

National College of Ireland

Project Submission Sheet

Student Name: Abhishek Murari Sharma

Student ID: X23406461

Programme: MSCCLOUDJAN25AO **Year:** 2025

Module: MSc Research Project

Lecturer: Prof. Shreyas Setlur Arun

Submission Due Date: 11/12/2025

Project Title: Securing Multi-tenant Kubernetes Cluster Using eBPF

Word Count:

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Signature: Abhishek Murari Sharma

Date: 11/12/2025

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AI Acknowledgement Supplement

MSc Research Project

Securing Multi tenant Kubernetes Cluster using eBPF

Your Name/Student Number	Course	Date

This section is a supplement to the main assignment, to be used if AI was used in any capacity in the creation of your assignment; if you have queries about how to do this, please contact your lecturer. For an example of how to fill these sections out, please click [here](#).

AI Acknowledgment

This section acknowledges the AI tools that were utilized in the process of completing this assignment.

Tool Name	Brief Description	Link to tool

Description of AI Usage

This section provides a more detailed description of how the AI tools were used in the assignment. It includes information about the prompts given to the AI tool, the responses received, and how these responses were utilized or modified in the assignment. **One table should be used for each tool used.**

[Insert Tool Name]	
[Insert Description of use]	
[Insert Sample prompt]	[Insert Sample response]

Evidence of AI Usage

This section includes evidence of significant prompts and responses used or generated through the AI tool. It should provide a clear understanding of the extent to which the AI tool was used in the assignment. Evidence may be attached via screenshots or text.

Additional Evidence:

[Place evidence here]

Additional Evidence:

[Place evidence here]

Configuration Manual (Securing Multi-Tenant Kubernetes Clusters Using eBPF)

MSc Research Project
Cloud Computing

Abhishek Murari Sharma
Student ID: 23406461

School of Computing
National College of Ireland

Supervisor: Prof: Shreyas Setlur Arun

**National College of Ireland
Project Submission Sheet
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Word Count:	XXX
Page Count:	9

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Signature:	
Date:	11th December 2025

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Configuration Manual

Abhishek Murari Sharma
x23406461

1 Introduction

The manual includes hardware and software requirements, installation procedure, configuration files and testing procedure eBPF (2025)Mazaheri et al. (2016)Nguyen and Kim (2022)

2 Hardware Requirements

2.1 Minimum System Specifications

Table 1: System Requirements

Component	Minimum Requirement	Recommended
CPU	4 cores	8+ cores
RAM	8 GB	16 GB or more
Storage	20 GB free space	50 GB SSD
Network	Internet connection	Stable broadband
OS	Ubuntu 22.04 LTS	Ubuntu 22.04 LTS or later

Before proceeding, verify your system meets the requirements:

2.2 Software Requirements and Steps for Running the Project

2.3 Required Software and Tools

The following software components are required for the testbed:

2.4 System Verification

2.5 Software Installation Script

Install the prerequisites which installs kubernetes kind, Docker, Kubectl, Helm, Cilium CLI 01-prerequisites.sh script:

Table 2: Required Software Components

Software	Version	Purpose
Docker	20.10+	Container runtime for kind
kubectl	1.28+	Kubernetes command-line tool
kind	0.20.0+	Kubernetes in Docker
helm	3.12+	Package manager (optional)
Cilium CLI	Latest	Cilium installation and management
Python 3	3.8+	Script execution (if needed)
curl	Latest	HTTP client for testing
iperf3	Latest	Network performance testing

```

kali@kali:~$ nproc
12
kali@kali:~$ free -h
               total        used        free      shared  buff/cache   available
Mem:           15Gi        11Gi        593Mi       1.8Gi        3.7Gi        3.7Gi
Swap:          7.5Gi         6.3Gi         1.2Gi
kali@kali:~$ df -h
Filesystem      Size  Used Avail Use% Mounted on
tmpfs            1.6G  3.6M  1.6G   1% /run
/dev/nvme0n1p6  136G  24G  106G  19% /
tmpfs            7.7G  21M  7.7G   1% /dev/shm
tmpfs            5.0M   8.0K  5.0M   1% /run/lock
efivarfs         438K  281K  153K  65% /sys/firmware/efi/efivars
/dev/nvme0n1p1   96M   55M   42M  58% /boot/efi
tmpfs            1.6G  3.7M  1.6G   1% /run/user/1000
/dev/sda1        30G   3.5G   26G  12% /media/kali/DA48-1102
kali@kali:~$ lsb_release -a
No LSB modules are available.
Distributor ID: Ubuntu
Description:    Ubuntu 24.04.3 LTS
Release:        24.04
Codename:       noble
kali@kali:~$

```

Figure 1: Check Systems Configuration and should meet this minimum Requirements

```

TERMINAL
kali@kali:~/Desktop/MSc Research Project/MSc-Research-Project/testbeds
* History restored

kali@kali:~/Desktop/MSc Research Project/MSc-Research-Project/testbeds$ chmod +x scripts/01-prerequisites.sh
kali@kali:~/Desktop/MSc Research Project/MSc-Research-Project/testbeds$ ./scripts/01-prerequisites.sh

Installing Prerequisites for eBPF/Cilium Testbed

[1/6] Updating system packages...
[sudo] password for kali:
Failed to allocate directory watch: Too many open files
Hit:1 http://ie.archive.ubuntu.com/ubuntu noble InRelease
Hit:2 http://security.ubuntu.com/ubuntu noble-security InRelease
Hit:3 https://packages.microsoft.com/repos/code stable InRelease
Hit:4 http://ie.archive.ubuntu.com/ubuntu noble-updates InRelease
Hit:5 https://ppa.launchpadcontent.net/obsproject/obs-studio/ubuntu noble InRelease
Hit:6 http://ie.archive.ubuntu.com/ubuntu noble-backports InRelease
Hit:7 https://downloads.cursor.com/aptrepo stable InRelease
Reading package lists... Done
Building dependency tree... Done
Reading state information... Done
17 packages can be upgraded. Run 'apt list --upgradable' to see them.
Reading package lists... Done
Building dependency tree... Done
Reading state information... Done
Calculating upgrade... Done
The following package was automatically installed and is no longer required:
  liblvm2
Use 'sudo apt autoremove' to remove it.
Get more security updates through Ubuntu Pro with 'esm-apps' enabled:
  libzvb1-common libjson1 libavdevice60 libpostproc57 libsn1 libavcodec60
  libstreamer-plugins-bad1.0-0 libzvb10t64 libavutil58 libswscale7
  libswresample libsn-perl libavformat60 libavfilter9
Learn more about Ubuntu Pro at https://ubuntu.com/pro
The following NEW packages will be installed:
  linux-headers-6.14.0-37-generic linux-hwe-6.14-headers-6.14.0-37 linux-hwe-6.14-tools-6.14.0-37
  linux-image-6.14.0-37-generic linux-modules-6.14.0-37-generic linux-modules-extra-6.14.0-37-generic
  linux-tools-6.14.0-37-generic
The following upgrades have been deferred due to phasing:
  libwhoopsie whoopsie
The following packages will be upgraded:
  apparmor cursor glib2-mutter-14 gnome-shell-extension-desktop-icons-ng libapparmor1 libmutter-14-0 libnetplan

```

2.6 Cluster Creation Script

The cluster creation is automated through `02-create-cluster.sh`:
Execution:

```
1 ./scripts/02-setup-tenants.sh
```

```
kali@kali:~/Desktop/MSC-Research-Project/MSC-Research-Project/testbed$ chmod +x scripts/02-create-cluster.sh
kali@kali:~/Desktop/MSC-Research-Project/MSC-Research-Project/testbed$ ./scripts/02-create-cluster.sh

=====
Creating Kind Multi-Node Cluster
=====
Cluster 'cilium-multitenant' already exists.
Do you want to delete it and create a new one? (y/N): y
Deleting existing cluster...
Deleting cluster 'cilium-multitenant'...
Creating cluster 'cilium-multitenant' with 3 nodes (1 control-plane, 2 workers)...
Preparing nodes...
Ensuring node image (kindnet/node:v1.27.3) is
Writing configuration
Starting control-plane
Installing CNI
Installing StorageClass
Joining worker nodes
Set kubect context to "kind-cilium-multitenant"
You can now use your cluster with:

kubectl cluster-info --context kind-cilium-multitenant

Thanks for using Kind!
Waiting for cluster to be ready...
Kubernetes control plane is running at https://127.0.0.1:44337
CoreDNS is running at https://127.0.0.1:44337/api/v1/namespaces/kube-system/services/kube-dns:dns/proxy

To further debug and diagnose cluster problems, use 'kubectl cluster-info dump':
node/cilium-multitenant-control-plane condition met
node/cilium-multitenant-worker1 condition met
node/cilium-multitenant-worker2 condition met
node/cilium-multitenant-worker3 condition met
node/cilium-multitenant-worker4 condition met

Cluster created successfully!

=====
NAME                STATUS    ROLES    AGE   VERSION   INTERNAL-IP   EXTERNAL-IP   OS-IMAGE             KERNEL-VERSION      CONTAINER-RUNTIME
cilium-multitenant-control-plane   Ready    control-plane   15s   v1.27.3   172.18.0.6    <none>         Debian GNU/Linux 11 (bullseye)   6.14.0-36-generic   containerd://1.7.1
cilium-multitenant-worker1         Ready    <none>          15s   v1.27.3   172.18.0.3    <none>         Debian GNU/Linux 11 (bullseye)   6.14.0-36-generic   containerd://1.7.1
cilium-multitenant-worker2         Ready    <none>          15s   v1.27.3   172.18.0.2    <none>         Debian GNU/Linux 11 (bullseye)   6.14.0-36-generic   containerd://1.7.1
cilium-multitenant-worker3         Ready    <none>          15s   v1.27.3   172.18.0.4    <none>         Debian GNU/Linux 11 (bullseye)   6.14.0-36-generic   containerd://1.7.1
cilium-multitenant-worker4         Ready    <none>          15s   v1.27.3   172.18.0.5    <none>         Debian GNU/Linux 11 (bullseye)   6.14.0-36-generic   containerd://1.7.1

Cluster context: kind-cilium-multitenant

Next step: Run ./scripts/03-install-cilium.sh
kali@kali:~/Desktop/MSC-Research-Project/MSC-Research-Project/testbed$
```

Figure 2: Cluster Creation Output

2.7 Setup Tenants

Create a Multi-tenant environment using this script (namespaces, RBAC, quotas) `03-setup-tenants.sh`:

```
kali@kali:~/Desktop/MSC-Research-Project/MSC-Research-Project/testbed$ chmod +x scripts/03-setup-tenants.sh
kali@kali:~/Desktop/MSC-Research-Project/MSC-Research-Project/testbed$ ./scripts/03-setup-tenants.sh

=====
Setting up Multi-Tenant Environment
=====
Switched to context "kind-cilium-multitenant".
[1/4] Creating tenant namespaces...
namespace/tenant-a created
namespace/tenant-b created
namespace/platform-tools created
namespace/tenant-a labeled
namespace/tenant-b labeled
[2/4] Applying RBAC policies...
serviceaccount/tenant-user created
role.rbac.authorization.k8s.io/tenant-namespace-admin created
rolebinding.rbac.authorization.k8s.io/tenant-user-binding created
serviceaccount/tenant-user created
role.rbac.authorization.k8s.io/tenant-namespace-admin created
rolebinding.rbac.authorization.k8s.io/tenant-user-binding created
[3/4] Applying resource quotas...
resourcequota/tenant-a-quotas created
limitrange/tenant-a-limits created
resourcequota/tenant-b-quotas created
limitrange/tenant-b-limits created
[4/4] Verifying setup...

Multi-tenant environment setup complete!

=====
NAME                STATUS    AGE
cilium-secrets      Active    4m46s
default             Active    7m48s
kube-node-lease     Active    7m48s
kube-public         Active    7m48s
kube-system         Active    7m48s
local-path-storage  Active    7m34s
platform-tools      Active    0s
tenant-a            Active    0s
tenant-b            Active    0s

=====
NAME                                CREATED AT
role.rbac.authorization.k8s.io/tenant-namespace-admin  2025-12-10T10:56:10Z

=====
NAME                ROLE                                AGE
rolebinding.rbac.authorization.k8s.io/tenant-user-binding  Role/tenant-namespace-admin  0s

=====
NAME                                CREATED AT
role.rbac.authorization.k8s.io/tenant-namespace-admin  2025-12-10T10:56:10Z

=====
NAME                ROLE                                AGE
rolebinding.rbac.authorization.k8s.io/tenant-user-binding  Role/tenant-namespace-admin  0s

=====
NAME                AGE   REQUEST
tenant-a-quotas    15s   pods: 0/10, requests.cpu: 0/2, requests.memory: 0/4Gi, services: 0/5
tenant-b-quotas    15s   pods: 0/10, requests.cpu: 0/2, requests.memory: 0/4Gi, services: 0/5
LIMIT
tenant-a-quotas    15s   pods: 0/10, requests.cpu: 0/2, requests.memory: 0/4Gi, services: 0/5
LIMIT
tenant-b-quotas    15s   pods: 0/10, requests.cpu: 0/2, requests.memory: 0/4Gi, services: 0/5
LIMIT

Next step: Run ./scripts/04-deploy-workloads.sh
kali@kali:~/Desktop/MSC-Research-Project/MSC-Research-Project/testbed$
```

2.8 Deploy worker nodes

Run this script to deploy worker nodes `04-deploy-workloads.sh`. It creates 4 worker nodes and 1 control plane and test the creation using this command

```
1 kubectl get nodes
2 kubectl -n kube-system get pods | grep kube-proxy
3 kubectl -n kube-system get pods -l k8s-app=cilium -o wide
4 kubectl get pods -n tenant-a
```

```

TERMINAL
Image ID:
Port: <none>
Host Port: <none>
Command:
sh
-c
cp /usr/bin/cilium-sysctlfix /hostbin/cilium-sysctlfix;
nsenter --mount=/hostproc/1/ns/mnt "${BIN_PATH}/cilium-sysctlfix";
rm /hostbin/cilium-sysctlfix

State: Waiting
Reason: PodInitializing
Ready: False
Restart Count: 0
Environment:
  BIN_PATH: /opt/cni/bin
Mounts:
  /hostbin from cni-path (rw)
  /hostproc from hostproc (rw)
  /var/run/secrets/kubernetes.io/serviceaccount from kube-api-access-v5th6 (ro)
mount-bpf-fs:
Container ID:
Image ID: quay.io/cilium/cilium:v1.18.2@sha256:858f807ea4e20e85c3ea3240a762e1f4b29f1cb5bbd0463b8aa77e7b097c0667
Port: <none>
Host Port: <none>
Command:
/bin/bash
-c
--
Args:
mount | grep "/sys/fs/bpf type bpf" || mount -t bpf bpf /sys/fs/bpf
State: Waiting
$ cd "/home/kali/Desktop/MSc Research Project/MSc-Research-Project-/testbed" && kubectl get nodes
NAME                                STATUS    ROLES    AGE    VERSION
cilium-multitenant-control-plane    Ready    control-plane    26m    v1.27.3
cilium-multitenant-worker           Ready    <none>          25m    v1.27.3
cilium-multitenant-worker2          Ready    <none>          25m    v1.27.3
cilium-multitenant-worker3          Ready    <none>          25m    v1.27.3
cilium-multitenant-worker4          Ready    <none>          25m    v1.27.3
$ cd "/home/kali/Desktop/MSc Research Project/MSc-Research-Project-/testbed" && kubectl -n kube-system get pods | grep kube-proxy
kube-proxy-2dxrn                    1/1      Running    0        26m
kube-proxy-zgq9g                    1/1      Running    0        26m
kube-proxy-c7846                    1/1      Running    10 (5m8s ago)    26m
kube-proxy-s4c5d                    1/1      Running    0        26m
kube-proxy-zg5dr                    1/1      Running    0        26m
$ cd "/home/kali/Desktop/MSc Research Project/MSc-Research-Project-/testbed" && kubectl -n kube-system delete pod cilium-q8k8w
pod "cilium-q8k8w" deleted from kube-system namespace
$ cd "/home/kali/Desktop/MSc Research Project/MSc-Research-Project-/testbed" && kubectl -n kube-system get pods -l k8s-app=cilium -o wide
NAME                                READY    STATUS    RESTARTS   AGE    IP              NODE                                NOMINATED NODE    READINESS GATES
cilium-bp8bw                        1/1      Running    0           3m25s   172.18.0.5      cilium-multitenant-worker4          <none>             <none>
cilium-l2mfq                        1/1      Running    0           3m25s   172.18.0.6      cilium-multitenant-control-plane    <none>             <none>
cilium-njk6q                        1/1      Running    0           23s     172.18.0.4      cilium-multitenant-worker3          <none>             <none>
cilium-st2kn                        1/1      Running    0           3m25s   172.18.0.2      cilium-multitenant-worker2          <none>             <none>
cilium-zhxqk                        1/1      Running    0           3m25s   172.18.0.3      cilium-multitenant-worker           <none>             <none>
$ cd "/home/kali/Desktop/MSc Research Project/MSc-Research-Project-/testbed" && kubectl get pods -n tenant-a
NAME                                READY    STATUS    RESTARTS   AGE
web-a-6b597544bf-fhlgh              1/1      Running    0           15m
web-a-6b597544bf-m66n5              1/1      Running    0           15m
$

```

2.9 Configure Hubble UI

- 1 `kubectl -n kube-system get deploy,svc | grep hubble`
- 2 `kubectl -n kube-system port-forward svc/hubble-ui 12000:80`

```

Problems Output Terminal Ports
TERMINAL
kali@kali:~/Desktop/MSc Research Project/MSc-Research-Project/testbed$ kubectl -n kube-system port-forward svc/hubble-ui 12000:80
Unable to listen on port 12000: Listeners failed to create with the following errors: [unable to create listener: Error listen tcp4 127.0.0.1:12000: bind: address already in use]
ble to create listener: Error listen tcp6 [::]:12000: bind: address already in use]
error: unable to listen on any of the requested ports: [{12000 8081}]
kali@kali:~/Desktop/MSc Research Project/MSc-Research-Project/testbed$ kubectl -n kube-system port-forward svc/hubble-ui 12000:80
Unable to listen on port 12000: Listeners failed to create with the following errors: [unable to create listener: Error listen tcp4 127.0.0.1:12000: bind: address already in use]
ble to create listener: Error listen tcp6 [::]:12000: bind: address already in use]
error: unable to listen on any of the requested ports: [{12000 8081}]
kali@kali:~/Desktop/MSc Research Project/MSc-Research-Project/testbed$ kubectl -n kube-system get deploy,svc | grep hubble
deployment.apps/hubble-relay        1/1      1          1          4m28s
service/hubble-peer                 ClusterIP 10.96.196.153 <none>    443/TCP    55m
service/hubble-relay                ClusterIP 10.96.236.7   <none>    80/TCP    4m57s
service/hubble-ui                    ClusterIP 10.96.145.119 <none>    80/TCP
kali@kali:~/Desktop/MSc Research Project/MSc-Research-Project/testbed$ kubectl -n kube-system port-forward svc/hubble-ui 12000:80
Unable to listen on port 12000: Listeners failed to create with the following errors: [unable to create listener: Error listen tcp4 127.0.0.1:12000: bind: address already in use]
ble to create listener: Error listen tcp6 [::]:12000: bind: address already in use]
error: unable to listen on any of the requested ports: [{12000 8081}]
kali@kali:~/Desktop/MSc Research Project/MSc-Research-Project/testbed$ kubectl -n kube-system get pods -l k8s-app=hubble-ui
NAME                                READY    STATUS    RESTARTS   AGE
hubble-ui-7bb7c5cd79-gjcd8          2/2      Running    0           6m11s
kali@kali:~/Desktop/MSc Research Project/MSc-Research-Project/testbed$ kubectl -n kube-system port-forward svc/hubble-ui 12000:80
Forwarding from 127.0.0.1:12000 -> 8081
Forwarding from [::]:12000 -> 8081
Handling connection for 12000
Handling connection for 12000
kali@kali:~/Desktop/MSc Research Project/MSc-Research-Project/testbed$ lsof -ti:12000 | xargs kill -9 2>/dev/null || true
kali@kali:~/Desktop/MSc Research Project/MSc-Research-Project/testbed$ kubectl -n kube-system port-forward svc/hubble-ui 12000:80
Forwarding from 127.0.0.1:12000 -> 8081
Forwarding from [::]:12000 -> 8081
Handling connection for 12000
Handling connection for 12000
Killed
kali@kali:~/Desktop/MSc Research Project/MSc-Research-Project/testbed$ kubectl -n kube-system port-forward svc/hubble-ui 12000:80
Forwarding from 127.0.0.1:12000 -> 8081
Forwarding from [::]:12000 -> 8081
Handling connection for 12000
Handling connection for 12000

```

2.10 Configure Prometheus and Grafana

```
1 install-prometheus.sh
2 kubectl -n monitoring port-forward svc/prometheus-kube-prometheus-
  prometheus 9090:9090
3 kubectl -n monitoring port-forward svc/prometheus-grafana 3000:80
```

```
kali@kali:~/Desktop/MSc Research Project/MSc-Research-Project-/testbed$ ./scripts/10-install-prometheus.sh

Installing Prometheus and Grafana
=====
Switched to context "kind-cilium-multitenant".
namespace/monitoring created
[1/4] Adding Prometheus Helm repository...
"prometheus-community" already exists with the same configuration, skipping
Hang tight while we grab the latest from your chart repositories...
...Successfully got an update from the "cilium" chart repository
...Successfully got an update from the "prometheus-community" chart repository
Update Complete. *Happy Helming!*
[2/4] Creating Prometheus configuration for Cilium...
[3/4] Installing Prometheus stack (this may take 3-5 minutes)...
NAME: prometheus
LAST DEPLOYED: Wed Dec 10 13:15:55 2025
NAMESPACE: monitoring
STATUS: deployed
REVISION: 1
NOTES:
kube-prometheus-stack has been installed. Check its status by running:
  kubectl --namespace monitoring get pods -l "release=prometheus"

Get Grafana 'admin' user password by running:

  kubectl --namespace monitoring get secrets prometheus-grafana -o jsonpath="{.data.admin-password}" | base64 -d ; echo

Access Grafana local instance:

  export POD_NAME=$(kubectl --namespace monitoring get pod -l "app.kubernetes.io/name=grafana,app.kubernetes.io/instance=prometheus"
  -oname)
  kubectl --namespace monitoring port-forward $POD_NAME 3000

Get your grafana admin user password by running:

  kubectl get secret --namespace monitoring -l app.kubernetes.io/component=admin-secret -o jsonpath="{.items[0].data.admin-password}"
```

```
kali@kali:~/Desktop/MSc Research Project$ kubectl -n monitoring port-forward svc/prometheus-kube-prometheus-prometheus 9090:9090
Forwarding from 127.0.0.1:9090 -> 9090
Forwarding from [::1]:9090 -> 9090
Handling connection for 9090
Handling connection for 9090
Handling connection for 9090
Handling connection for 9090
Handling connection for 9090
error: lost connection to pod
kali@kali:~/Desktop/MSc Research Project$ kubectl -n monitoring port-forward svc/prometheus-kube-prometheus-prometheus 9090:9090
Error from server (NotFound): namespaces "monitoring" not found
kali@kali:~/Desktop/MSc Research Project$ kubectl -n monitoring port-forward svc/prometheus-kube-prometheus-prometheus 9090:9090
Forwarding from 127.0.0.1:9090 -> 9090
Forwarding from [::1]:9090 -> 9090
Handling connection for 9090
Handling connection for 9090
Handling connection for 9090

```

2.11 Check Cilium Status and Pods

```
1 cilium status
```

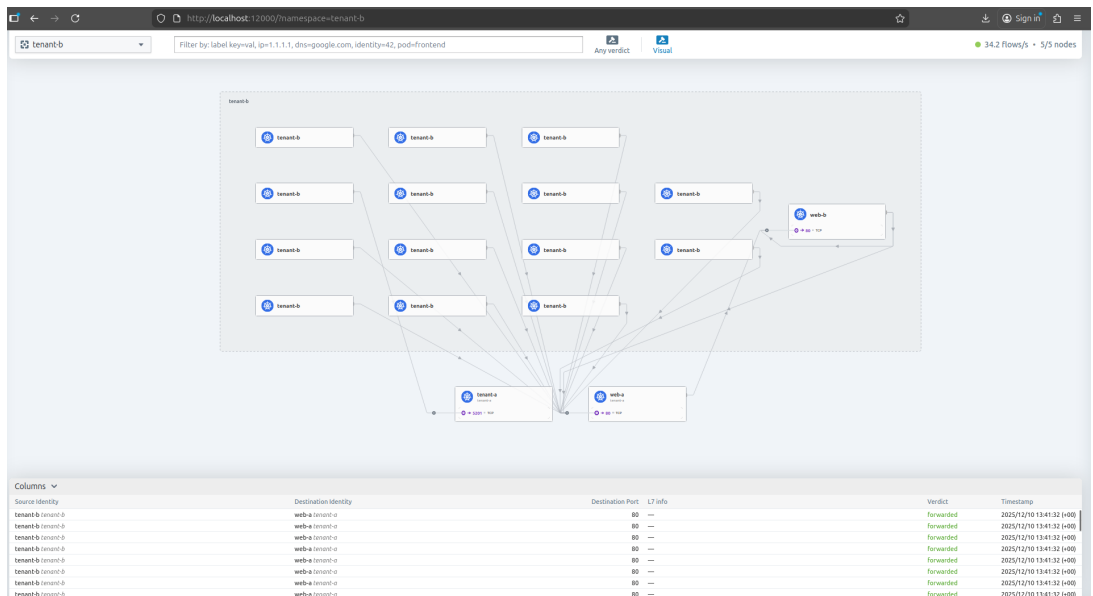
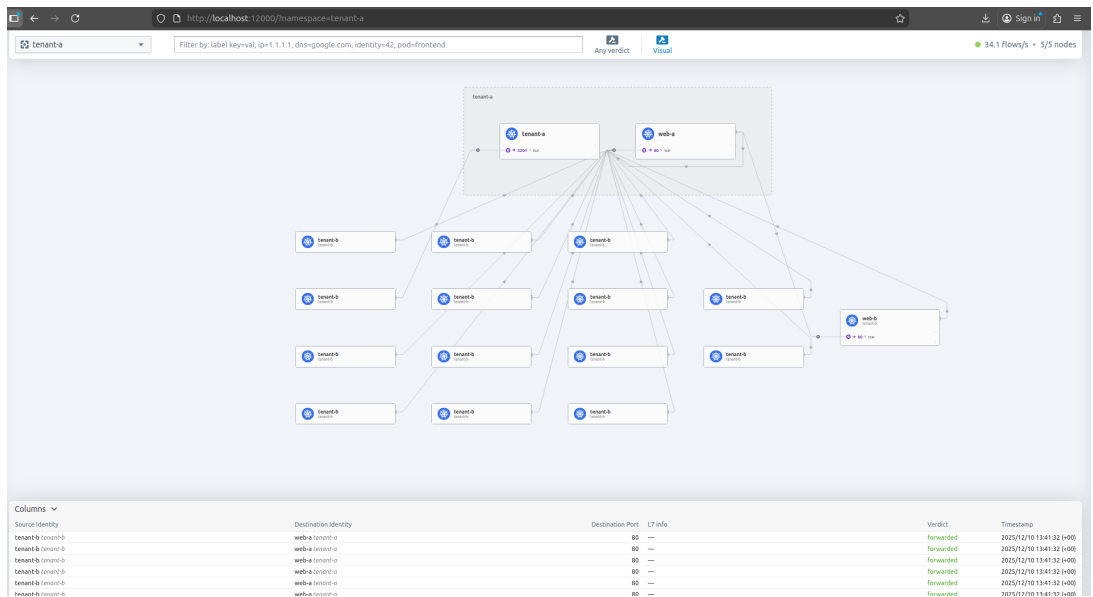

Attack Simulation Tests

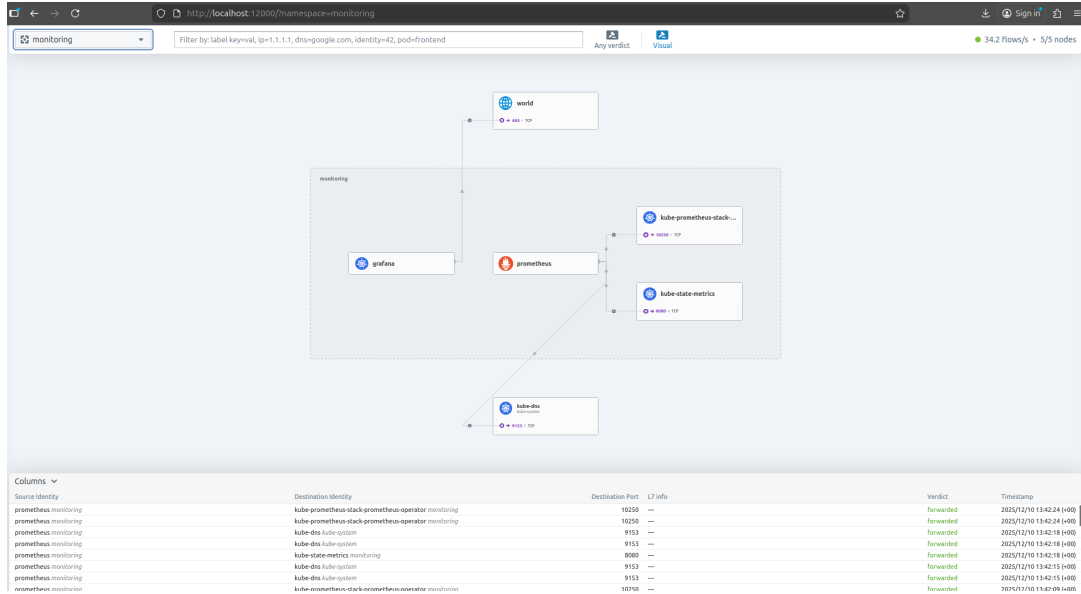
Performance Benchmarking Tests

```
Error from server (AlreadyExists): pods "iperf3-server" already exists
pod/iperf3-server condition met
Deploying iperf3 client in tenant-b...
Error from server (AlreadyExists): pods "iperf3-client" already exists
Throughput: Mb/s/sec
pod "iperf3-server" deleted from tenant-a namespace
pod "iperf3-client" deleted from tenant-b namespace
```

```
Workload resource usage:
△ Warning: metrics-server not ready yet for tenant-a
△ Warning: metrics-server not ready yet for tenant-b
```

[illegible]





References

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