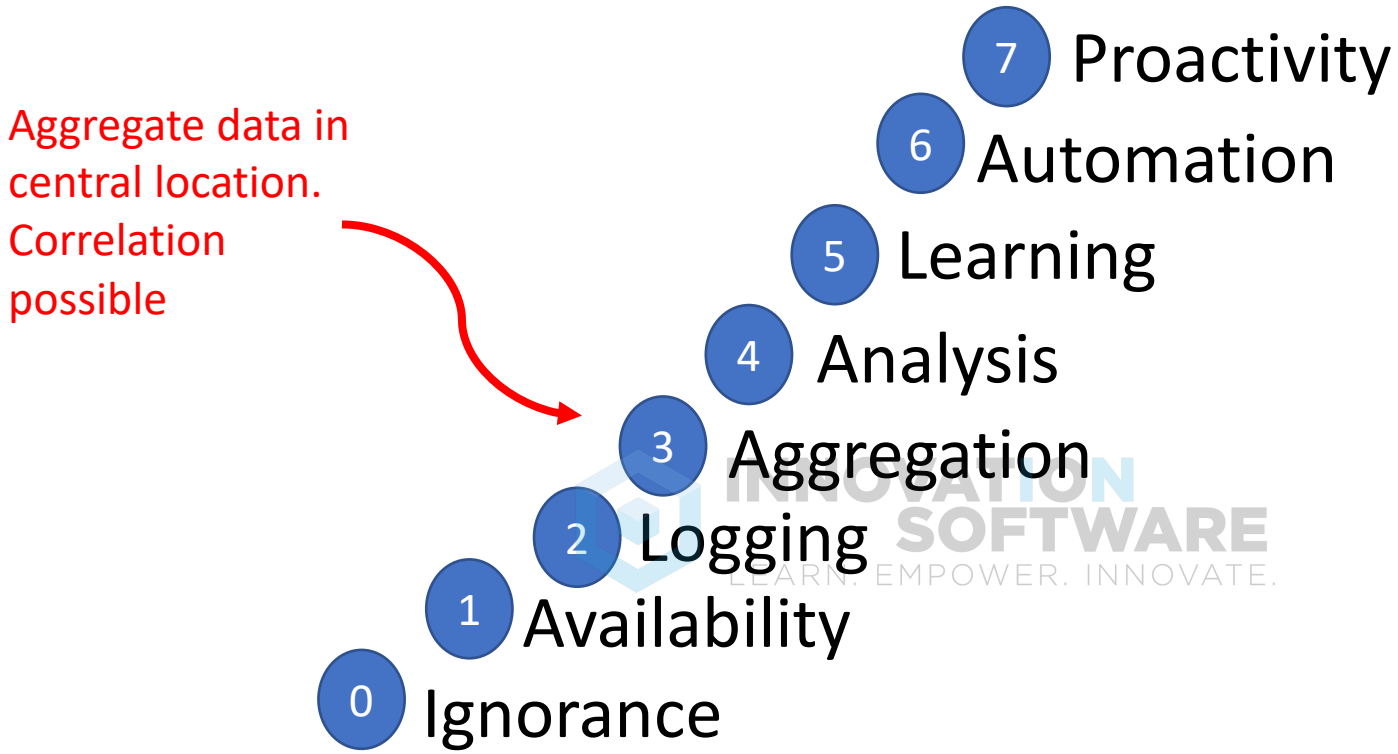
Monitoring


You know if systems are available & may have alerts
7 Proactivity
6 Automation
5 Learning
4 Analysis
3 Aggregation
2 Logging
1 Availability
0 Ignorance

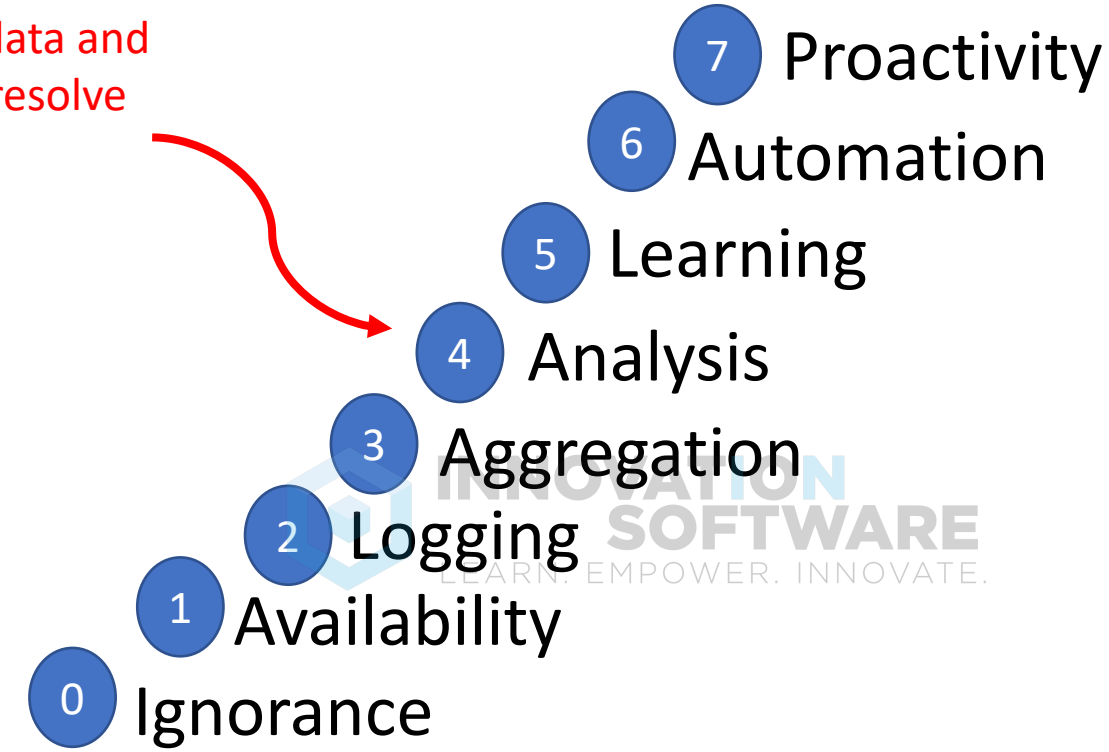
Monitoring


You collect logs (forensics is possible)
7 Proactivity
6 Automation
5 Learning
4 Analysis
3 Aggregation
2 Logging
1 Availability
0 Ignorance

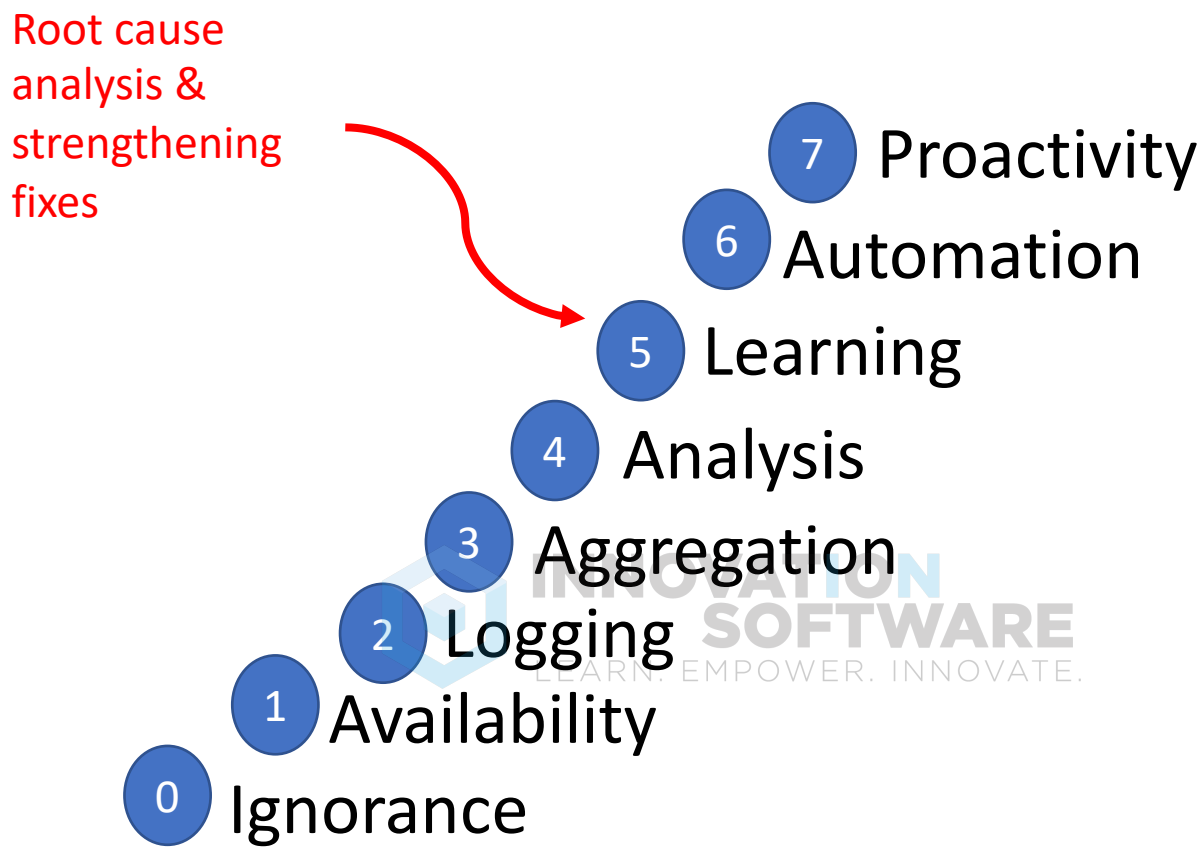
Monitoring


Aggregate data in central location. Correlation possible
7 Proactivity
6 Automation
5 Learning
4 Analysis
3 Aggregation
2 Logging
1 Availability
0 Ignorance

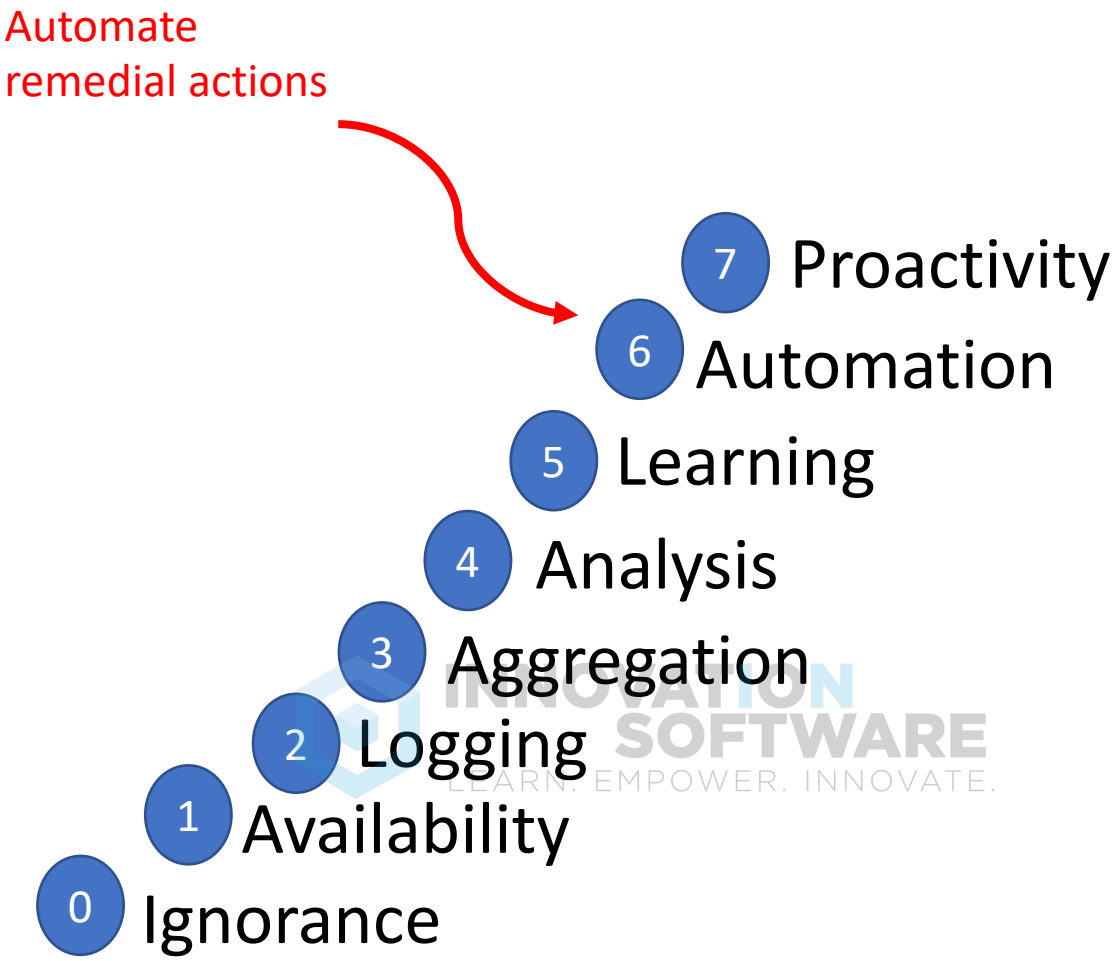
Monitoring


Analyze data and use it to resolve issues
7 Proactivity
6 Automation
5 Learning
4 Analysis
3 Aggregation
2 Logging
1 Availability
0 Ignorance

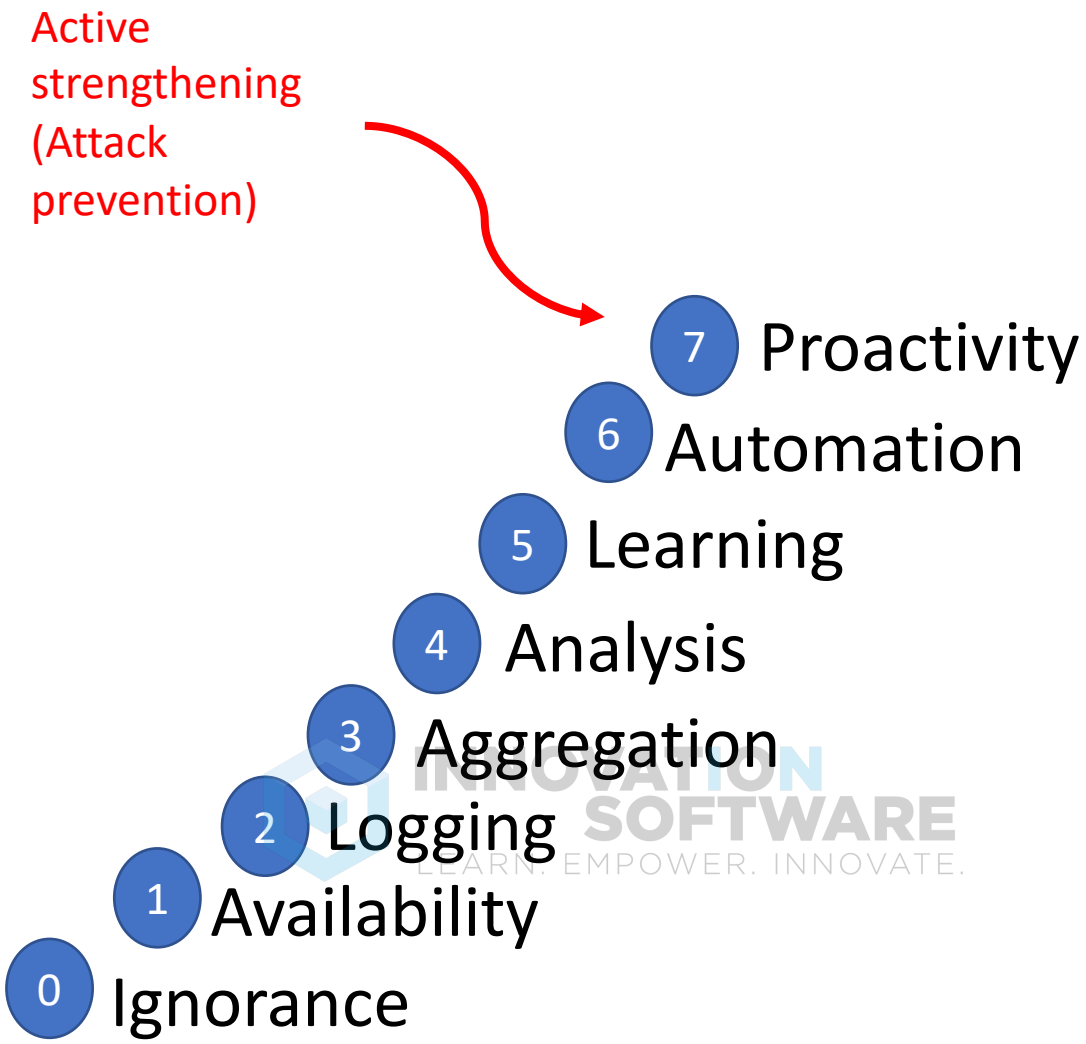
Monitoring


Root cause analysis & strengthening fixes
7 Proactivity
6 Automation
5 Learning
4 Analysis
3 Aggregation
2 Logging
1 Availability
0 Ignorance

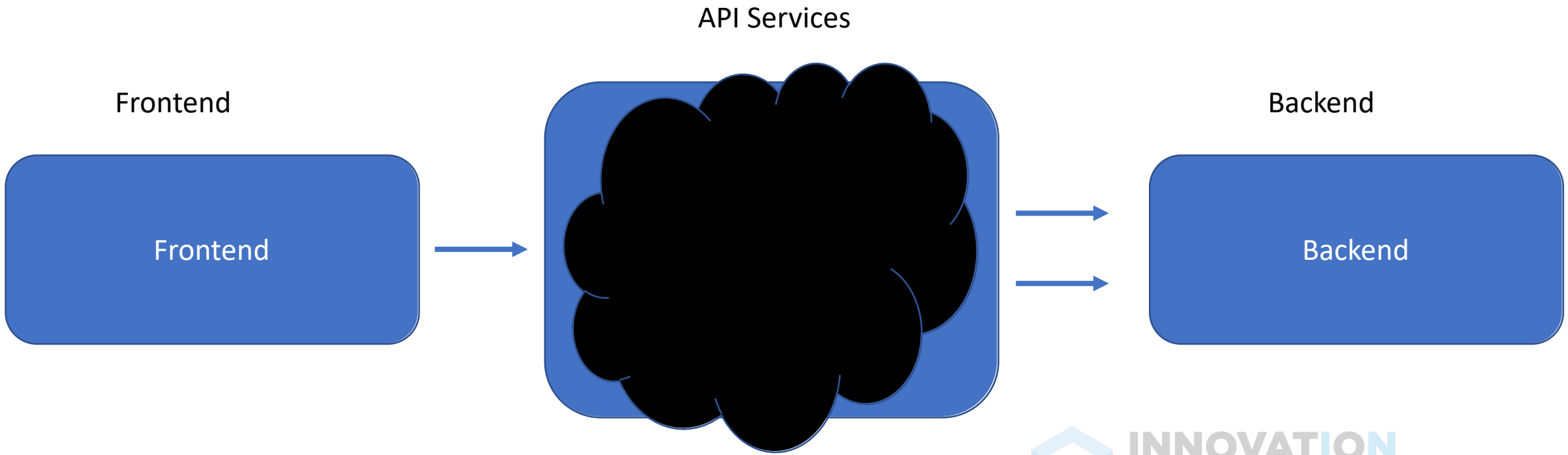
Monitoring


Automate
remedial actions
7 Proactivity
6 Automation
5 Learning
4 Analysis
3 Aggregation
2 Logging
1 Availability
0 Ignorance

Monitoring

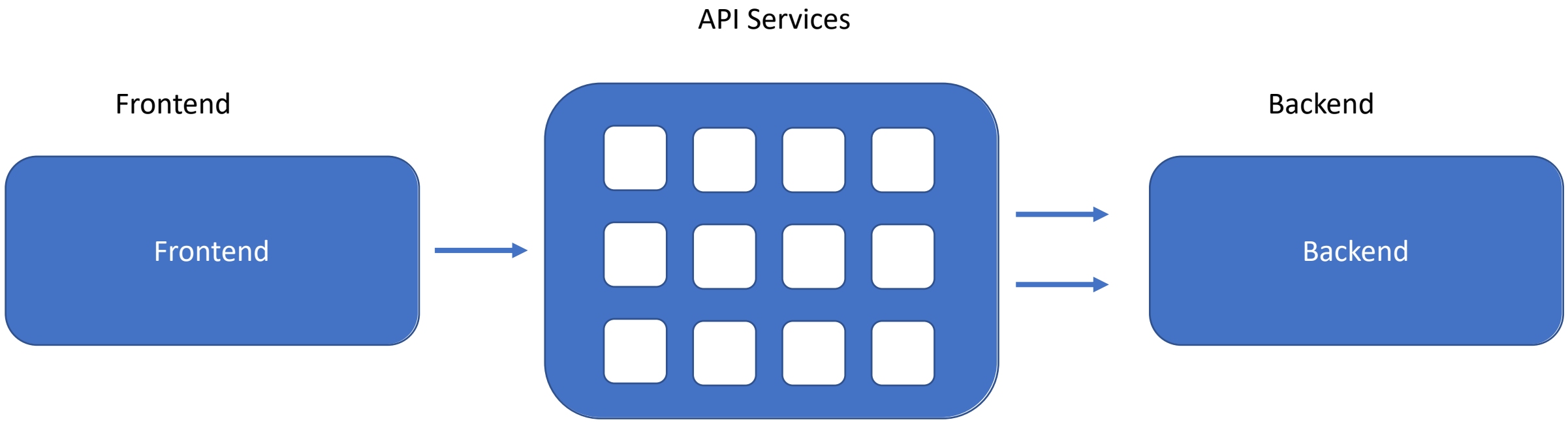

Active strengthening (Attack prevention)
7 Proactivity
6 Automation
5 Learning
4 Analysis
3 Aggregation
2 Logging
1 Availability
0 Ignorance

Monitoring



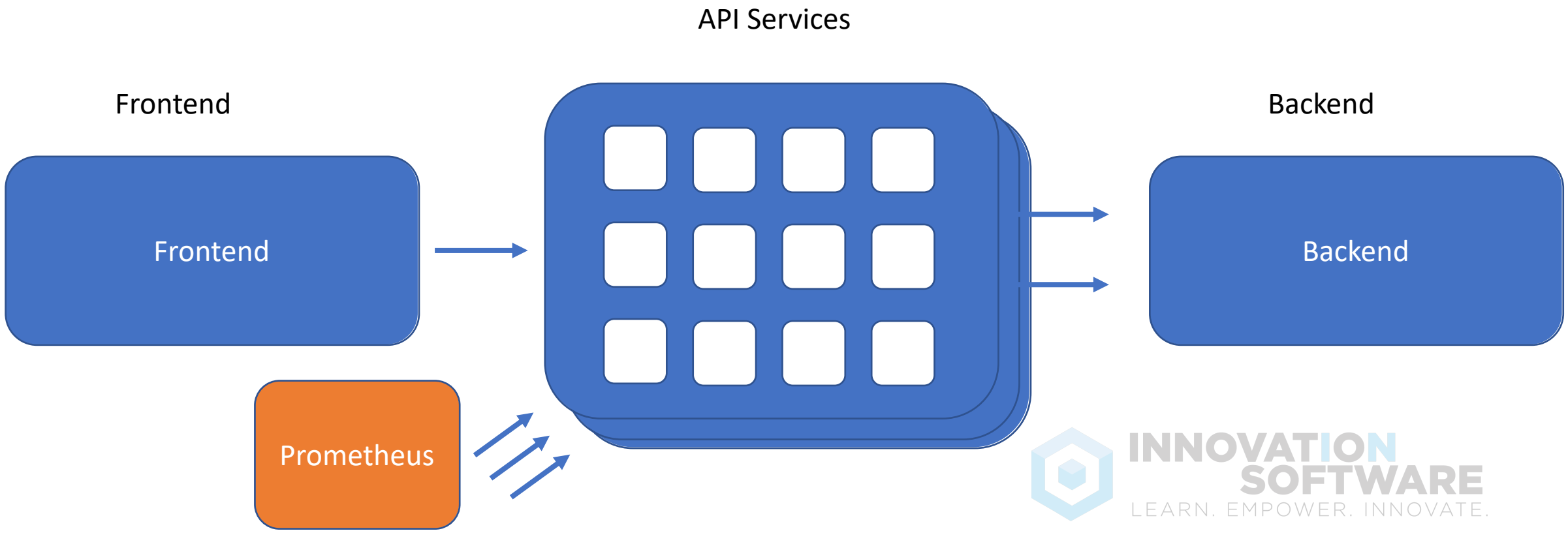
Limited visibility

Monitoring



Monitor Internals

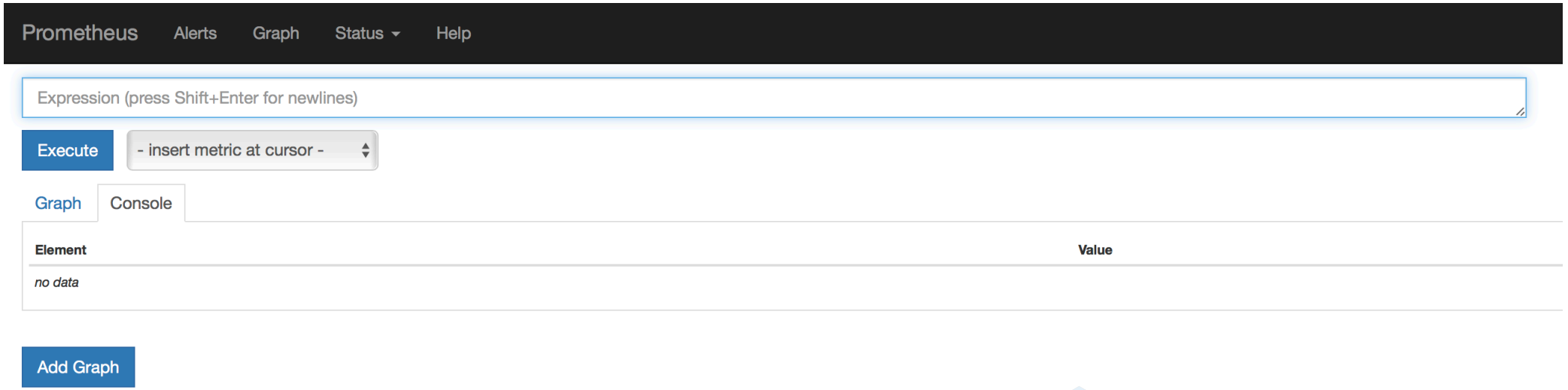
Monitoring



Monitor Services

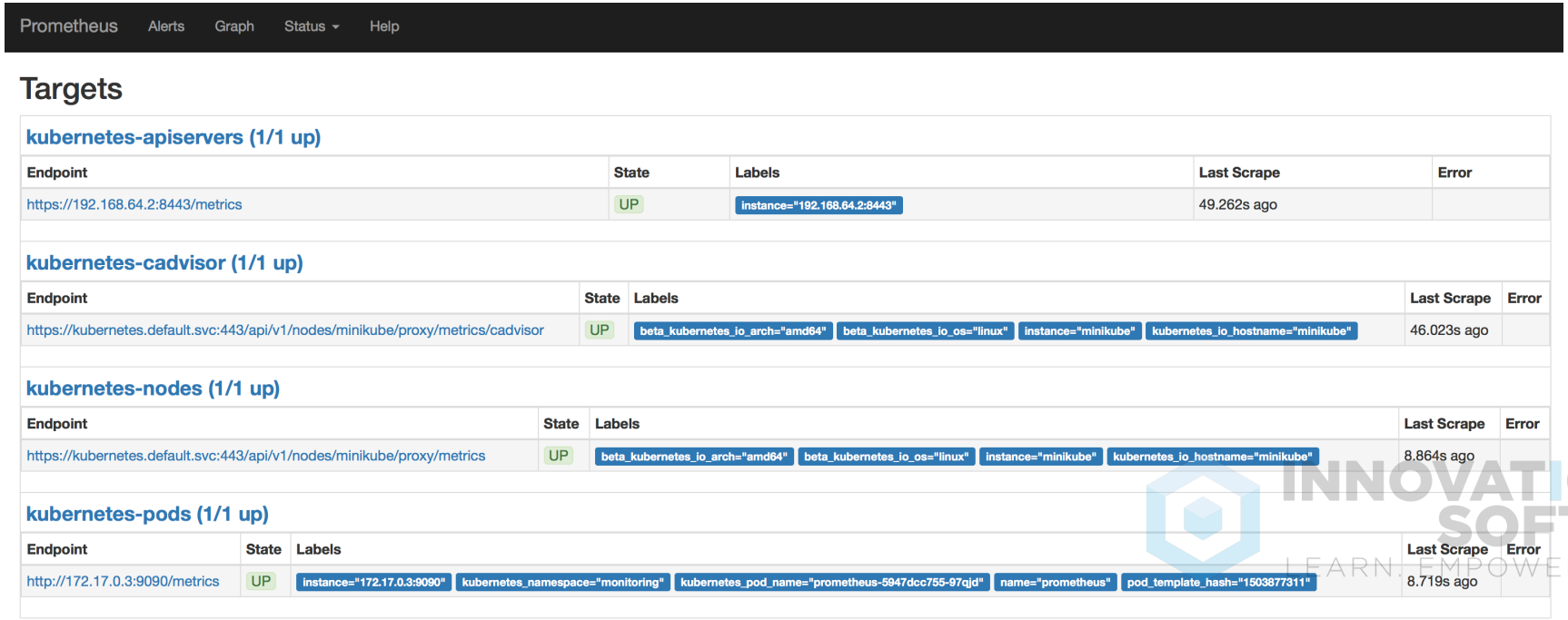
Monitoring

Prometheus



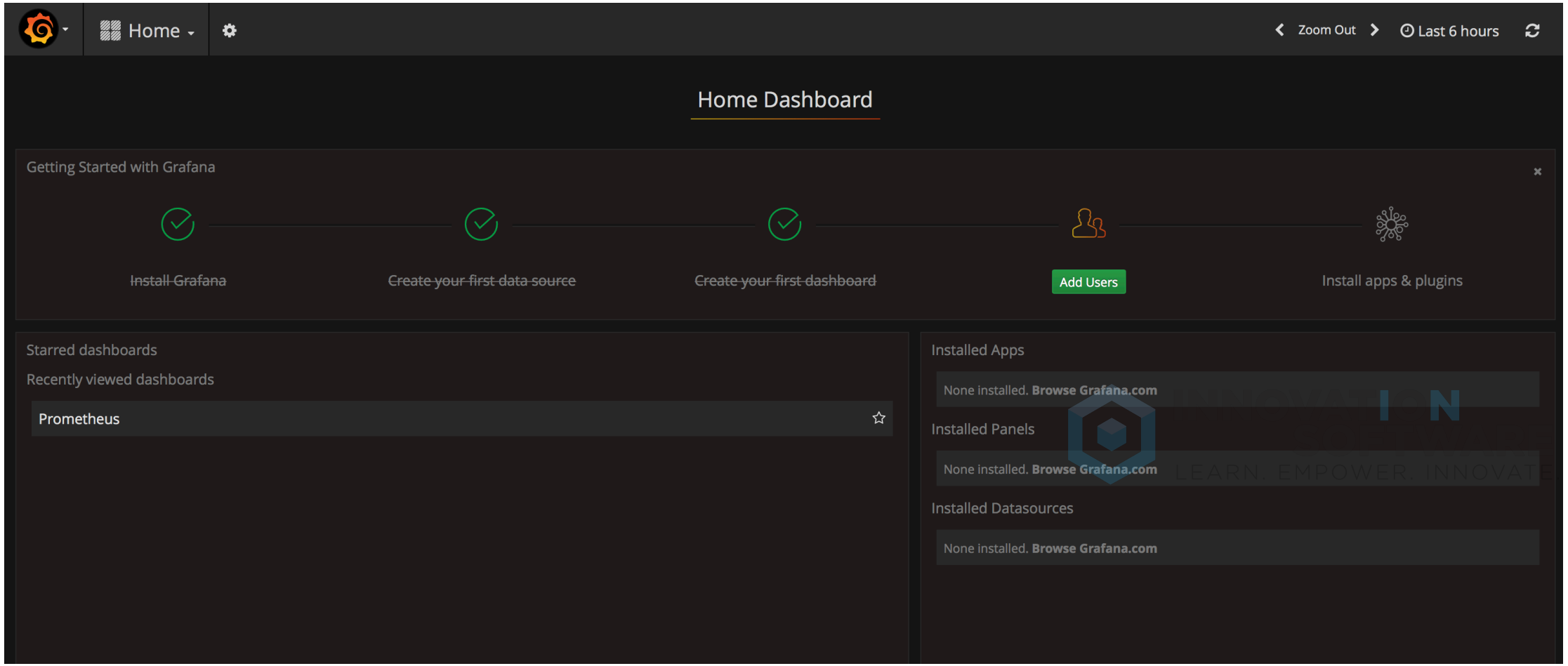
Monitoring

Prometheus



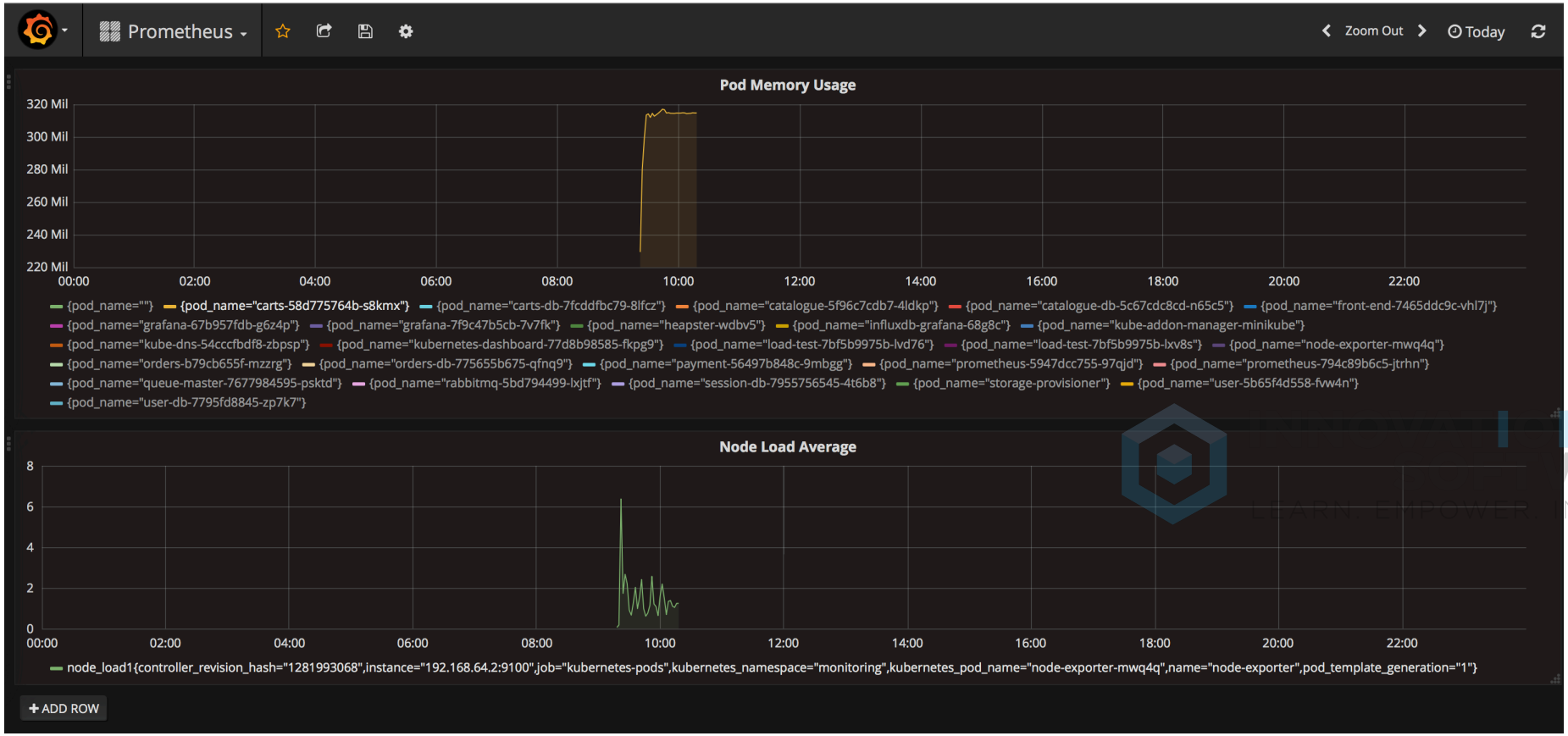
Monitoring

Grafana



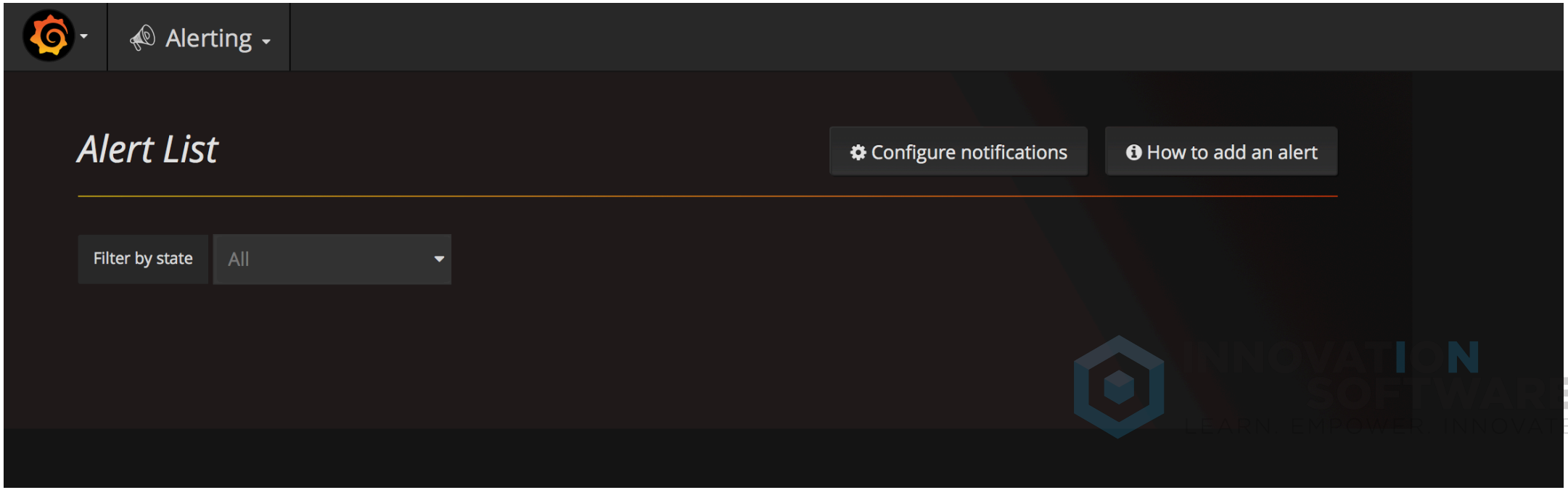
Monitoring

Grafana



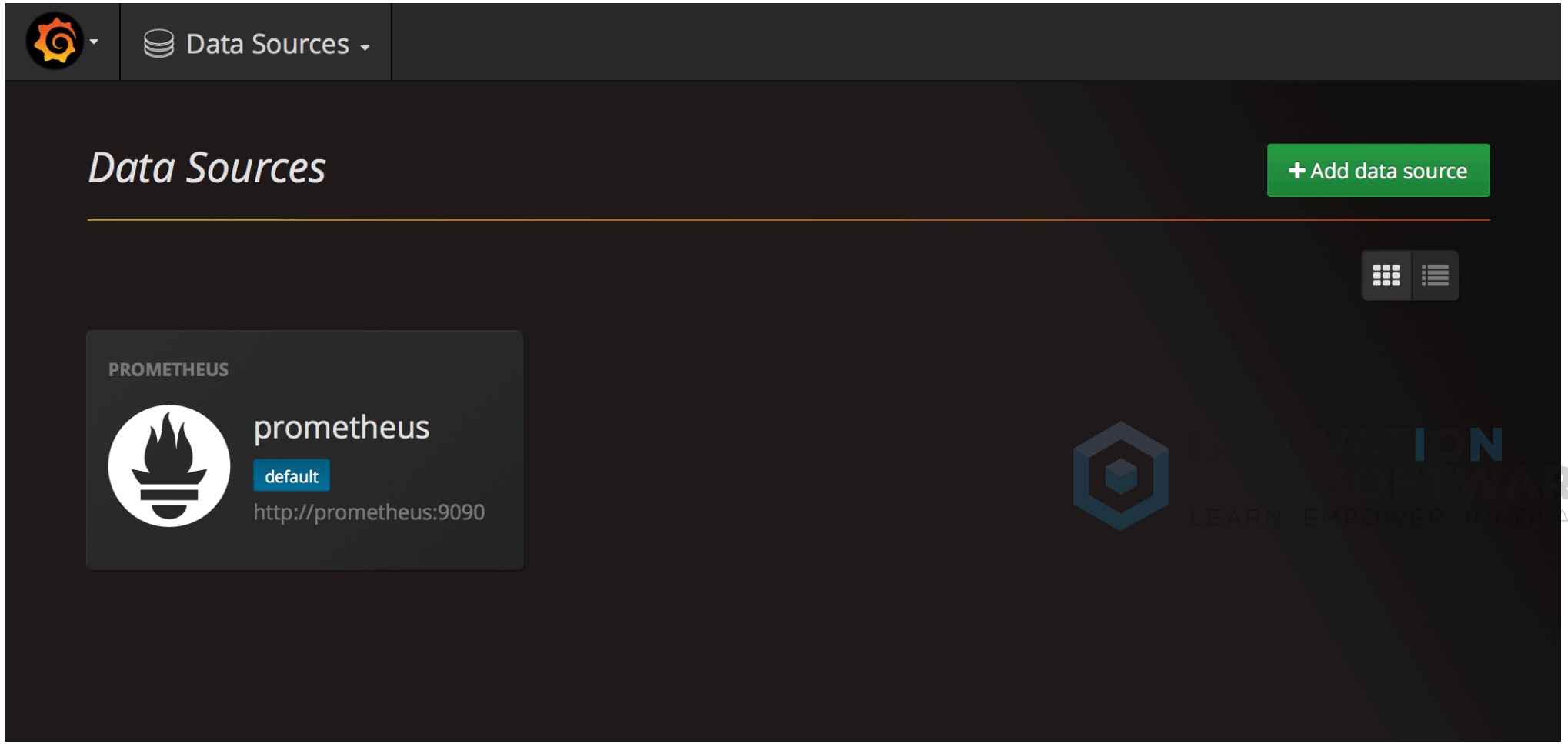
Monitoring

Grafana



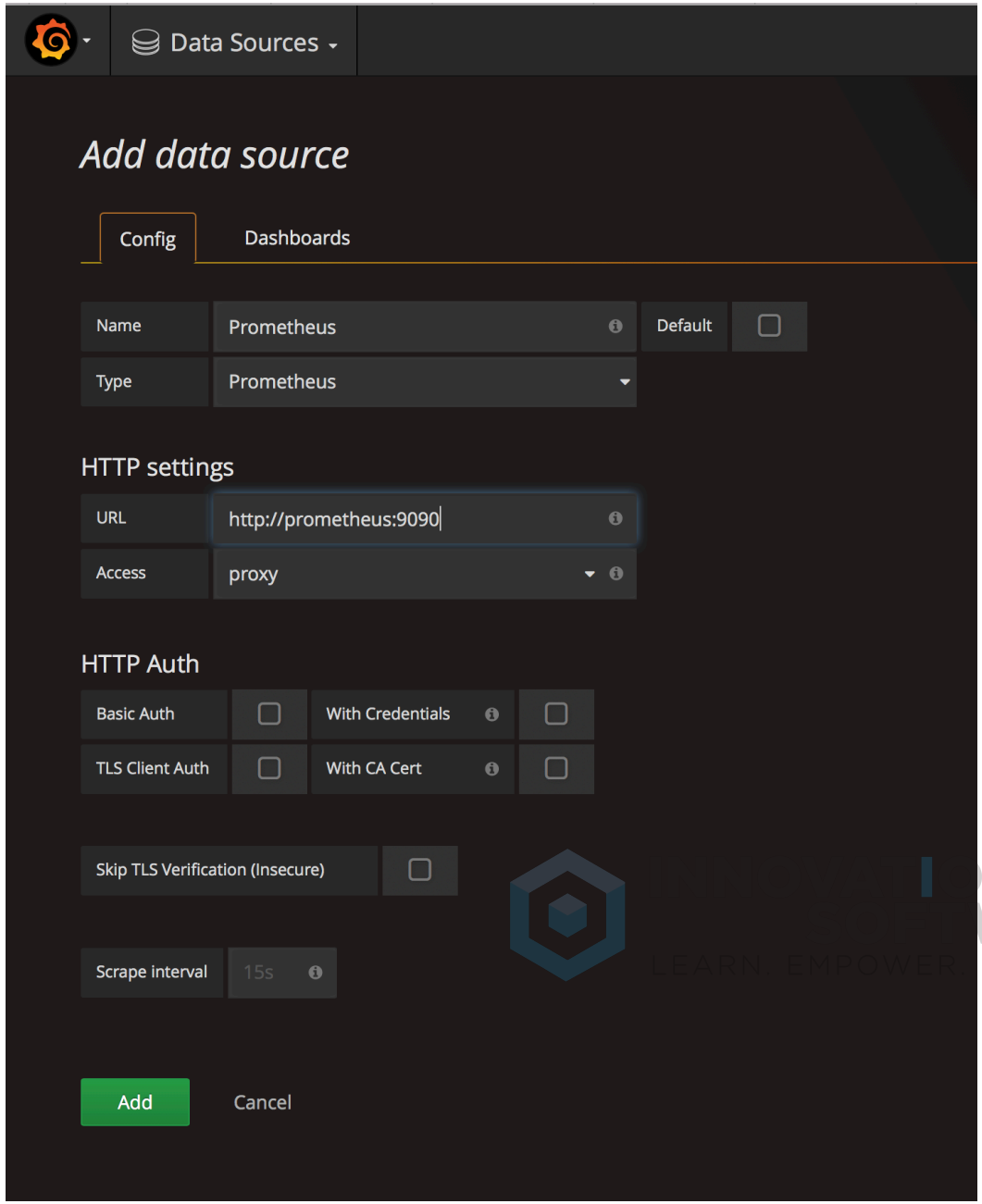
Monitoring

Grafana



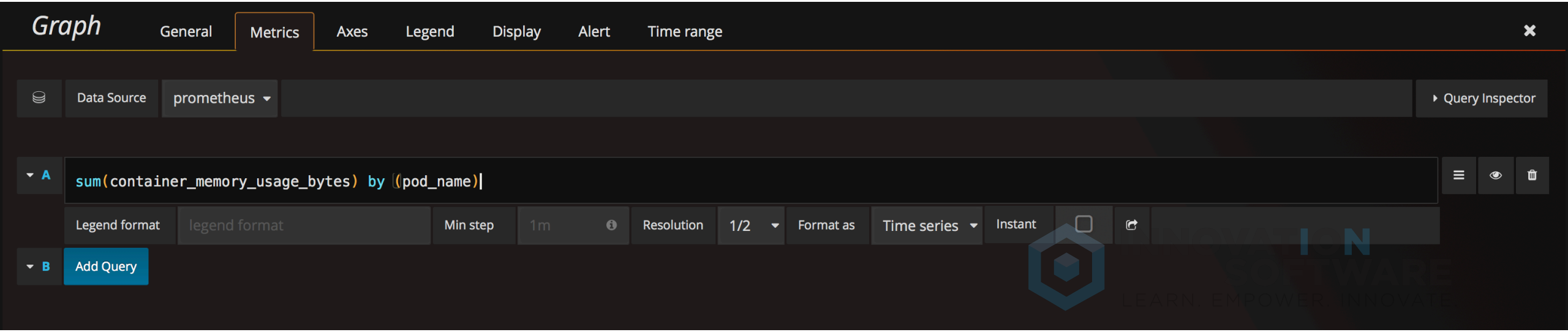
Monitoring

Grafana
&
Prometheus



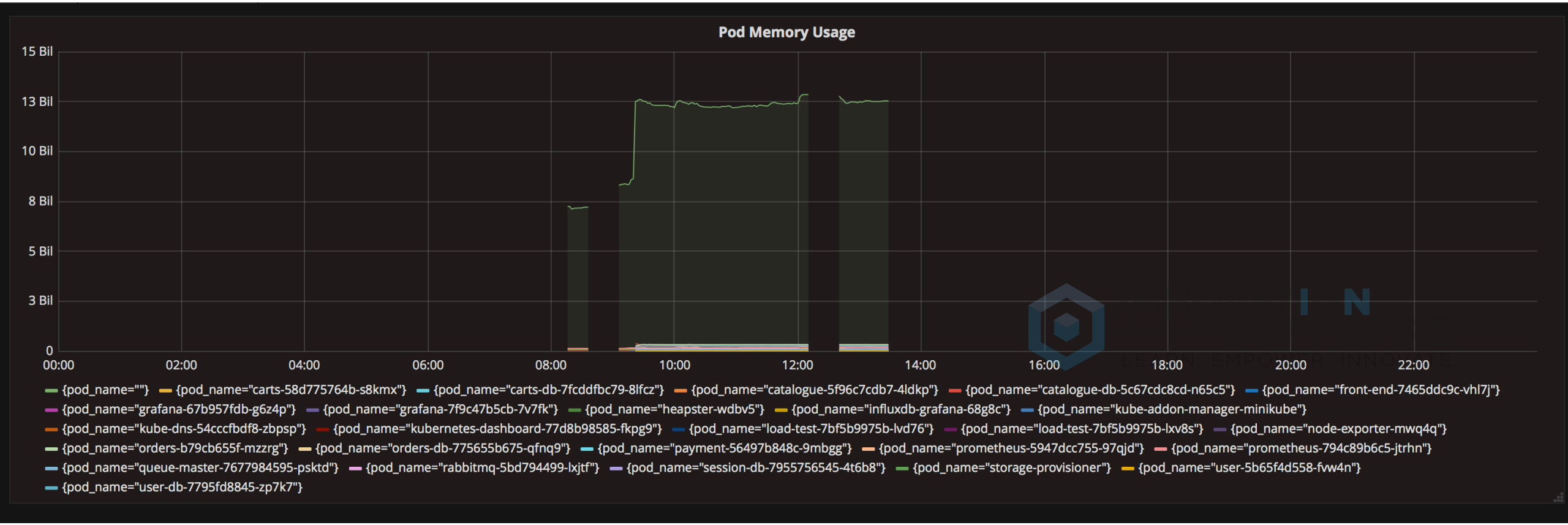
Monitoring

Add graph

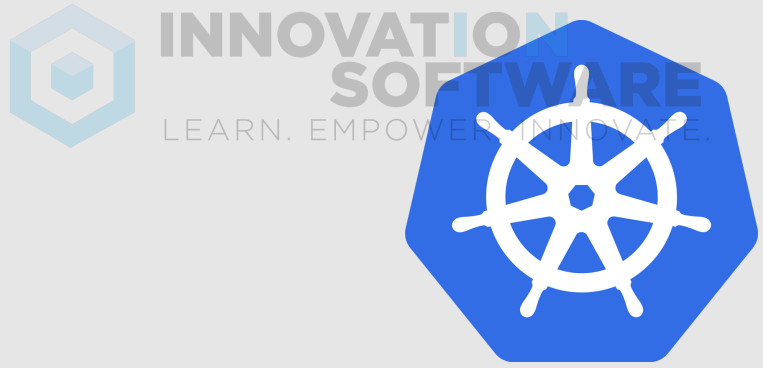


Monitoring

Grafana graph



Kubernetes Secrets



Application Secrets

What secrets do applications have?

- Database credentials
- API credentials & endpoints (Twitter, Facebook etc.)
- Infrastructure API credentials (Google, Azure, AWS)
- Private keys (TLS, SSH)
- Many more!

INNOVATION SOFTWARE

LEARN. EMPOWER. INNOVATE.

Application Secrets

It is a bad idea to include these secrets in your code.

- Accidentally push up to GitHub with your code
- Push into your file storage and forget about
- Etc.

Application Secrets

There are bots crawling GitHub searching for secrets

Real life example:
Dev put keys out on GitHub, woke up next morning with a ton of emails and missed calls from Amazon

- 140 instances running under Dev's account.
- $2,375 worth of Bitcoin mining

Create Secret

- Designed to hold all kinds of sensitive information
- Can be used by Pods (filesystem & environment variables) and the underlying kubelet when pulling images

```
apiVersion: v1
kind: Secret
metadata:
  name: mysecret
Type: Opaque
data:
   password: mmyWfoidfIuL==
   username: NyhdOKwB
```


INNOVATION SOFTWARE
LEARN. EMPOWER. INNOVATE.

Pod Secret

```
kind: Pod
metadata:
   name: secret-env-pod
spec:
  containers:
  - name: mycontainer
    image: redis
    env:
    - name: SECRET_USERNAME
        valueFrom:
          secretKeyRef:
            name: mysecret
            key: username
```

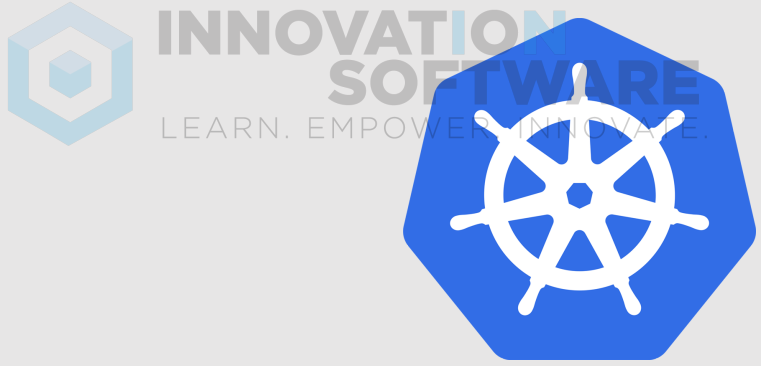
Volume Secret

```
spec:
  containers
  - name: mycontainer
    image: redis
    volumeMounts:
    - name: “secrets”
      mountPath: “/etc/my-secrets”
      readOnly: true
  volumes:
   - name: “secrets”
      secret:
        secretName: “mysecret”
```

Secrets Lab

- Create secrets file
- Deploy application that uses secrets
- Decrypt secrets

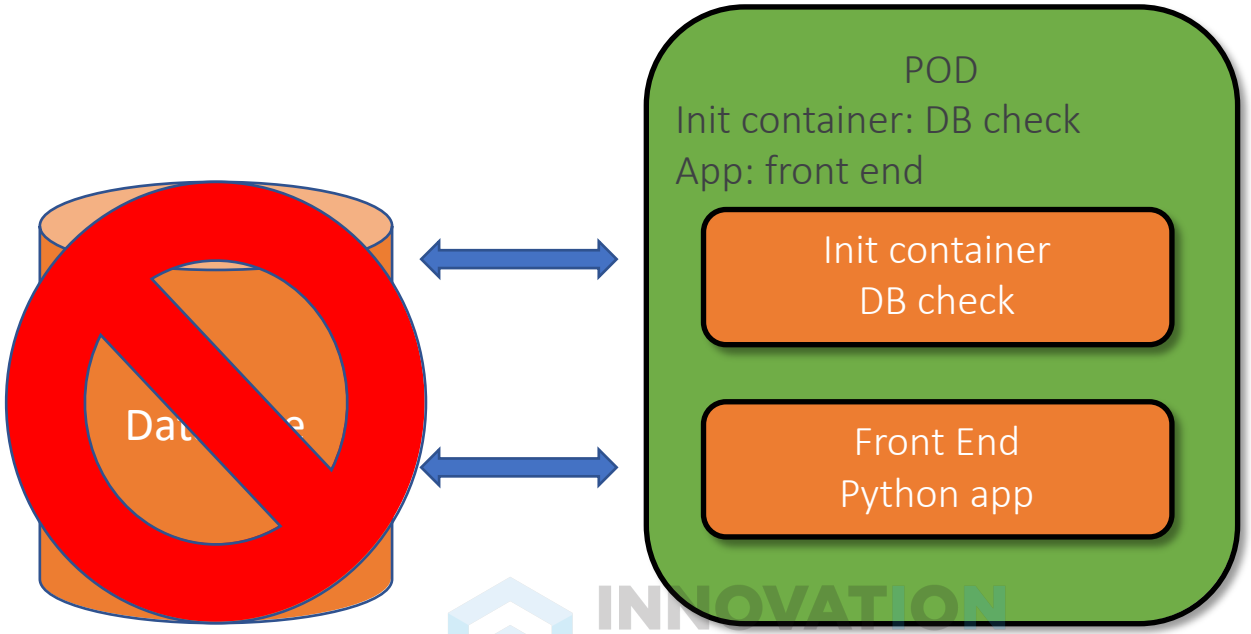
Kubernetes Init Containers



Init containers

Application orchestration

- Init container runs first to completion
  - If failure, POD is restarted until successful.



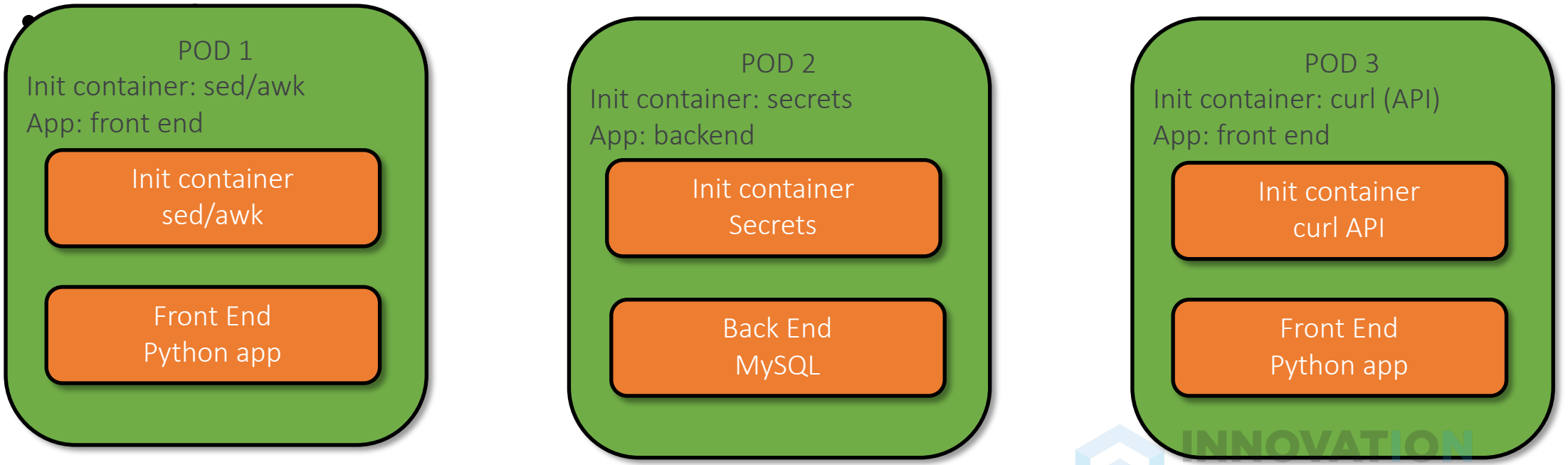
Init containers

- Support same features as application containers.
  - Resource limits
  - Volumes
  - Security settings
  - Etc.
- Do not support readiness probes since they must run to completion before POD can be “ready”

Kubernetes 1.6+ syntax

```yaml
apiVersion: v1
kind: Pod
metadata:
  name: myapp-pod
  labels:
    app: myapp
spec:
  containers:
  - name: myapp-container
    image: busybox
    command: ['sh', '-c', 'echo The app is running! && sleep 3600']
  initContainers:
  - name: init-myservice
    image: busybox
    command: ['sh', '-c', 'until nslookup myservice; do echo waiting for myservice; sleep 2; done;']
  - name: init-mydb
    image: busybox
    command: ['sh', '-c', 'until nslookup mydb; do echo waiting for mydb; sleep 2; done;']
```

Init container use-cases

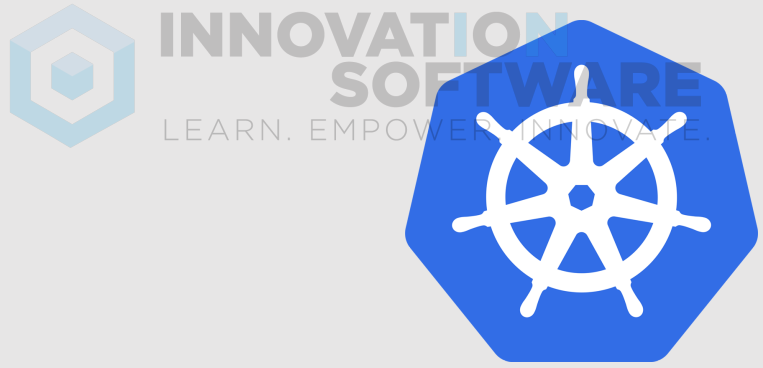


Init containers Lab

- Deploy POD with init containers that wait for services to come online
- Investigate POD status
- Create services
- Confirm init containers executed and POD was started

- Create POD with init container that fetched webpage for nginx web server.

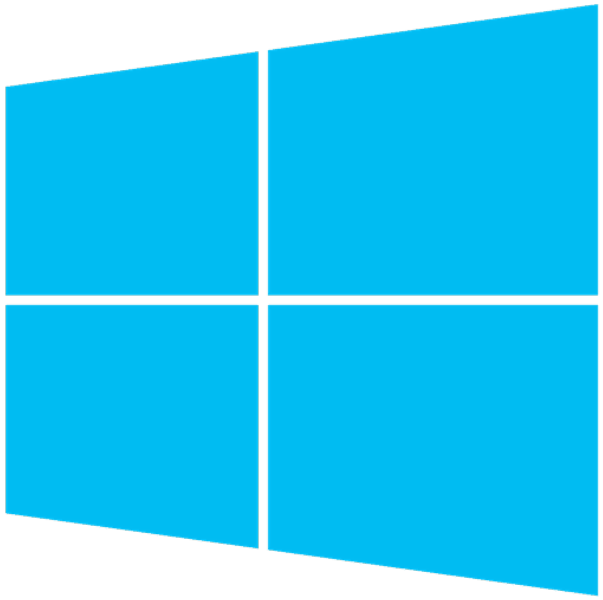
Local Kubernetes Cluster



Minikube: Run Kubernetes All-In-One

Run single-node Kubernetes cluster on local machine

- Minikube runs on all 3 operating systems
  - Windows, Mac, and Linux



- VirtualBox
- Hyper-V

- VirtualBox
- Xhyve
- Vmware Fusion

- VirtualBox
- KVM

Minikube: Supported Features

DNS

NodePorts

Ingress

~~Load Balancer~~

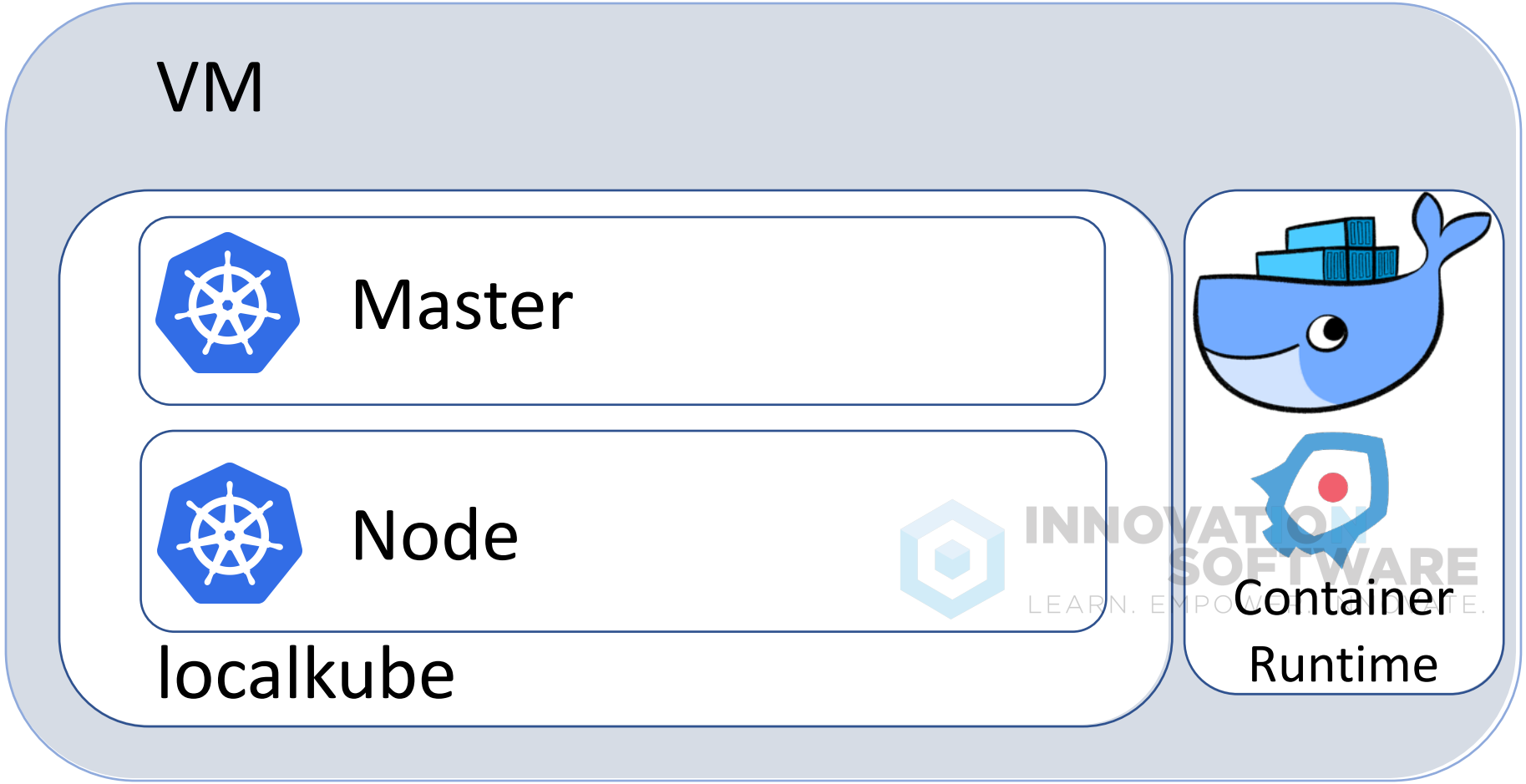
Container Runtime

Persistent Volumes

ConfigMaps
Secrets

Dashboard

Minikube: Architecture



Capstone Lab

- Create ConfigMap that contains value of “success”
- Create secret with a passphrase (i.e. “KubernetesRocks”
- Deploy web application:
  - Serves webpage with contents of ConfigMap
  - Secret is available at /secrets/passphrase.txt
- Create service for web application
  - Served on port 8081
  - Available externally


THANK
YOU