Welcome to

Kubernetes Security

– for Unix people running on-premise K8s

Henrik Kramselund he/him han/ham hlk@zencurity.com @kramse

Slides are available as PDF, kramse@Codeberg

kubernetes-security-unix.tex in the repo security-courses

Contact information

- Henrik Kramselund, he/him internet samurai mostly networks and infosec
- Network and security consultant Zencurity, teach at KEA and activist
- Master from the Computer Science Department at the University of Copenhagen (DIKU)
- Email: hlk@zencurity.com Mobile: +45 2026 6000
- Run a small network for fun AS57860

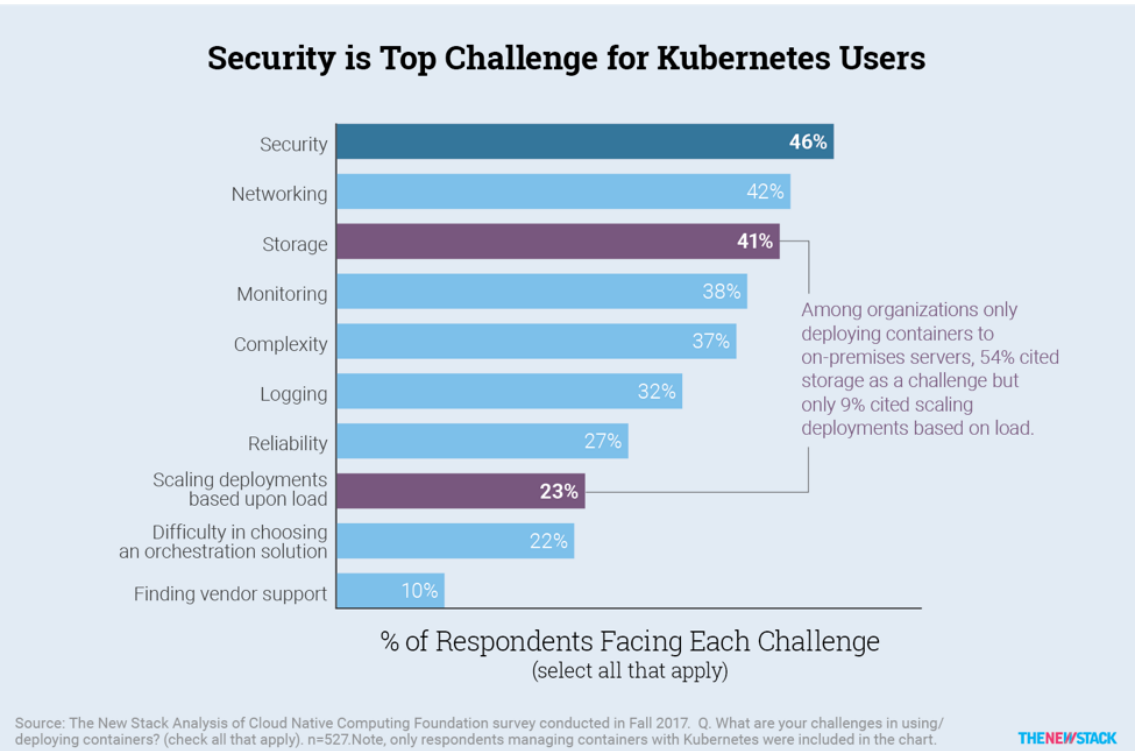
You are welcome to drop me an email

Goals for today

- Get an idea of the work needed to create a small secure Kubernets deployment
- Present some parts of the solution – including specific tools 🔧
- Point you towards resources, so you can get started with Kubernetes on-premise more securely
- Lay out a plan for a modern featureful reasonably secure K8s bare-metal install

Note: slides include lots of references, and some blocks of text not intended for reading while I talk! Download and get them later from Codeberg or Github

Security is a Concern in Kubernetes Deployments



Source: https://thenewstack.io/top-challenges-kubernetes-users-face-deployment/

My Intentions

I suspect you want to work with Kubernetes, maybe you already do, but:

- You are responsible for all of it
- You don't have the resources, knowledge, time, etc. for getting to know it all
- You have to create an architecture, as well as implement it
- ... and monitor it, ... and secure it
- If you come from a Unix background it is certainly doable, and similar features exist in K8s land

My intention is to be your sparring partner today, list all the parts I think must be considered.

Target Audience

- Overall target audience: operators, and developers becoming operators – devops
- Maybe secdevops - security personnel that needs some scalable systems running on K8s - like myself
- People being told to setup a K8s cluster – for some app

Disclaimer: I am not an expert in EVERYTHING Kubernetes

I am not an EXPERT
– but I have read a lot and watched youtube videos. ☺

Kubernetes is such a big ecosystem

The list is long, and an incomplete list contains:

- Kubernetes core components – software written by the project RBAC etc.
- Kubernetes supported container technologies, docker etc.
- Kubernetes dependencies – etcd software used for storing data
- Operating systems – and that lies below, storage
- Kubernetes networking providers – multiple exist, which one to choose – like Cilium
- Monitoring solutions – logging solutions

and on top all the applications in and around Kubernetes – NGINX, PostgreSQL, ...

Why are we here today then?!

We are here to get an overview:

- Identify what we *need* for a Kubernetes production environment
- Consider more parts of the picture than *just Kubernetes core*
- Find a solution that works, with some example technologies
- Provide a kind of check list for your deployment

In general I want to take a more holistic approach to Kubernetes Security which I hope can help you

More Disclaimers

- Disclaimer: **We cover security today**
  We will not cover all parts of K8s - only the ones that we need for security, as few as possible.
  This slideshow is not a replacement for the official docs, and we also recommend multiple resources books, articles and papers detailing specific parts
- Disclaimer: **Deprecation**
  Things are built, and later deprecated. Even while preparing this a few things were deprecated! Core things even change from time to time, which is good. In general I don't trust older references, but verify with newest official docs
- Disclaimer: **New features**
  New and very useful features are added with every new version. If you have an older setup which is not updated, you might not have the same features. New features can also have interesting bugs, and may not work as intended right away. For this presentation I recommend some features that are newer
- Disclaimer: **Single tenant only**
  Running a K8s cluster for your organization is hard enough, I don't claim I could run a production multi-tenancy setup or public cloud

Materials – where to start

- This presentation – slides for today, start here
- *Kubernetes: Up and Running*, 3rd Edition, Brendan Burns, Joe Beda, Kelsey Hightower, August 2022
  Introduces containers and Kubernetes, books in 3rd ed also has been fixed and updated
- *Container Security*, (CS) Liz Rice, O'Reilly, Apr 2020
  A classic text about containers and a must read for everyone
- *Networking and Kubernetes: A Layered Approach*, James Strong, Vallery Lancey, O'Reilly, 2021
  K8s uses a lot of intricate networking – great for understanding this more
- *Learn Kubernetes Security* (LKS), Kaizhe Huang , Pranjal Jumde, Packt, July 2020
  This is a very complete and detailed view at K8s security, covering many many parts
- Advanced security practioners will enjoy security focused books like:
  Hacking Kubernetes: Threat-Driven Analysis and Defense, Andrew Martin, Michael Hausenblas, O'Reilly, October 2021
- *Kubernetes Best Practices: Blueprints for Building Successful Applications on Kubernetes*, Brendan Burns, Eddie Villalba, Dave Strebel and Lachlan Evenson, O'Reilly 2020

Creating a lab is not expensive

I use ordinary IT-equipment like switches, PCs and servers, with some additional 10Gbps network devices – nothing really special running Debian Linux

The main purposes for showing this box, is to show

- These are standard network devices, bought the Arista 7150 24-port 10G used on ebay
- This specific switch does VXLAN VTEP and BGP, which I use in my labs
- OpenBSD which I use for routing also has built-in VXLAN and BGP

You should have similar (or better) devices in your production network, and they can be configured to do a LOT more than you use them for right now

Before your first K8s Production Deployment

- Run K8s locally, as in your laptop! Easy to do on most platforms
- Get it up and running, deploy a sample container
- Configure 🔧 `kubectl`

I don't remember when I ran K8s first, or how many times I have run it locally or in various example labs on the internet. Recently I ran some K8s BGP labs in my browser

Trying out K8s on your laptop:

- Smallest demo with single node minikube running inside Debian 11 "start and run a hello world"
- Next one might be multiple VMs running K8s nodes – multi node with OpenBSD VM for BGP
- I can run all of this inside Qubes as HVM

Kubernetes: Production-Grade Container Orchestration

> Kubernetes, also known as K8s, is an open-source system for automating deployment, scaling, and management of containerized applications.
>
> It groups containers that make up an application into logical units for easy management and discovery. Kubernetes builds upon 15 years of experience of running production workloads at Google, combined with best-of-breed ideas and practices from the community.

Source: https://kubernetes.io/

Basics:

- Create Cluster, Deploy App, Expose your app, Scale up, Update your app
- Plus a thousand buzz words – scaling, micro-services,

Don't get me wrong, I really like Kubernetes!

K8s Run Programs, Processes and Applications

> Kubernetes is a platform for creating, deploying, and managing distributed applications. These applications come in many different shapes and sizes, but ultimately, they are all comprised of one or more programs that run on individual machines.

Source: *Kubernetes: Up and Running*, 3rd Edition, Brendan Burns, Joe Beda, Kelsey Hightower

- Containers – running processes and container images
- Interfaces API – management interfaces are of special interest, including things like Service accounts
- Ports and Services – running applications, what is exposed
- **K8s security is software security**

Initial security advice, read the documentation

Learn Kubernetes Basics

- Apply Pod Security Standards at the Cluster Level
- Apply Pod Security Standards at the Namespace Level
- Restrict a Container's Access to Resources with AppArmor
- Restrict a Container's Syscalls with seccomp

Source: tutorial linked from front page of https://kubernetes.io/, https://kubernetes.io/docs/tutorials/kubernetes-basics/

- I like that security is listed within the first tutorial!
- This links to further documentation
- Security is also being added continuously

Pod Security Standards (PSA)

Pod Security Standards

The Pod Security Standards define three different *policies* to broadly cover the security spectrum. These policies are *cumulative* and range from highly-permissive to highly-restrictive. This guide outlines the requirements of each policy.

Profile	Description
Privileged	Unrestricted policy, providing the widest possible level of permissions. This policy allows for known privilege escalations.
Baseline	Minimally restrictive policy which prevents known privilege escalations. Allows the default (minimally specified) Pod configuration.
Restricted	Heavily restricted policy, following current Pod hardening best practices.

Source: https://kubernetes.io/docs/concepts/security/pod-security-standards/

- Note: versions from 1.23, with varying features added later
  "Pod Security admission (PSA) is enabled by default in v1.23 and later, as it graduated to beta."

Restricting the Kubernetes API

By default, the Kubernetes API server listens on port 6443 on the first non-localhost network interface, protected by TLS. In a typical production Kubernetes cluster, the API serves on port 443. The port can be changed with the –secure-port, and the listening IP address with the –bind-address flag.

...

If your cluster uses a **private certificate authority, you need a copy of that CA certificate configured into your /.kube/config on the client**, so that you can trust the connection and be confident it was not intercepted.

- If an attacker can run Kubectl with credentials – they can do anything
- Defense in Depth is suggested – so restrict at multiple levels
- Only allow connections from specific network – firewall filtering
- Use TLS and verify/copy certificates

Security From low level and outside

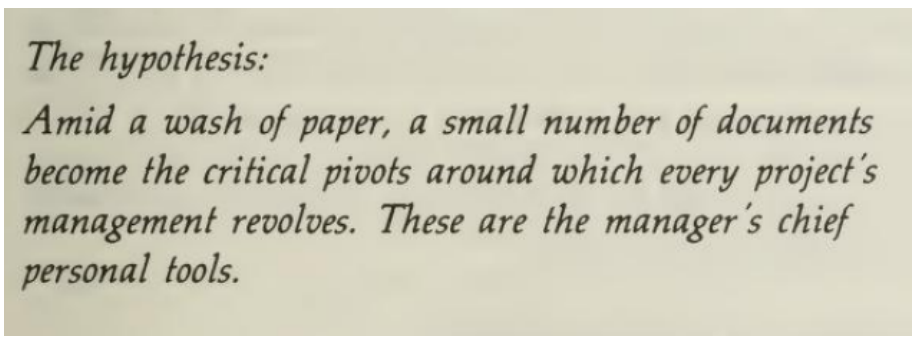
Now you have built a cluster – great, is it secure? Does it even work, can you run it?

Keeping it short on purpose:

- Hardware - DRAC, ILO, KVM, IPMI etc.
- Connections - how to connect your clusters
- Have some jump host, perhaps OpenBSD with wireguard VPN

Consider threats and access from the outside and inwards, from bottom and upwards

Document or it didn't happen

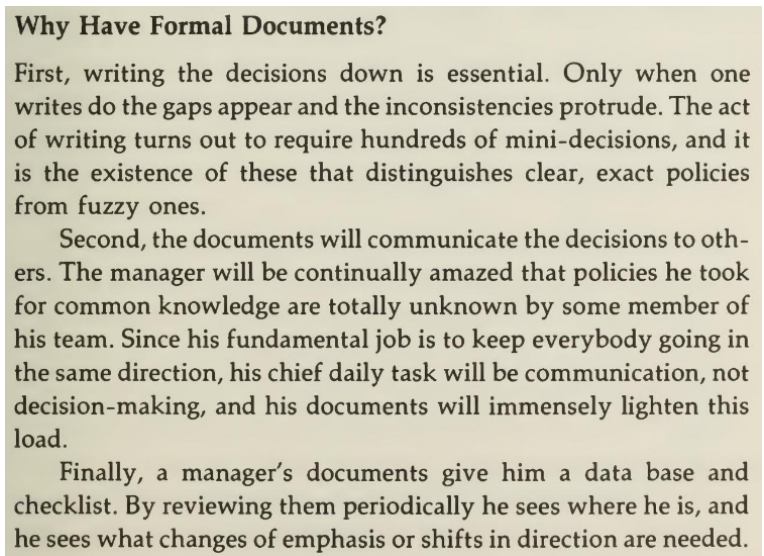


The hypothesis:

Amid a wash of paper, a small number of documents become the critical pivots around which every project's management revolves. These are the manager's chief personal tools.

- Make sure to document!
- There are so many parts, so many decisions, soo many places thing can mess up
- Have a minimum of documentation – and the YAML files are not enough
- Hint: you can read the Mythical Man Month at https://archive.org/details/MythicalManMonth

Why Have Formal Documents



Why Have Formal Documents?

First, writing the decisions down is essential. Only when one writes do the gaps appear and the inconsistencies protrude. The act of writing turns out to require hundreds of mini-decisions, and it is the existence of these that distinguishes clear, exact policies from fuzzy ones.

Second, the documents will communicate the decisions to others. The manager will be continually amazed that policies he took for common knowledge are totally unknown by some member of his team. Since his fundamental job is to keep everybody going in the same direction, his chief daily task will be communication, not decision-making, and his documents will immensely lighten this load.

Finally, a manager's documents give him a data base and checklist. By reviewing them periodically he sees where he is, and he sees what changes of emphasis or shifts in direction are needed.

Source: *The Mythical Man-Month (Anniversary Edition)* by Frederick P. Brooks Jr.

- I use Git version control for my documentation purposes, some is in Zim Personal Wiki https://zim-wiki.org/
- I also use an IPAM https://spritelink.github.io/NIPAP/

Role-based Access Control (RBAC)

One thing you should document, create a policy for is access and permissions.

> In computer systems security, **role-based access control (RBAC)**[1][2] or role-based security[3] is an approach to restricting system access to unauthorized users. It is used by the majority of enterprises with more than 500 employees,[4] and can implement mandatory access control (MAC) or discretionary access control (DAC).
>
> Role-based access control (RBAC) is a policy-neutral access-control mechanism defined around **roles and privileges**. The components of RBAC such as role-permissions, user-role and role-role relationships make it simple to perform user assignments. A study by NIST has demonstrated that RBAC addresses many needs of commercial and government organizations[citation needed]. RBAC can be used to facilitate administration of security in large organizations with hundreds of users and thousands of permissions. Although RBAC is different from MAC and DAC access control frameworks, it can enforce these policies without any complication.

Quote from https://en.wikipedia.org/wiki/Role-based_access_control

New to RBAC?

To get an idea about roles, permissions within software projects, you can use Github as an example.

- Go to GitHub web page:
  https://help.github.com/en/articles/access-permissions-on-github
- Follow links to other pages, like:
  https://help.github.com/en/articles/permission-levels-for-an-organization
- Your K8s deployment might need more than this, but it is a nice starting point

Kubernetes Initial RBAC

> The `admin.conf` file gives the user superuser privileges over the cluster. This file should be used sparingly. For normal users, it's recommended to generate an unique credential to which you grant privileges. You can do this with the `kubeadm alpha kubeconfig user --client-name <CN>` command. That command will print out a KubeConfig file to STDOUT which you should save to a file and distribute to your user. After that, grant privileges by using `kubectl create (cluster)rolebinding`.

- Right after install you can run `kubectl` – great
- Age old advice do not use shared administration accounts – have individual accounts

Adding administrators

```
kubeadm config print init-defaults > kubeadm.conf
kubeadm kubeconfig user --client-name=hlkadmin --config=kubeadm.conf > hlkadmin.conf
```

- I would recommend having multiple configs, even for yourself
- hlkadmin config used for administration
- hlkdeploy for deploying
- hlktester maybe even a testing user
- Read more about https://kubernetes.io/docs/reference/access-authn-authz/rbac/
- Not any worse than configuring a root user and personal users, with Sudo or Doas

RBAC, groups and Namespace

Kubernetes starts with three initial namespaces:

* default The default namespace for objects with no other namespace
* kube-system The namespace for objects created by the Kubernetes system
* kube-public This namespace is created automatically and is readable by all users (including those not authenticated).

Source: https://kubernetes.io/docs/tasks/administer-cluster/namespaces/

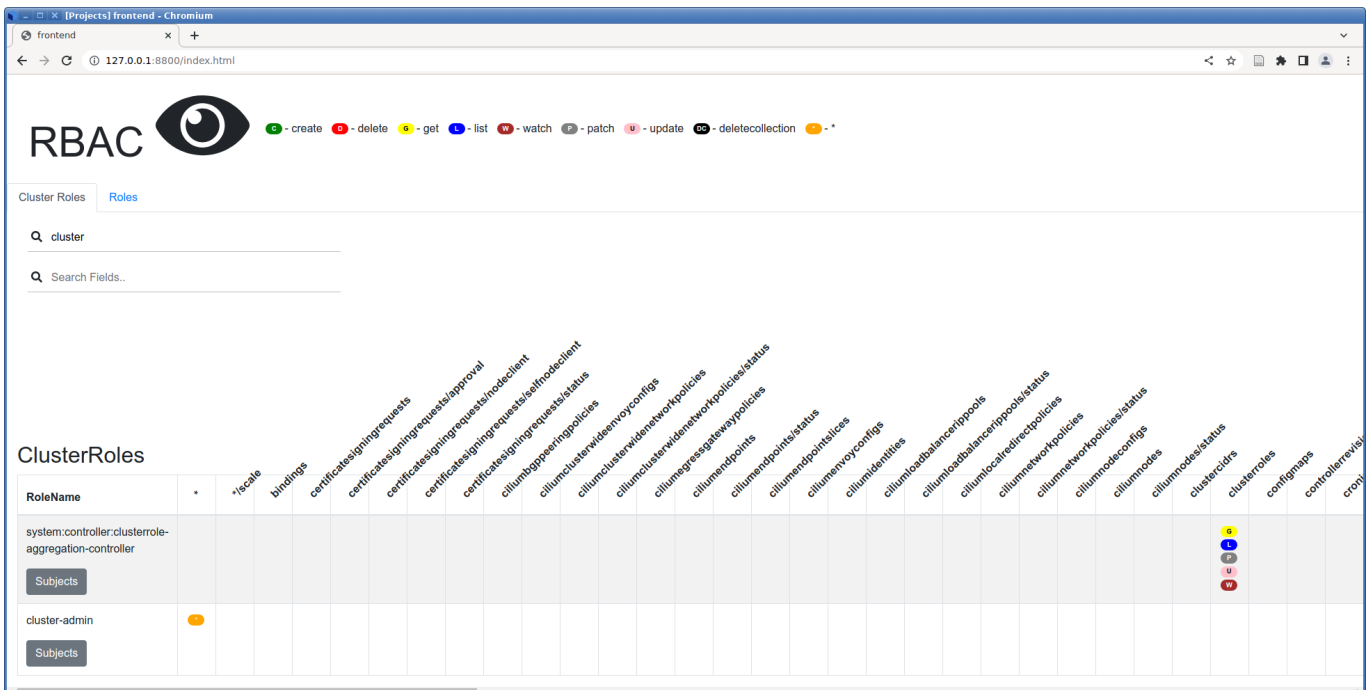
- I like namespaces, easy way to isolate stuff
- Allow for quotas – don't allow a test application to use all resources
- Easy network segregation – network policies
- Allows easy data isolation – who can access sensitive data
- I recommend groups, namespaces and roles for granting access – **do not grant permission to named users!**

Installing tools and plugins

```
hlk@k8s-1:~$ kubectl krew update
Updated the local copy of plugin index.
hlk@k8s-1:~$ kubectl krew install rbac-view
Updated the local copy of plugin index.
Installing plugin: rbac-view
Installed plugin: rbac-view
\
 | Use this plugin:
 |         kubectl rbac-view
 | Documentation:
 |         https://github.com/jasonrichardsmith/rbac-view
 | Caveats:
 | \
 |  | Run "kubectl rbac-view" to open a browser with an html view of your permissions.
 | /
/
```

- "This project is considered prerelease and is under active development."
- What I have found in many books – tools, hints and tips, above from:
  Hacking Kubernetes: Threat-Driven Analysis and Defense, Andrew Martin, Michael Hausenblas

Example tool RBAC-view



https://github.com/jasonrichardsmith/rbac-view

RBAC Audit tools

Multiple tools exist – I most often only link open source tools in my presentations, feel free to suggest others

- 🔧 `rbac-view` – view RBAC data interactively and search as shown above https://github.com/jasonrichardsmith/rbac-view via:
  Hacking Kubernetes: Threat-Driven Analysis and Defense, Andrew Martin, Michael Hausenblas
- 🔧 `rback` – generates a graph representation (in Graphviz dot format) of a Kubernetes cluster's RBAC settings https://github.com/team-soteria/rback
- 🔧 `rbac-tool` – A collection of Kubernetes RBAC tools to sugar coat Kubernetes RBAC complexity https://github.com/alcideio/rbac-tool via Rapid7
- 🔧 `KubiScan` – a tool by Eviatar Gerzi to scan Kubernetes cluster for risky RBAC permissions https://github.com/cyberark/KubiScan
- 🔧 `krane` – a Kubernetes RBAC static analysis and visualisation tool https://github.com/appvia/krane
- What is best current practice? More tools and articles available at: https://rbac.dev/

You MUST control your permissions, so find the tools that work for you!

Network parts

Lets move to networking and CNI plugin alternatives

- Container Network Interface (CNI) and Cloud Native Computing Foundation (CNCF) project https://github.com/containernetworking/cni
- Multiple options – popular and common ones Calico, Flannel, Weave and Cilium
- Calico - available multiple places
- What does changing CNI plugin bring? and importantly what do you need!
- Usually some tunneling and encapsulation between nodes, VXLAN, IP in IP
- Allow dynamic routing like Border Gateway Protocol (BGP)
- Often more advanced features for filtering, observability, ...
- Cilium - I have followed Cilium for a while, so I choose that

Compare CNI Features

CNI	Encryption	Network Policies
Calico	No	Ingress + Egress
Canal	No	Ingress + Egress
Cilium	Yes	Ingress + Egress
Flannel	No	No
Kube-router	No	Ingress only
WeaveNet	Yes	Ingress + Egress

Source: *Learn Kubernetes Security* (LKS), Kaizhe Huang , Pranjal Jumde

- Can you live with kube-router really, probably not

Compare CNI Performance

CNI Benchmark August 2020 infraBuilder	Config	Performances (bandwidth)				Resources consumption (cpu/ram)					Security features			
	MTU	Pod to Pod		Pod to Service		Idle	Pod to Pod		Pod to Service		Network Policies		Encryption	
	setting	TCP	UDP	TCP	UDP	none	TCP	UDP	TCP	UDP	in	out	activation	Performance
Antrea	auto	Very fast	Very fast	Very fast	Slow	Low	Low	Low	Low	Low	yes	yes	at deploy time	Slow
Calico	manual	Very fast	Very fast	Very fast	Fast	Low	Very low	Very low	Very low	Very low	yes	yes	anytime	Very fast
Canal	manual	Very fast	Very fast	Very fast	Very fast	Low	Very low	Very low	Very low	Very low	yes	yes	no	n/a
Cilium	auto	Fast	Very fast	Very fast	Very fast	High	High	High	High	High	yes	yes	at deploy time	Slow
Flannel	auto	Very fast	Very fast	Very fast	Very fast	Very low	Very low	Very low	Very low	Very low	no	no	no	n/a
Kube-OVN	auto	Fast	Very slow	Fast	Very slow	High	High	High	High	High	yes	yes	no	n/a
Kube-router	none	Slow	Very slow	Slow	Very slow	Low	Very low	Low	Very low	Low	yes	yes	no	n/a
Weave Net	manual	Very fast	Very fast	Very fast	Fast	Very low	Low	Low	Low	Low	yes	yes	at deploy time	Slow

Source: https://platform9.com/blog/the-ultimate-guide-to-using-calico-flannel-weave-and-cilium/

- What is most important for you, features or performance? I cannot tell you which CNI to choose!

Installing Cilium

```
helm repo add cilium https://helm.cilium.io/

API_SERVER_IP=<your_api_server_ip>
# Kubeadm default is 6443
API_SERVER_PORT=<your_api_server_port>
helm install cilium cilium/cilium --version 1.12.5 \
    --namespace kube-system \
    --set kubeProxyReplacement=strict \
    --set k8sServiceHost=${API_SERVER_IP} \
    --set k8sServicePort=${API_SERVER_PORT}
```

- Note: I ended up deciding to run without the kube-proxy, only Cilium
- Document!

Document what you did, what it did

```
cilium install --version=1.13.0-rc4 \
               --helm-set ipam.mode=kubernetes --helm-set tunnel=disabled \
               --helm-set ipv4NativeRoutingCIDR="10.0.0.0/8" --helm-set bgpControlPlane.enabled=true \
               --helm-set k8s.requireIPv4PodCIDR=true --helm-set kube-proxy-replacement=strict
   Using Cilium version 1.13.0-rc4
  Auto-detected cluster name: kubernetes
  Auto-detected datapath mode: tunnel
  Auto-detected kube-proxy has not been installed
   Cilium will fully replace all functionalities of kube-proxy
   helm template --namespace kube-system cilium cilium/cilium --version 1.13.0-rc4 --set bgpControlPlane.enabled=true,
cluster.id=0,cluster.name=kubernetes,encryption.nodeEncryption=false,ipam.mode=kubernetes,
ipv4NativeRoutingCIDR=10.0.0.0/8,k8s.requireIPv4PodCIDR=true,k8sServiceHost=10.137.0.26,
k8sServicePort=6443,kube-proxyreplacement=strict,kubeProxyReplacement=strict,operator.replicas=1,
serviceAccounts.cilium.name=cilium,serviceAccounts.operator.name=cilium-operator,tunnel=disabled
...
  Waiting for Cilium to be installed and ready...
  Cilium was successfully installed! Run 'cilium status' to view installation health
```

How I ran the kubeadm for building cluster - note the skip:

```
sudo kubeadm init --pod-network-cidr=10.50.0.0/16 --skip-phases=addon/kube-proxy
```

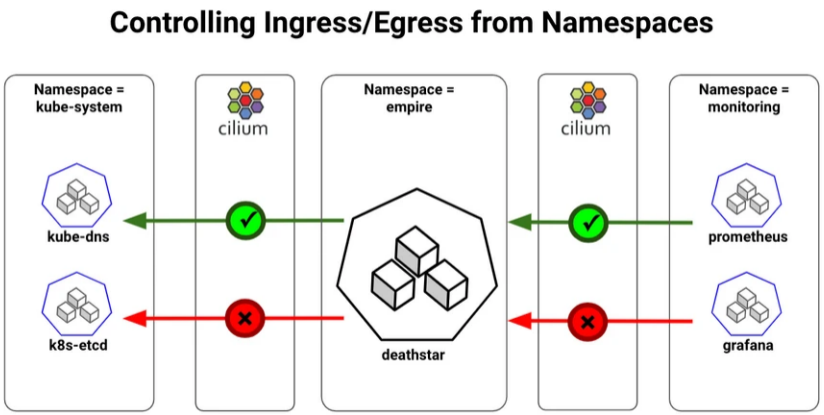
After install Cilium

```
root@k8s-1:~# kubectl get po -n kube-system
NAME                                READY   STATUS    RESTARTS       AGE
cilium-2287c                        1/1     Running   1 (161m ago)   3d
cilium-9kjhv                        1/1     Running   1 (160m ago)   3d
cilium-operator-5589744cf4-7mwqx    1/1     Running   1 (160m ago)   3d
coredns-f74b98ccc-4hg4n             1/1     Running   1 (161m ago)   3d
coredns-f74b98ccc-ts55j             1/1     Running   1 (160m ago)   3d
etcd-k8s-1                          1/1     Running   4 (161m ago)   5d
kube-apiserver-k8s-1                1/1     Running   4 (161m ago)   5d
kube-controller-manager-k8s-1       1/1     Running   4 (161m ago)   5d
kube-scheduler-k8s-1                1/1     Running   4 (161m ago)   5d
```

Cilium CLI tool

- Many tools are executed via `kubectl`
- Others have their own command
- This can be very confusing, and again – document which tools you use!
- Having a jump host with updated tools installed might help – helps me!

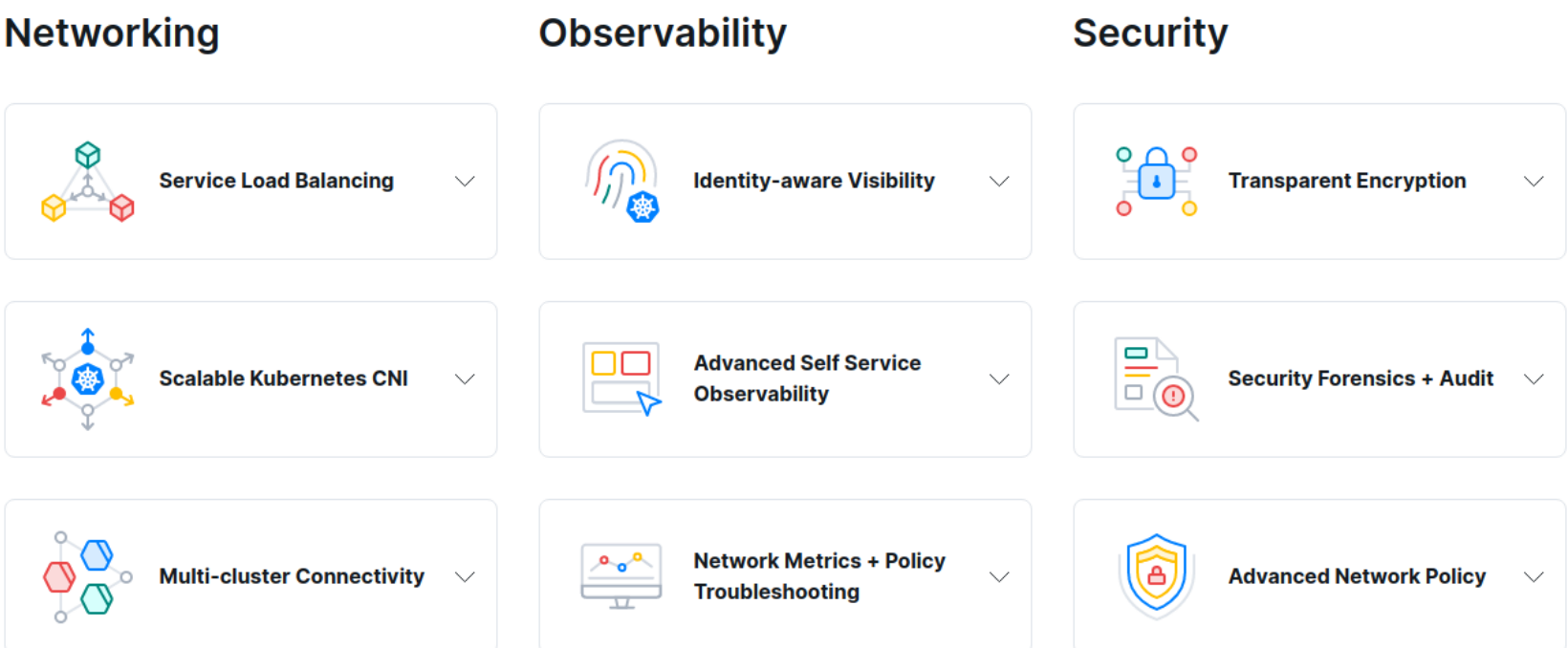
Cilium overview



Kubernetes provides Network Policies for controlling traffic going in and out of the pods. Cilium implements the Kubernetes Network Policies for L3/L4 level and extends with L7 policies for granular API-level security for common protocols such as HTTP, Kafka, gRPC, etc

Source: picture and text from https://cilium.io/blog/2018/09/19/kubernetes-network-policies/

Security is more than blocking!



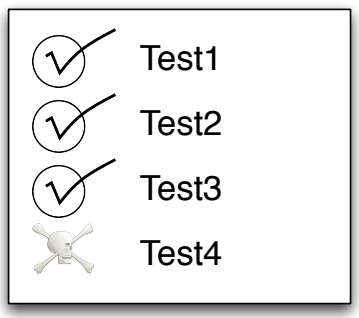
- A lot of features relate to *security*

Testing Connectivity

Cilium has a very nice built-in connectivity test:

```
root@k8s-1:~# cilium connectivity test
   Monitor aggregation detected, will skip some flow validation steps
  [kubernetes] Creating namespace cilium-test for connectivity check...
  [kubernetes] Deploying echo-same-node service...
  [kubernetes] Deploying DNS test server configmap...
  [kubernetes] Deploying same-node deployment...
  [kubernetes] Deploying client deployment...
  [kubernetes] Deploying client2 deployment...
  [kubernetes] Deploying echo-other-node service...
  [kubernetes] Deploying other-node deployment...
  [kubernetes] Waiting for deployments [client client2 echo-same-node] to become ready...
  [kubernetes] Waiting for deployments [echo-other-node] to become ready...
...
  All 31 tests (232 actions) successful, 0 tests skipped, 0 scenarios skipped.
root@k8s-1:~#
```

Checking your Kubernetes deployment



- It can actually be hard to check your Kubernetes installation
- Especially networking in detail
- I would recommend spending a little time investigating Maximum Transmission Unit (MTU) https://en.wikipedia.org/wiki/Maximum_transmission_unit
- Your devices – switches and network cards can probably also offload some features to hardware
- Advanced users could dive deeper into *BPF and XDP Reference Guide* https://docs.cilium.io/en/latest/bpf/

External IPs

Jumping directly in, I am running on bare metal. Getting external access into K8s is a bit hard. I decided to use Cilium, BGP, and IP pools

```
$ cat pool-zencurity.yaml
---
apiVersion: "cilium.io/v2alpha1"
kind: CiliumLoadBalancerIPPool
metadata:
  name: "pool"
spec:
  cidrs:
  - cidr: "185.129.62.144/28"
  - cidr: "2a06:d380:0:85::0/64"
```

- https://docs.cilium.io/en/latest/network/lb-ipam/
- I run a LIR (Local Internet Registry) with network AS57860 which have these addresses
- I have successfully connected Cilium with BGP to OpenBSD and Arista, it works nicely!

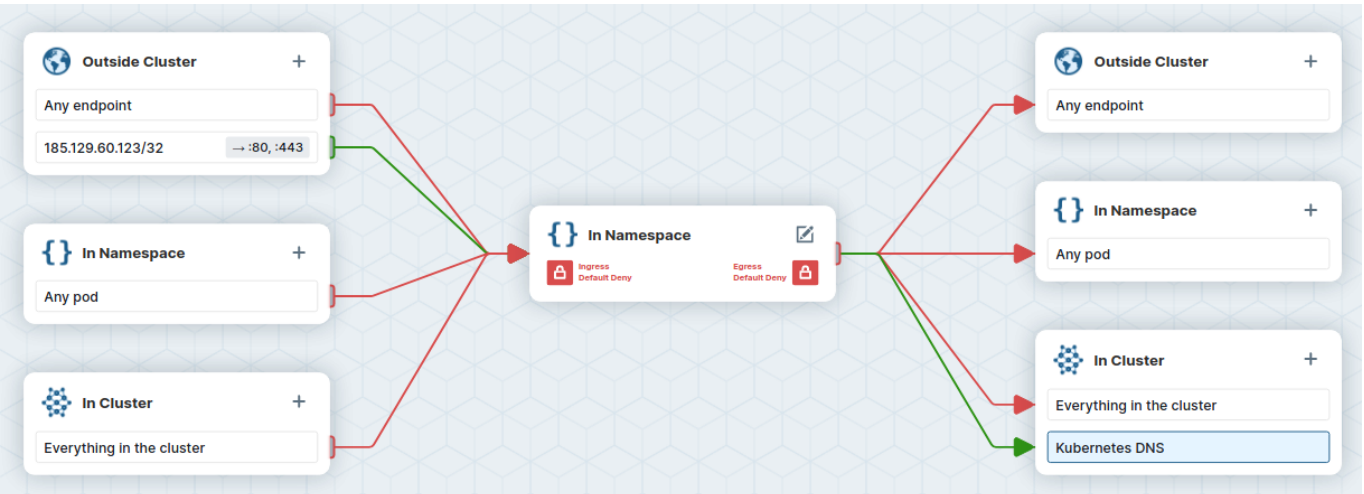
Result in my setup

```
root@k8s-1:/home/hlk/bin# k get svc
NAME           TYPE           CLUSTER-IP      EXTERNAL-IP      PORT(S)          AGE
kubernetes     ClusterIP      10.96.0.1       <none>           443/TCP          5d
service-test   LoadBalancer   10.108.127.95   185.129.62.154   1234:30378/TCP   4d22h
```

References that were useful:

- https://sue.eu/blogs/expose-loadbalanced-kubernetes-services-with-bgp-cilium/
- https://nicovibert.com/2022/07/21/bgp-with-cilium/
- https://isovalent.com/resource-library/labs/ - has labs where you can try running BGP

Network Policy Editor for Kubernetes



- Nice Editor for Policies https://editor.cilium.io/
- Recommendation: always specify a Network Policy - be specific, who CAN access
- Make positive lists - as normally only a limited number of other resources will need access
- Then also make sure to specify an egress policy - so both ingress and egress rules

Example Network Policy

```
apiVersion: networking.k8s.io/v1
kind: NetworkPolicy    see more at https://docs.cilium.io/en/v1.8/concepts/kubernetes/policy/
metadata:
  name: example-policy
spec:
  podSelector:
  policyTypes:
    - Egress
  ingress:
    - from: - ipBlock: cidr: 185.129.60.123/32
      ports:
        - port: 80
        - port: 443
  egress:
    - to:
        - namespaceSelector:
          podSelector:
            matchLabels:
              k8s-app: kube-dns
      ports:
        - port: 53          protocol: UDP
```

Cilium for Host Firewall

Deploy Cilium release via Helm:

```
helm install cilium ./cilium   --namespace kube-system  --set hostFirewall.enabled=true    --set devices='ethX,ethY'
```

The devices flag refers to the network devices Cilium is configured on such as eth0. Omitting this option leads Cilium to auto-detect what interfaces the host firewall applies to.

At this point, the Cilium-managed nodes are ready to enforce network policies.

Source: https://docs.cilium.io/en/latest/security/host-firewall/

- I find it cleaner to use Cilium for all network policies, ignoring IPtables
- You need only a few CiliumClusterwideNetworkPolicy resources defined for the cluster to work, and then you can allow Secure Shell from only a few places
- Note: While booting there might be a very short time where Cilium is starting, where packets are allowed YMMV

Monitoring and updating – upgrades

Since Kubernetes is a complex system, I recommend making an initial deployment plan which is longer than a release cycle of Kubernetes. Currently new releases are coming out rapidly, so a 3-4 month plan should suffice.
Main goal is to try upgrading the cluster *before* you have production running!

https://kubernetes.io/releases/

You need to upgrade all parts, so remember which parts you use:

- Firmwares and supporting systems, routers, switches, server control, storage, ...
- Operating systems
- Kubernetes core components
- Cilium upgrade and various other plugins

Performing upgrades

When rolling out an upgrade with Kubernetes, Kubernetes will first terminate the pod followed by pulling the new image version and then finally spin up the new image. In order to reduce the downtime of the agent and to prevent ErrImagePull errors during upgrade, the pre-flight check pre-pulls the new image version.

```
root@gouda01:~# cilium upgrade
  Auto-detected datapath mode: tunnel
  Upgrading cilium-operator to version quay.io/cilium/operator-generic:v1.12.5...
  Upgrading cilium to version quay.io/cilium/cilium:v1.12.5...
  Waiting for Cilium to be upgraded...
```

- Cilium recommend a pre-flight check – pulls images beforehand etc: https://docs.cilium.io/en/v1.12/operations/upgrade/
- A good example of how to prepare upgrades

Resource monitoring and capacity planning

Metrics A series of numbers measured over a period of time

Logs Used for exploratory analysis of a system

Source: *Kubernetes Best Practices: Blueprints for Building Successful Applications on Kubernetes*, Brendan Burns, Eddie Villalba, Dave Strebel and Lachlan Evenson, O'Reilly 2020

- The book is mostly interested in poorly performing applications, but the same data is used in security
- I always install Kubernetes dashboard, and I am going to use 🔧 `Prometheus` a lot more

Security monitoring and auditing

Why isn't K8s secure?!

We will cover the following topics in this chapter:

- The path traversal issue in kubectl cp—CVE-2019-11246
- The DoS issue in JSON parsing—CVE-2019-1002100
- The DoS issue in YAML parsing—CVE-2019-11253
- The privilege-escalation issue in role parsing—CVE-2019-11247
- Scanning known vulnerabilities using 🔧 `kube-hunter`

Source: Chapter 13 *Learn Kubernetes Security* (LKS), Kaizhe Huang , Pranjal Jumde, Packt, July 2020

TL;DR look at previous problems – which ones would have hurt our design and architecture?

Intrusion Detection on Kubernetes

Chapter 9. Intrusion Detection

In this chapter we will see how container intrusion detection operates with the new low-level eBPF interface, what forensics looks like for a container, and how to catch attackers who have evaded all other controls.

Source: *Hacking Kubernetes: Threat-Driven Analysis and Defense*, Andrew Martin, Michael Hausenblas, O'Reilly, October 2021

- Tool they present is Falco an eBPF-Based IDS
- They also mention my favourites Zeek https://zeek.org/ and Suricata https://suricata.io/
- I recommend doing your usual, and then evaluate options

Tools that might help

- 🔧 `Falco` detect anomalous behaviour, have not tried it yet
- 🔧 `Prometheus grafana elasticsearch` - usual suspects, keep it short
- 🔧 `Netflow` and `Elastiflow` generic netflow collect information about traffic flows

Cloud and Container Forensics

I am definitely not an expert here!

> Tools like kube-forensics "create checkpoint snapshots of the state of running pods for later off-line analysis," so malicious workloads can be dumped and killed, and the system returned to use.

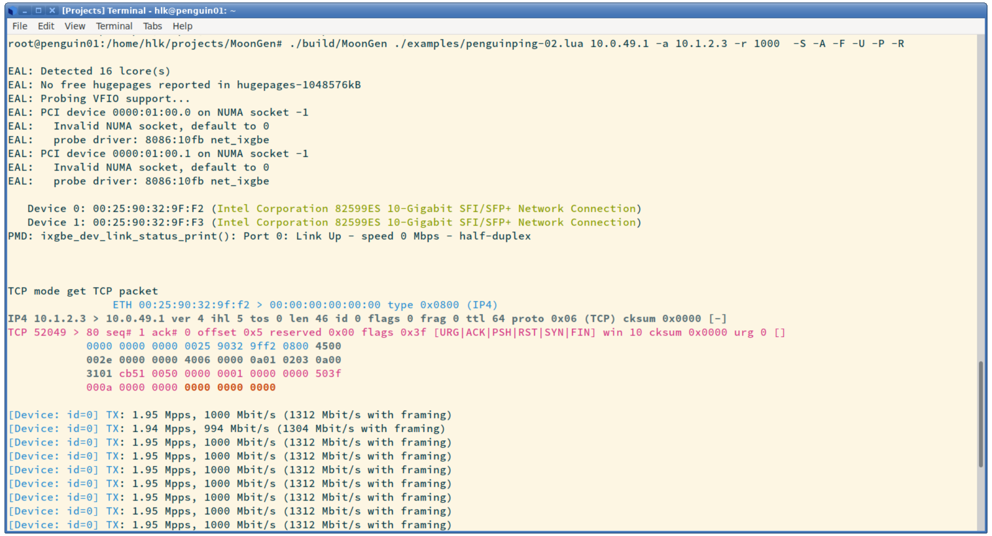
Source: *Hacking Kubernetes: Threat-Driven Analysis and Defense*, Andrew Martin, Michael Hausenblas, O'Reilly, October 2021

- Sysdig - advanced logging and inspection
- 🔧 `sysdig` and 🔧 `sysdig-inspect` https://github.com/draios/sysdig https://github.com/draios/sysdig-inspect

Monitoring Networking

- Cilium has Setting up Hubble Observability
  https://docs.cilium.io/en/stable/gettingstarted/hubble_setup/#hubble-setup
- Attack types DDoS slow and fast, volumetric and PPS based
- Pro/cons with having another layer - manually configured, only allow few protocols and ports 80, 443, 8080
- If you have allow lists only, you will reduice noise

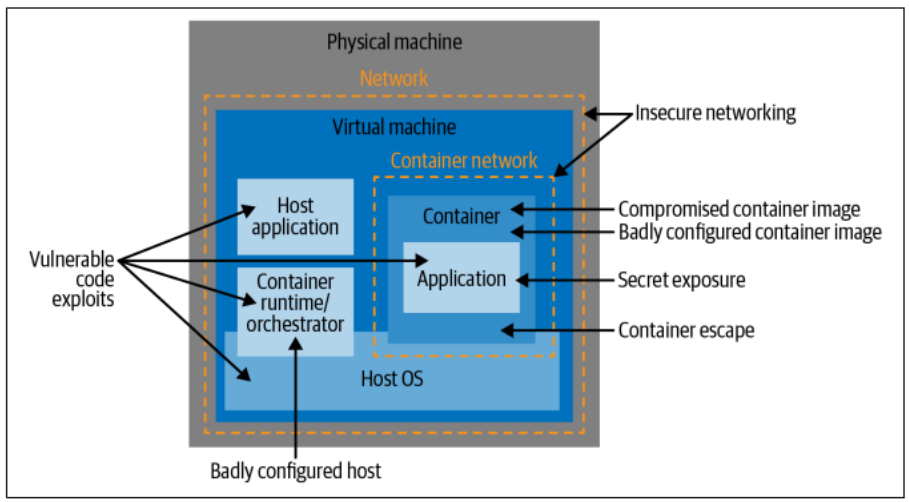
Stress testing and DDoS



- PenguinPing packet generator, my high speed packet generator home page: https://penguinping.org
- First versions are only about 230 lines of Lua code and implement basic command line to replace hping3
- Built on top of MoonGen/libmoon https://github.com/emmericp/MoonGen

Extremely fast and allows easy customization

Kubernetes Security is more than just the core



Source: *Container Security*, (CS) Liz Rice, O'Reilly, Apr 2020

- Attacks from inside, attacks inside containers
- Some just use up resources, some attacks others, some attack the system from the inside
- Hacking Kubernetes have a whole *Chapter 3 Container Runtime Isolation*

Harden Container Images and Update Your Procedures

- Change the goddamn passwords!
  Container postgresql with user postgres and password *postgres*, REALLY!!!!!!1111
- and NO MORE ROOT! Dont run as root, we realized this was bad in the 1990s!
- CIS Docker Benchmarking also Learn Kubernetes Security *Chapter 8: Securing Kubernetes Pods*
- Hacking Kubernetes *Chapter 8: Policy* - describe things like Resource Quotas, Runtime Policies

Recommendations from CIS Docker Benchmark

Container Images and Build File Configuration

Container base images and the build files used to create them dictate what is inside a container and how it operates. Ensure your base images and build files are safe and trusted. Here are CIS recommendations for images.

Configuration Element	Recommendations
Permissions	1. Create a user for the container 2. Remove setuid and setgid permissions
Container content	1. Avoid unnecessary packages in the container 2. Only install verified packages 3. Define HEALTHCHECK instructions for the container 4. Enable content trust for Docker
Images	1. Only use trusted base images 2. Perform security scans on images 3. Rebuild images to include security patches
Dockerfiles	1. Ensure update instructions are not use alone 2. Use COPY instead of ADD 3. Do not store secrets in Dockerfiles

Summary from: https://www.aquasec.com/cloud-native-academy/docker-container/docker-cis-benchmark/

- Latest version: CIS Docker Benchmark v1.5.0 - 12-28-2022

Benchmarking tools

🔧 `Kube-bench` is the industry-standard tool to automate checking Kubernetes compliance with the Center for Internet Security (CIS) Benchmark.

Kube-bench makes it easy for operators to check whether each node in their Kubernetes cluster is configured according to security best practices.

Source: https://info.aquasec.com/open-source

- CIS Kubernetes V1.24 Benchmark v1.0.0 - 09-21-2022 – other versions exist
- CIS Docker Benchmark v1.5.0 - 12-28-2022

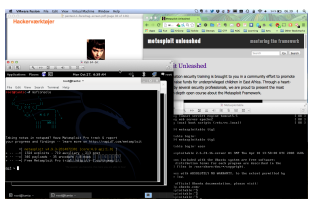
Tool example kube-bench

```
hlk@timon:~/bin/kube-bench/kube-bench$ kubectl logs kube-bench-gdf62
[PASS] 1.1.7 Ensure that the etcd pod specification file permissions are set to 600 or more restrictive (Automated)
[PASS] 1.1.8 Ensure that the etcd pod specification file ownership is set to root:root (Automated)
[WARN] 1.1.9 Ensure that the Container Network Interface file permissions are set to 600 or more restrictive (Manual)
[WARN] 1.1.10 Ensure that the Container Network Interface file ownership is set to root:root (Manual)
[PASS] 1.1.11 Ensure that the etcd data directory permissions are set to 700 or more restrictive (Automated)
[FAIL] 1.1.12 Ensure that the etcd data directory ownership is set to etcd:etcd (Automated)
...
== Summary policies ==
0 checks PASS
0 checks FAIL
35 checks WARN
0 checks INFO

== Summary total ==
63 checks PASS
10 checks FAIL
58 checks WARN
0 checks INFO
```

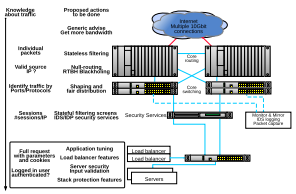
- https://github.com/aquasecurity/kube-bench also check out Lynis https://cisofy.com/lynis/

Kubernetes lab setup – proof of concept



- Hardware: any modern PC with modern CPU and virtualisation
  Don't forget to enable it in the BIOS
- Software: your favourite Linux distribution, I choose Debian
- Container software: pick your poison
- Hacker software: Kali as a Virtual Machine https://www.kali.org/
- Smallest Kubernetes: Minikube - I run this on Debian 11
- Production deployment probably would use better tools like 🔧 `Kubeadm`

Conclusion Kubernetes Security



- It is hard!
- Multiple books have checklist – depending on your interests, some for developers, some for ops
- Example: Hacking Kubernetes chapter 10. has good advice too, including a small checklist for On-Premises Environments links on p249 to Build K8s Bare-metal cluster with external access
  https://medium.com/swlh/on-premise-kubernetes-clusters-b36660ca6914
  https://www.datapacket.com/blog/build-kubernetes-cluster
  https://medium.com/@apiotrowski312/bare-metal-kubernetes-with-helm-rook-ingress-prometheus-grafana-6a74857cc74

Questions?

Henrik Kramselund he/him han/ham hlk@zencurity.com @kramse

You are always welcome to send me questions later via email

Mobile: +45 2026 6000

Email: hlk@zencurity.com

Books and educational materials

We could keep recommending books, articles, papers and official documentation. These are examples, and even if some details are changed, may be good to read

- *Kubernetes Security and Observability* Brendan Creane, Amit Gupta Mastering Kubernetes, **Third Edition**, Gigi Sayfan, Packt 2020
- *kubectl: Command-Line Kubernetes in a Nutshell*, Rimantas Mocevicius, Packt, 2020
- *The Kubernetes Workshop*,Zachary Arnold, Sahil Dua, Wei Huang, Faisal Masood, Melony Qin, and Mohammed Abu Taleb, Packt, 2020
- *Kubernetes A Complete DevOps Cookbook*, Murat Karslioglu, Packt, 2020
- *Cloud Native with Kubernetes*, Alexander Raul, Packt, 2020
- *Kubernetes and Docker – An Enterprise Guide*, Scott Surovich, Marc Boorshtein, Packt, 2020
- *Kubernetes in Production Best Practices: Build and manage highly available production-ready Kubernetes clusters*, Aly Saleh, Murat Karslioglu, Packt 2021

These are the ones I selected for *my Kubernetes education* some via a Humble Ultimate Devops bundle

Linux and Internet Resources

Let's face it, K8s is Unix, so basic Linux and Internet Security resources help too:

- *The Linux Command Line: A Complete Introduction*, 2nd Edition
  by William Shotts, internet edition https://sourceforge.net/projects/linuxcommand
- *Gray Hat Hacking: The Ethical Hacker's Handbook*, 5. ed. Allen Harper and others ISBN: 978-1-260-10841-5
- *Defensive Security Handbook: Best Practices for Securing Infrastructure*, Lee Brotherston, Amanda Berlin ISBN: 978-1-491-96038-7 284 pages
- *Web Application Security*, Andrew Hoffman, 2020, ISBN: 9781492053118
- *Practical Packet Analysis, Using Wireshark to Solve Real-World Network Problems* by Chris Sanders, 3rd ed, ISBN: 978-1-59327-802-1

We teach using these books and others! Diploma in IT-security at KEA Kompetence
https://zencurity.gitbook.io/