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Benchmarking Various CNI Plugins

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Agenda

- Overview of Various CNI Plugins
- Experiments
    - Goals
    - Environment
    - Results
- Takeaways

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Overview of Various CNI Plugins

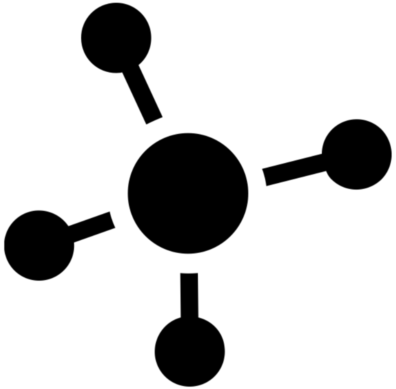
Kubernetes Network Model

- All containers communicate **without NAT**
- All nodes communicate with containers **without NAT**
- Container sees its own IP as others see it

Kubernetes **doesn't provide default network implementation**, it leaves it to **third party tools**

source: https://kubernetes.io/docs/concepts/cluster-administration/networking/#kubernetes-model

What CNI do?



Connectivity

Reachability

CNI Plugins

Project Calico - a layer 3 virtual network
Weave - a multi-host Docker network
Contiv Networking - policy networking for various use cases
SR-IOV
Cilium - BPF & XDP for containers
Infoblox - enterprise IP address management for containers
Multus - a Multi plugin
Romana - Layer 3 CNI plugin supporting network policy for Kubernetes
CNI-Genie - generic CNI network plugin
Nuage CNI - Nuage Networks SDN plugin for network policy kubernetes support
Silk - a CNI plugin designed for Cloud Foundry
Linen - a CNI plugin designed for overlay networks with Open vSwitch and fit in SDN/OpenFlow network environment
Vhostuser - a Dataplane network plugin - Supports OVS-DPDK & VPP
Amazon ECS CNI Plugins - a collection of CNI Plugins to configure containers with Amazon EC2 elastic network interfaces (ENIs)
Bonding CNI - a Link aggregating plugin to address failover and high availability network
ovn-kubernetes - an container network plugin built on Open vSwitch (OVS) and Open Virtual Networking (OVN) with support for both Linux and Windows
Juniper Contrail / TungstenFabric - Provides overlay SDN solution, delivering multicloud networking, hybrid cloud networking, simultaneous overlay-underlay support, network policy enforcement, network isolation, service chaining and flexible load balancing
Knitter - a CNI plugin supporting multiple networking for Kubernetes

source: https://github.com/containernetworking/cni#3rd-party-plugins

Scope

So many CNI plugins to test, limit scope to:

- Flannel
- Calico
- Weave
- Cilium
- Kube-Router
- AWS CNI
- Kopeio
- Romana

Flannel

Simple way to configure L3 network fabric with VXLAN as default

source: https://github.com/coreos/flannel

Calico

Pure L3 approach which enables unencapsulated networks and BGP peering

source: https://projectcalico.org

Weave

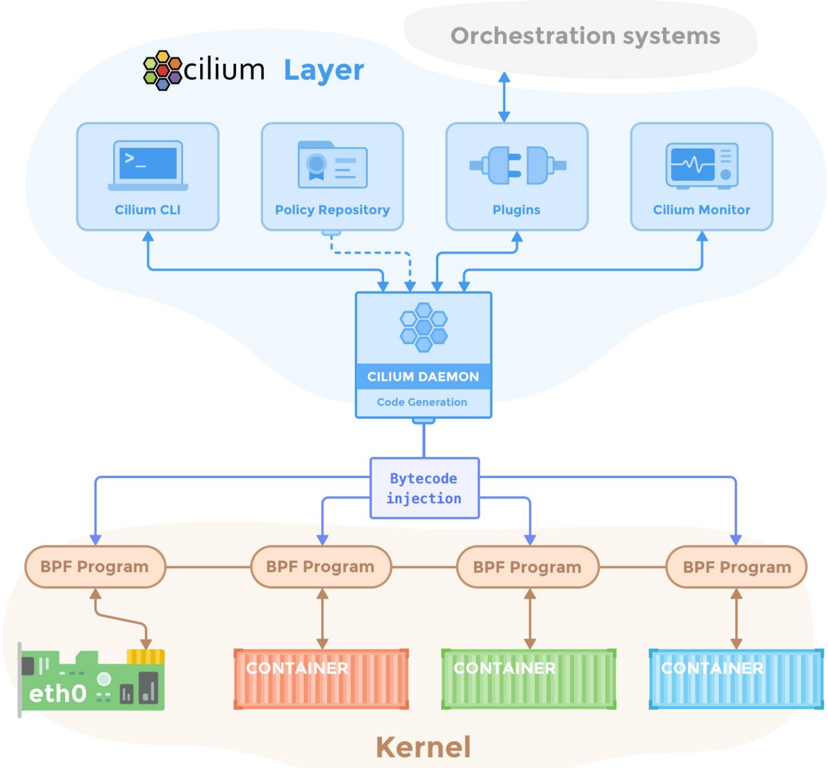
Support overlay network with different cloud network config

weaveworks

source: https://www.weave.works/docs

Cilium

Based on Linux kernel technology called **BPF**



source: https://cilium.readthedocs.io

Kube-Router

Built on standard Linux networking toolset: ipset, iptables, IPVS, LVS

KUBE ROUTER

source: https://github.com/cloudnativelabs/kube-router

AWS CNI

Using AWS ENI interface for pod networking

source: https://github.com/aws/amazon-vpc-cni-k8s

Kopeio

Simple VXLAN, but also support L2 with GRE and IPSEC

source: https://github.com/kopeio/networking

Romana

Use standard L3, distributed routes with BGP or OSPF

source: https://romana.io

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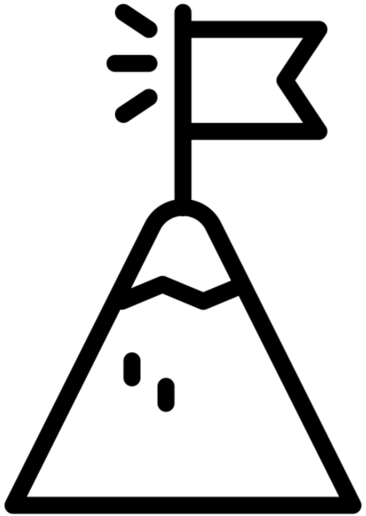
Experiments

Goals

- **Lowest latency** and **highest throughput**
- **Different protocols** and various **packet sizes**
- **CPU consumption** and **launch time**
- Kubernetes **network policies**



Environment

- **8 Kubernetes clusters** with different CNIs
- 2 nodes cluster with **m4.xlarge** type by Amazon AWS EC2 with **Debian 9**, **kernel 4.9**
- **Kubernetes** v1.10.9 with **Kops**

Environment

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- All CNI plugins deployed with default config in Kops
  - No tuning or custom configuration

  - **Flannel** v0.10.0
  - **Calico** v2.6.7
  - **Weave** v2.4.0
  - **Cilium** v1.0
  - **Kube-Router** v0.1.0
  - **AWS CNI** v1.0.0
  - **Kopeio** v1.0.20180319
  - **Romana** v2.0.2

CNI

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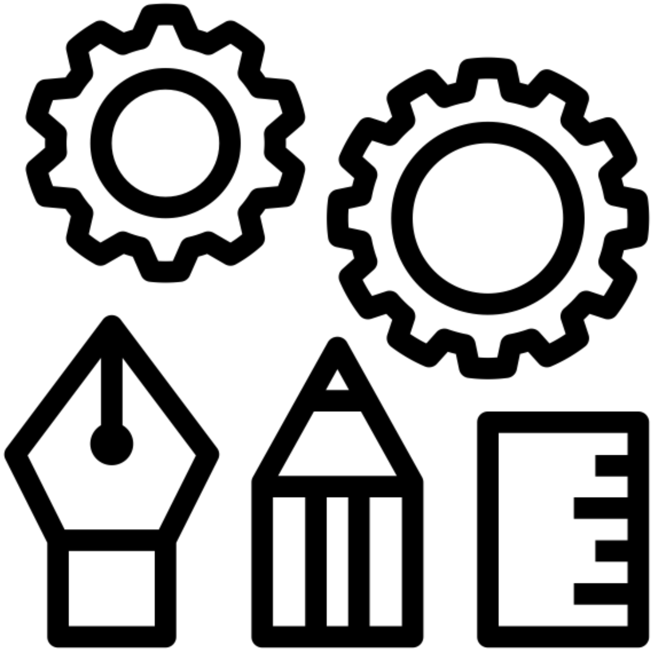
Tools



- Sockperf (v3.5.0)
  - Util over socket API for latency/throughput measurement
- Netperf (v2.6.0)
  - Unidirectional throughput and end-to-end latency measurement
- Tool from PaniNetworks
  - Generate HTTP workloads and measure response

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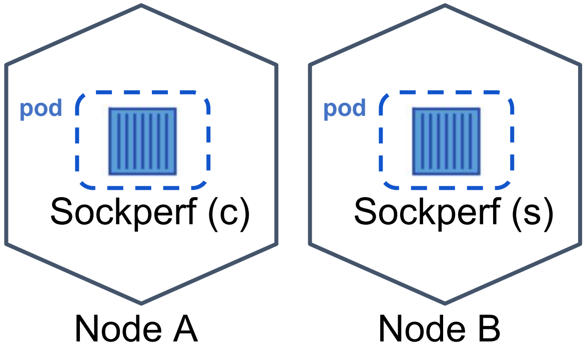
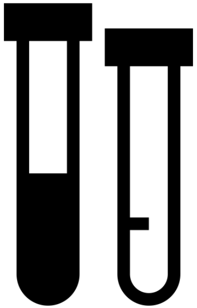
Experiment #1

Throughput & Latency

Steps

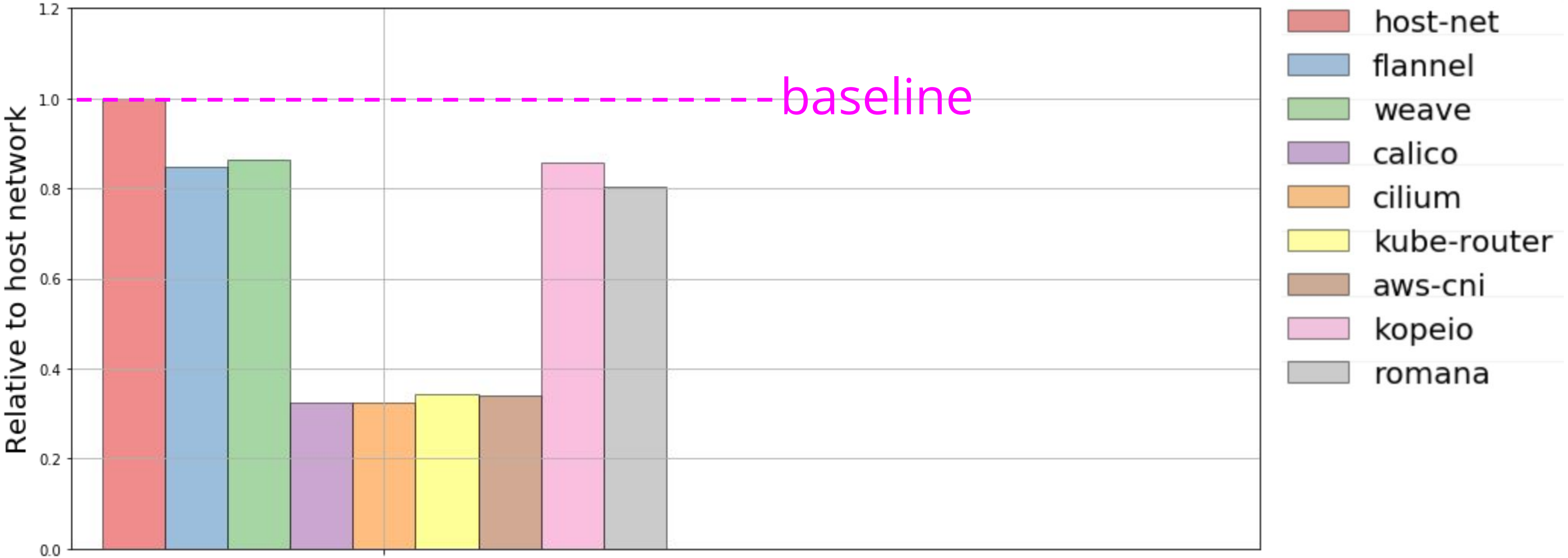




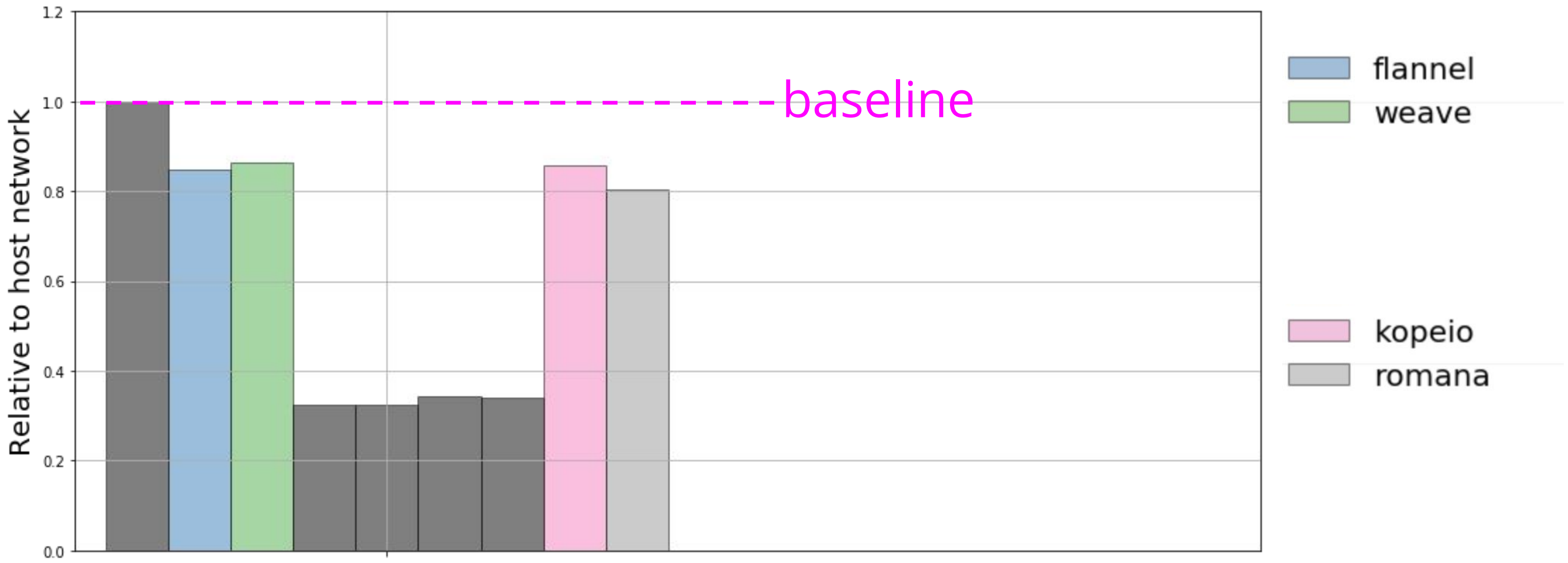
- Sockperf client pod in Node A
- Sockperf server pod in Node B

- 256 bytes for TCP throughput test
- 16 bytes for TCP latency test

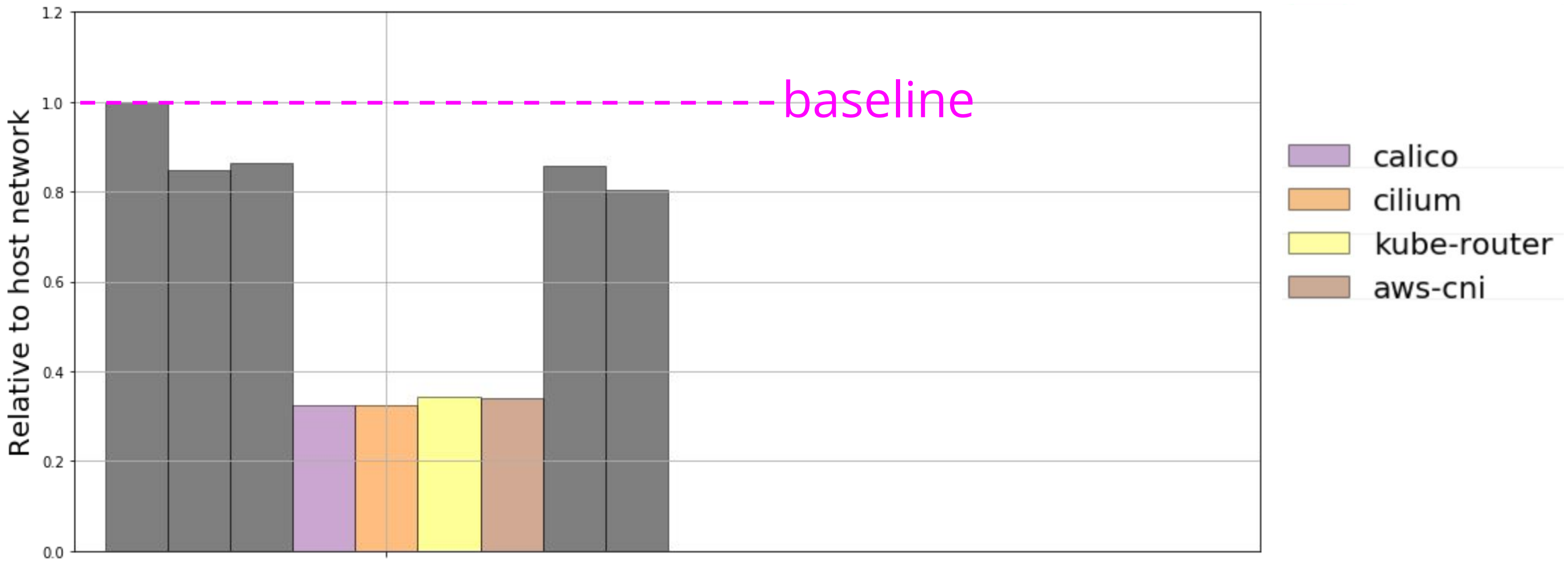
TCP throughput



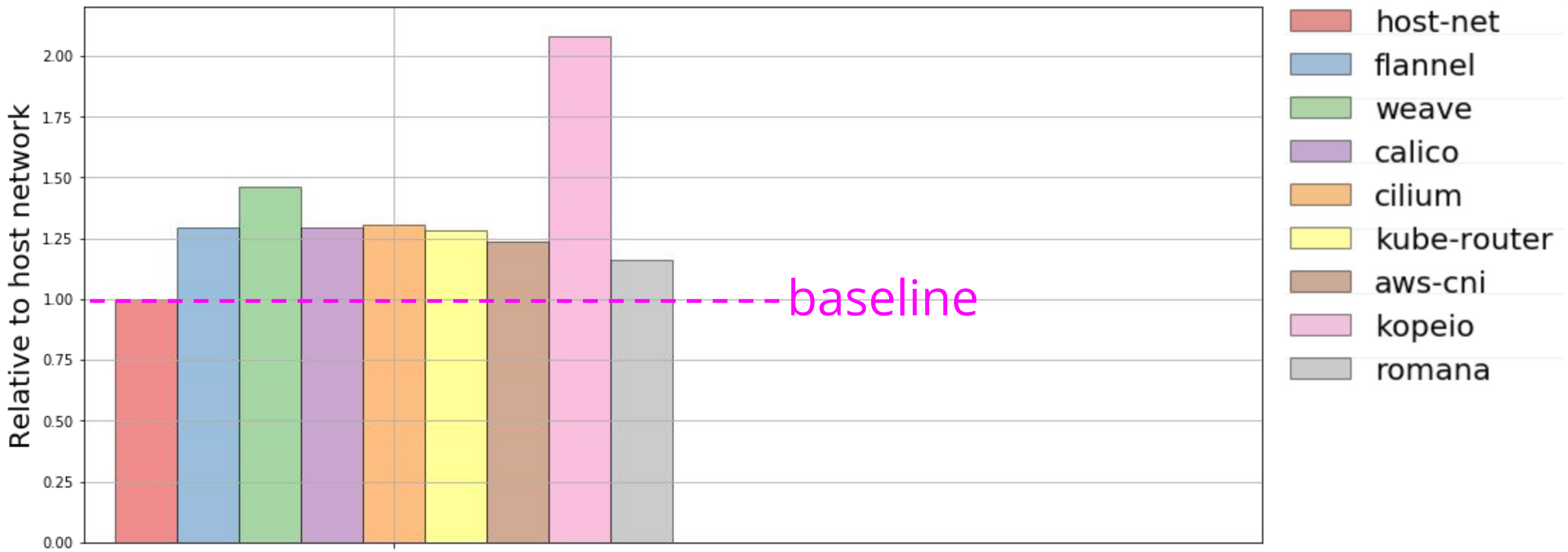
TCP throughput



TCP throughput

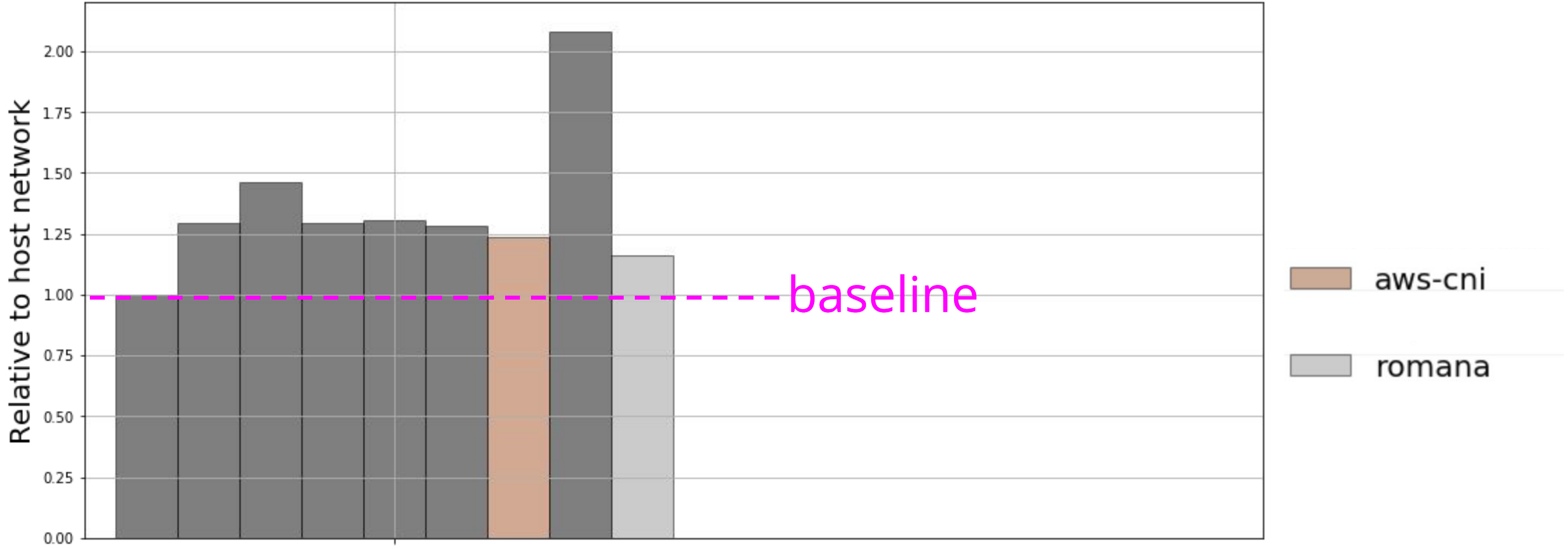


TCP latency



Relative to host network
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
baseline
host-net
flannel
weave
calico
cilium
kube-router
aws-cni
kopeio
romana

TCP latency



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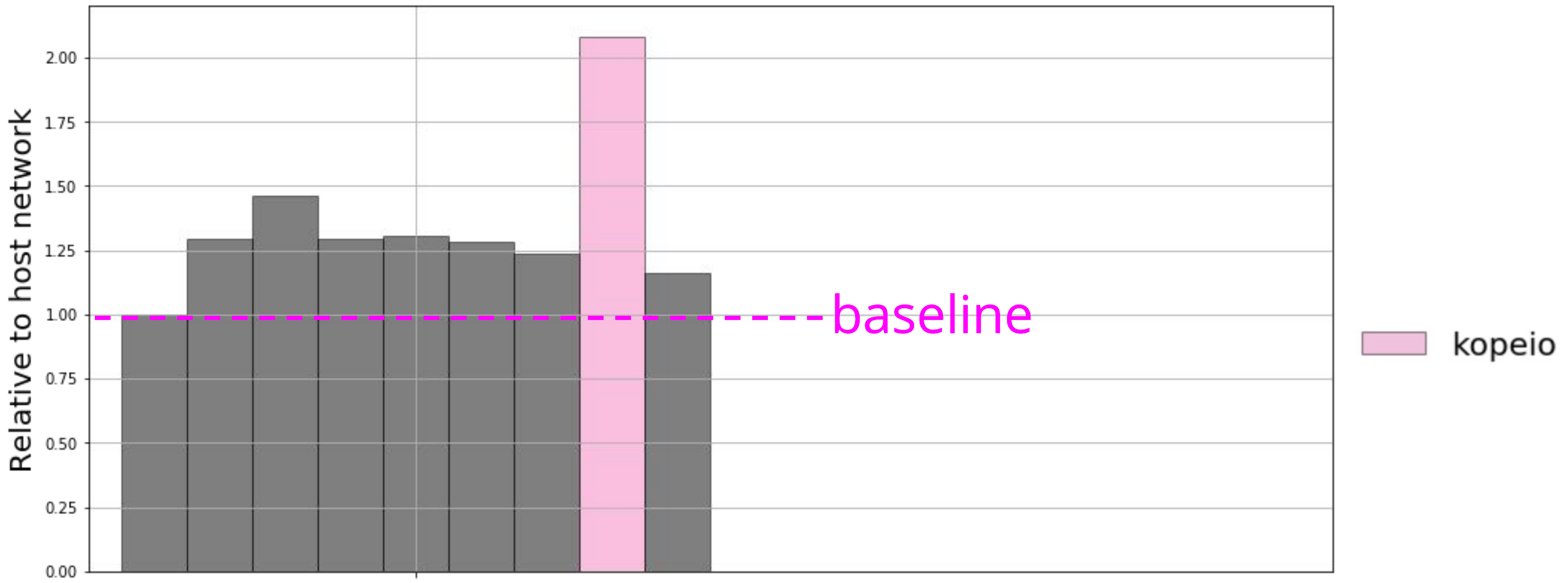
TCP latency



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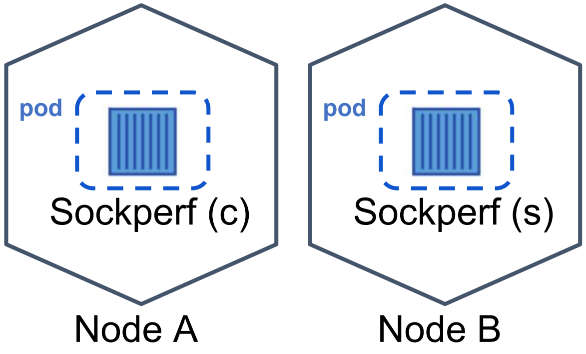
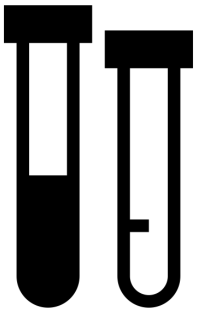
Experiment #2

Protocol & Packet Sizes

Steps

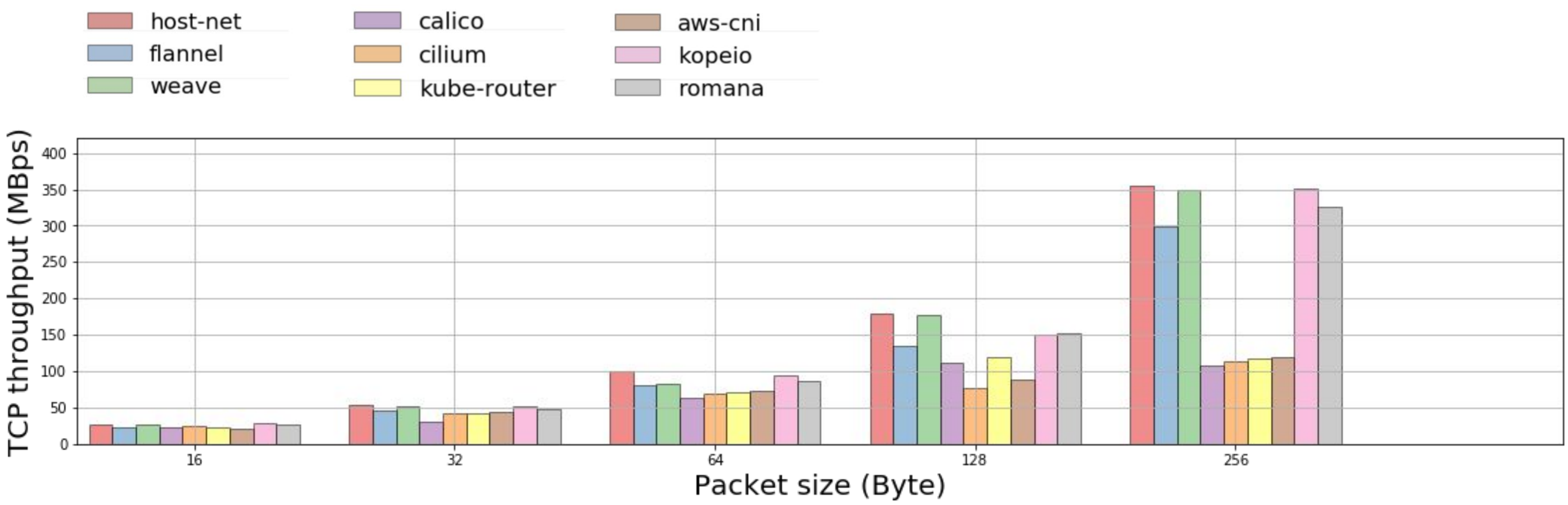


- Sockperf client pod in Node A
- Sockperf server pod in Node B



- Measure
  TCP and UDP throughput from 16 to 256 bytes

TCP throughput vs packet sizes



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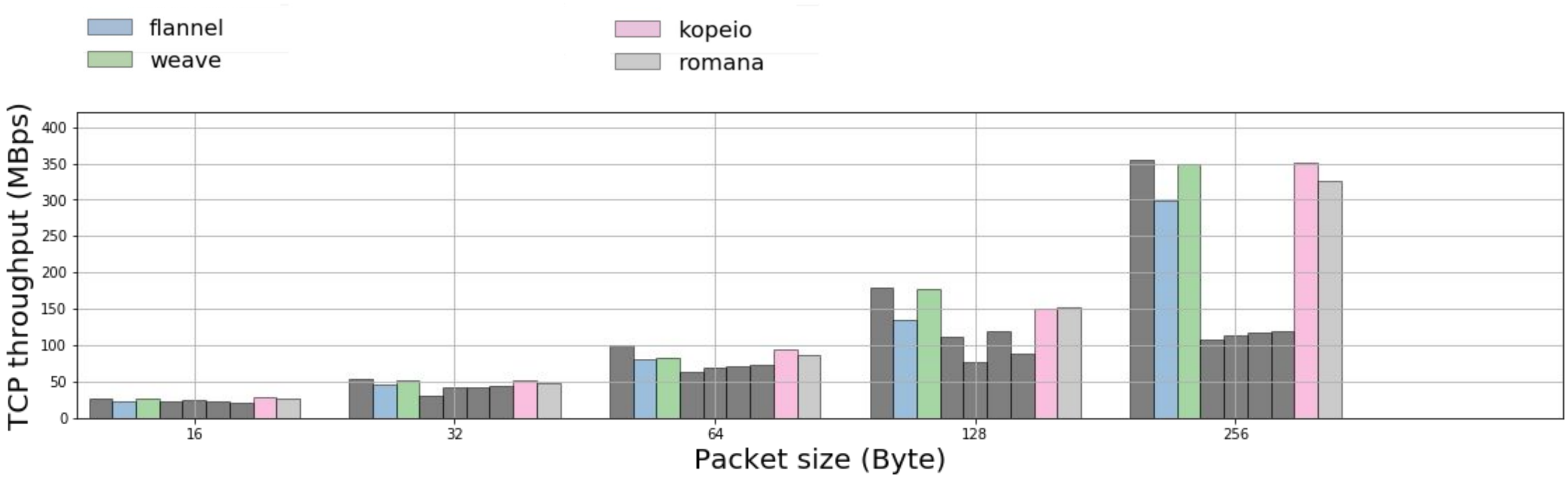
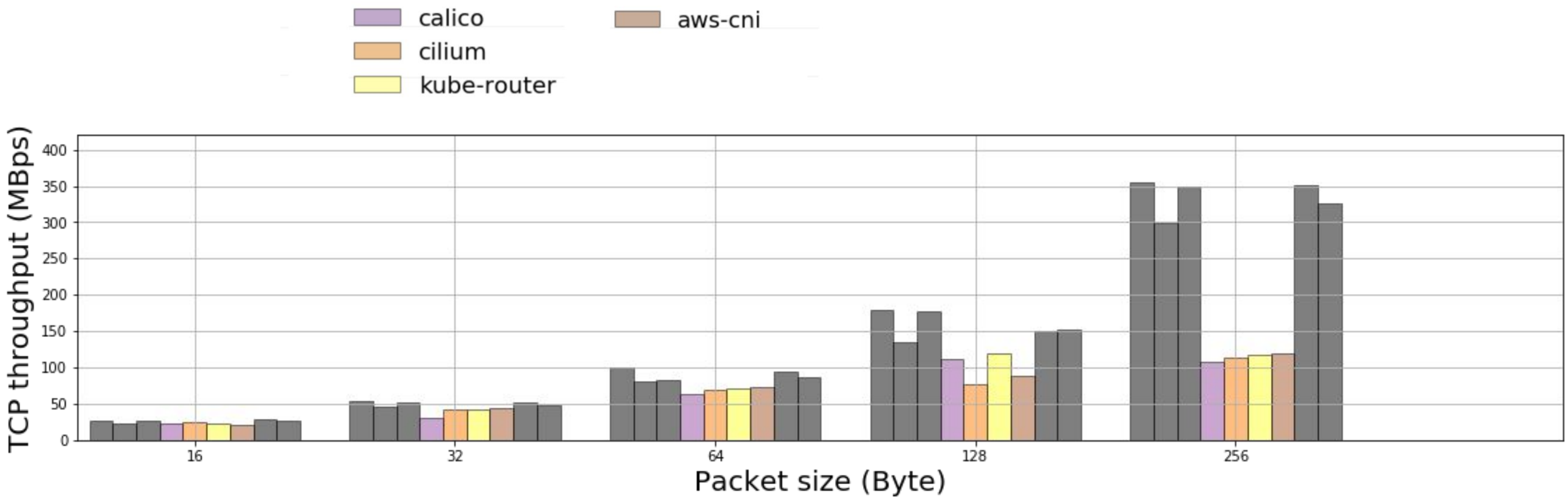
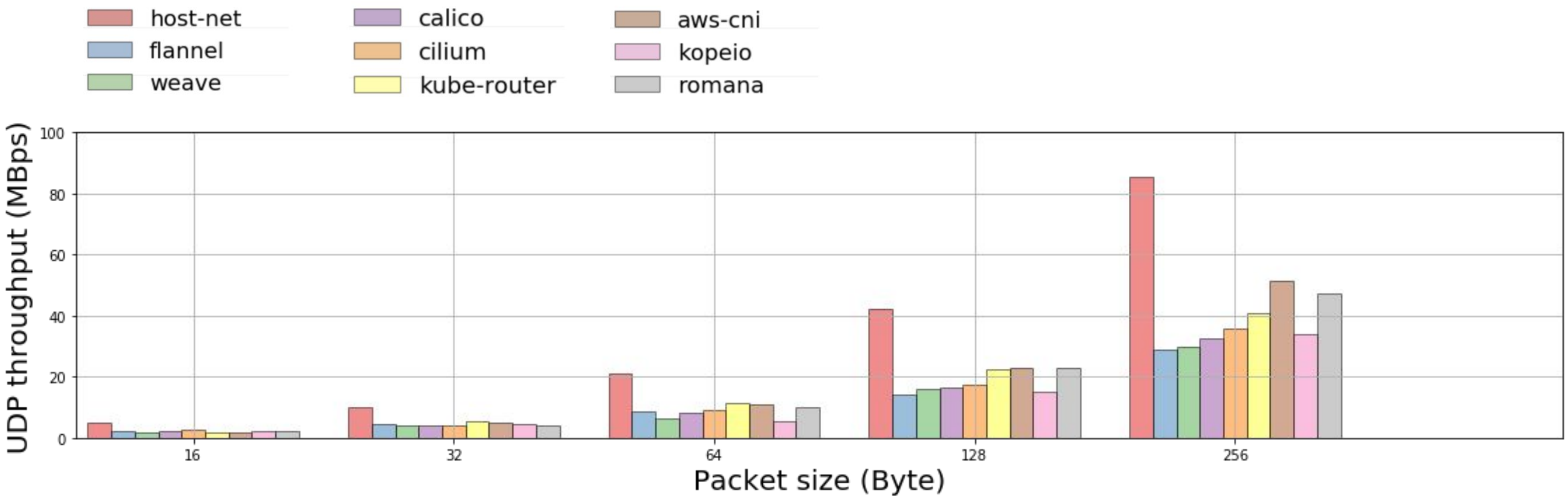
TCP throughput vs packet sizes



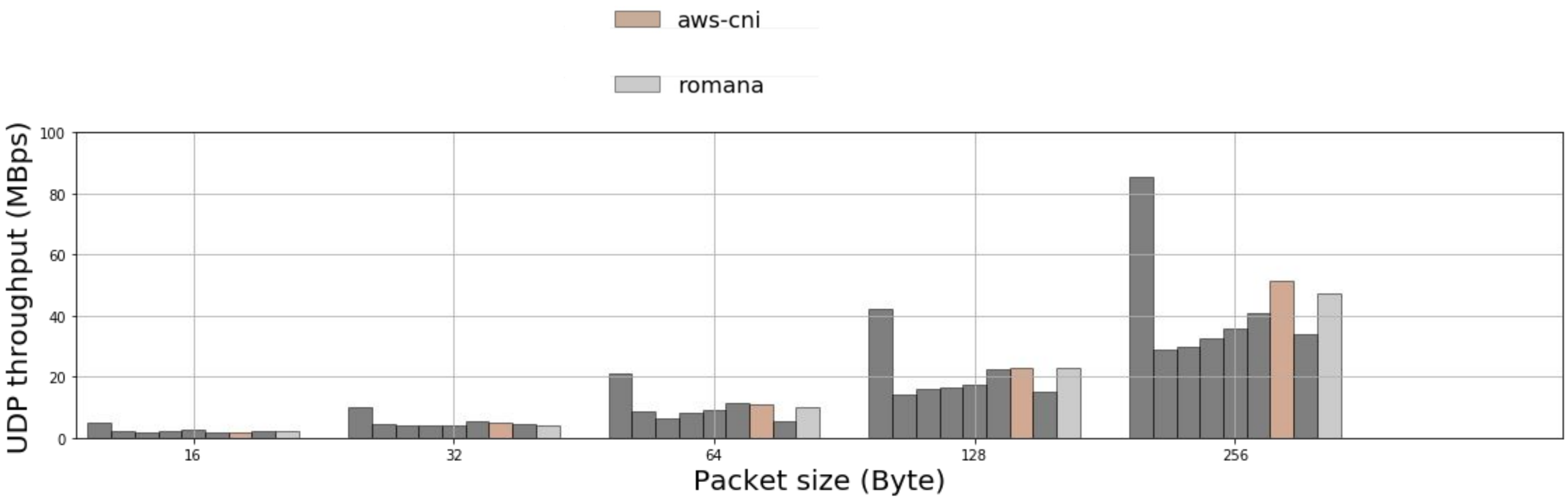
TCP throughput vs packet sizes



UDP throughput vs packet sizes



UDP throughput vs packet sizes



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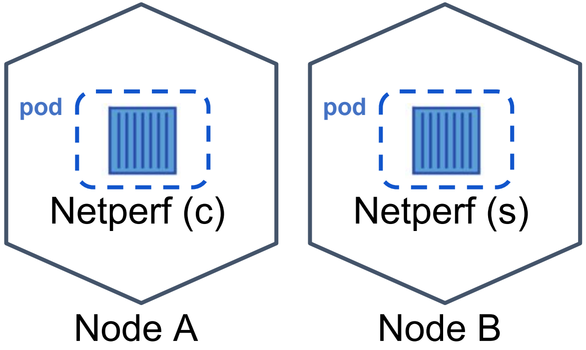
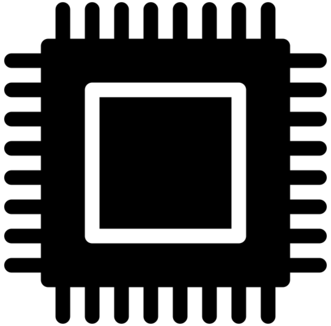
Experiment #3

CPU Overhead

Steps

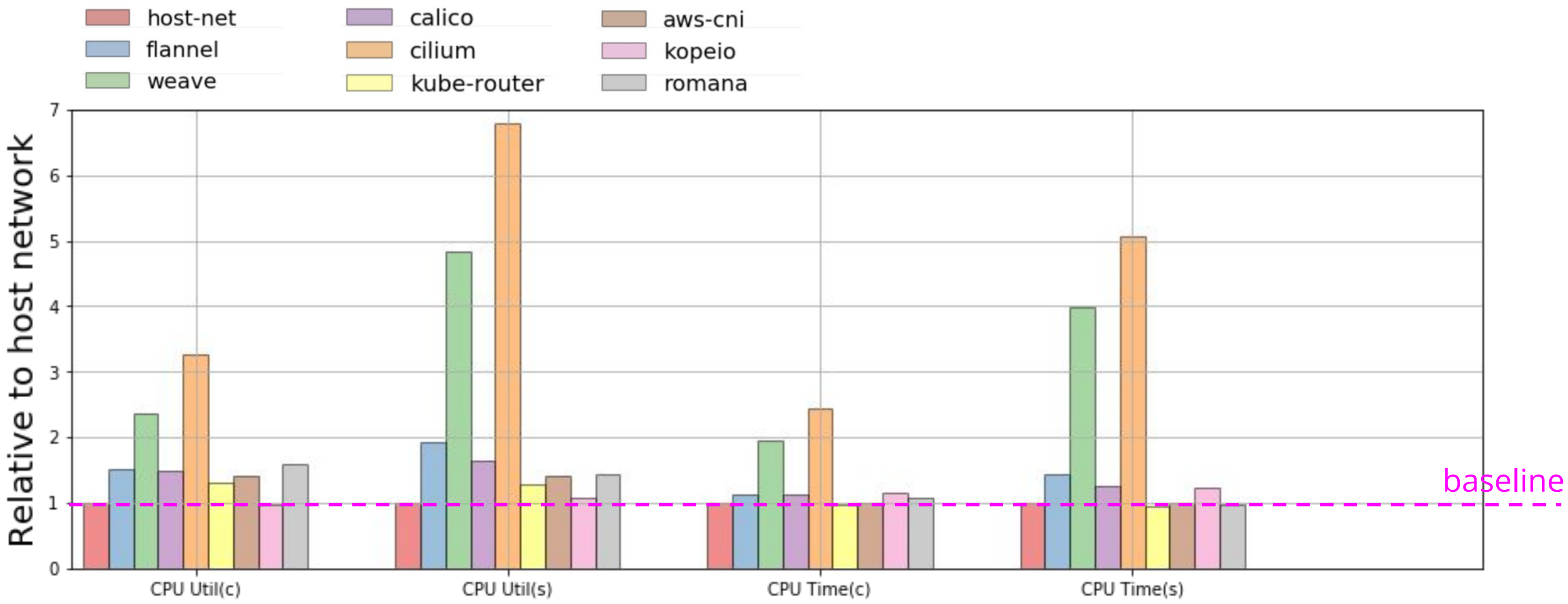




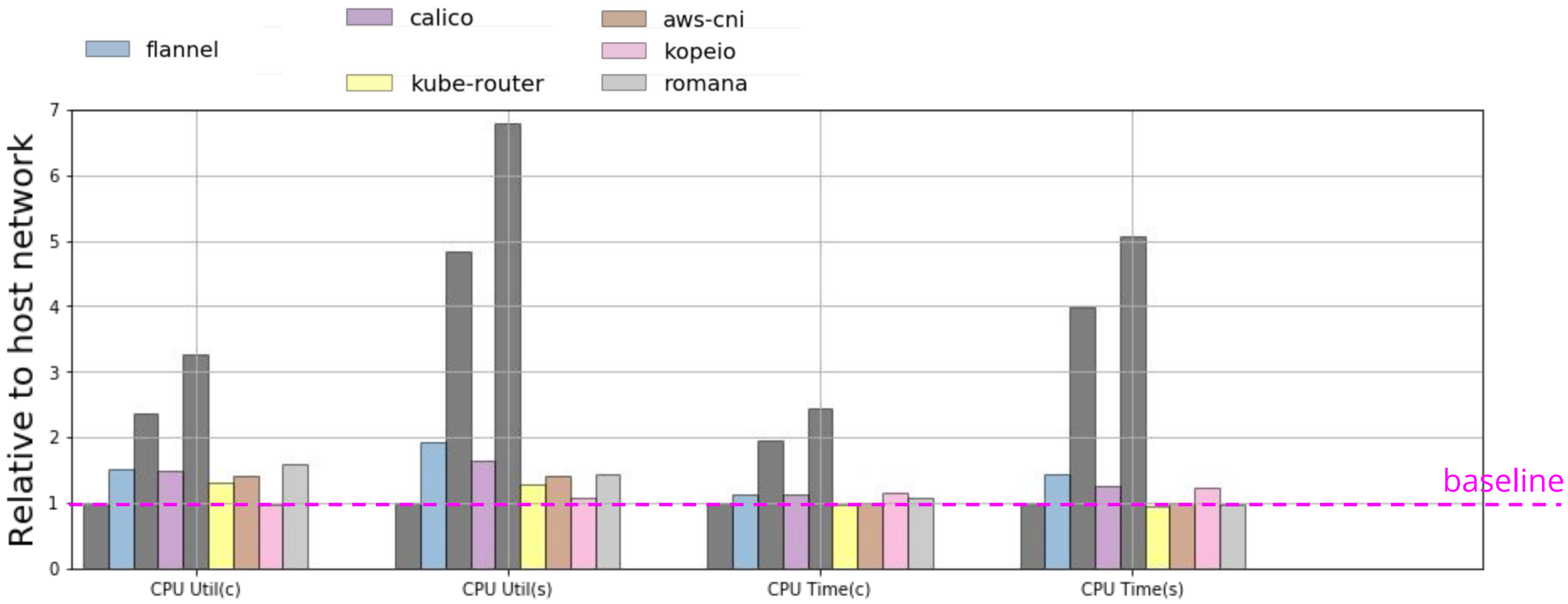
- Netperf client pod in Node A
- Netperf server pod in Node B

- Netperf UDP_RR to measure CPU utilization
- Time spent in user space, kernel space, and waiting for I/O

CPU Overhead



CPU Overhead



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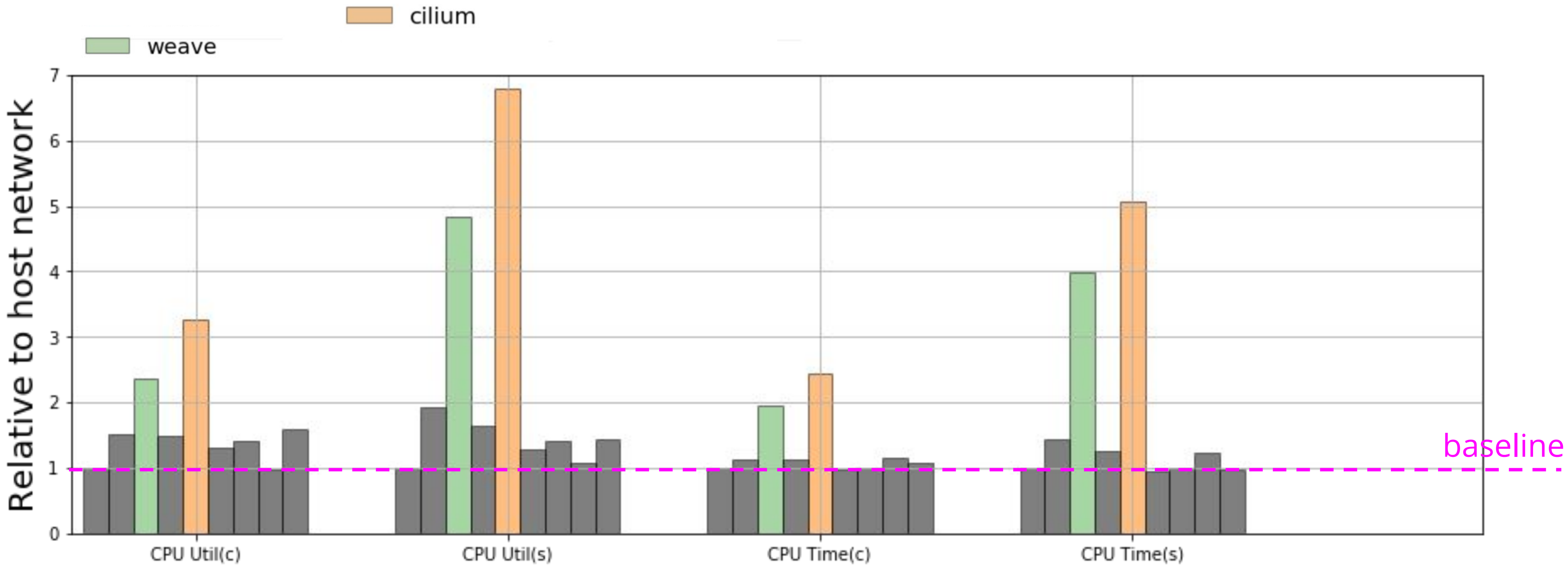
CPU Overhead



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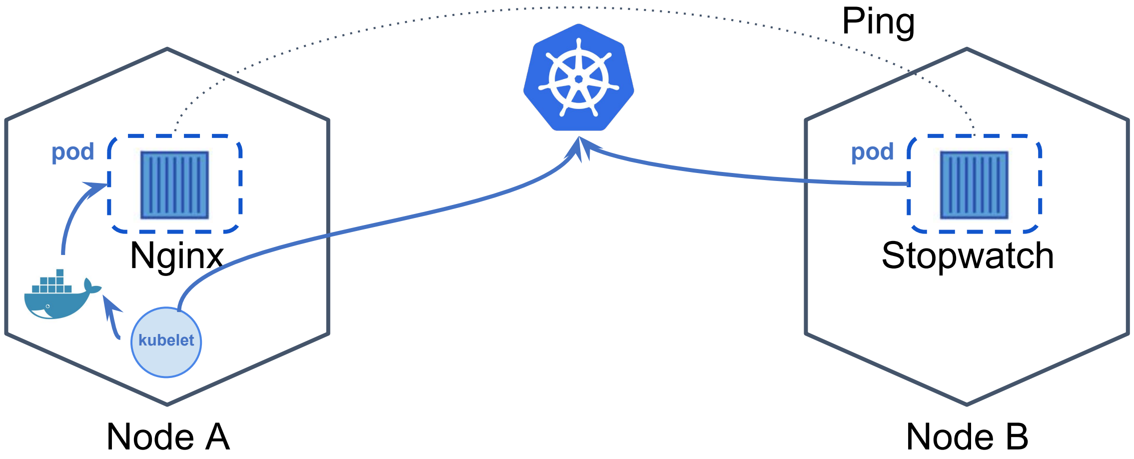
Experiment #4

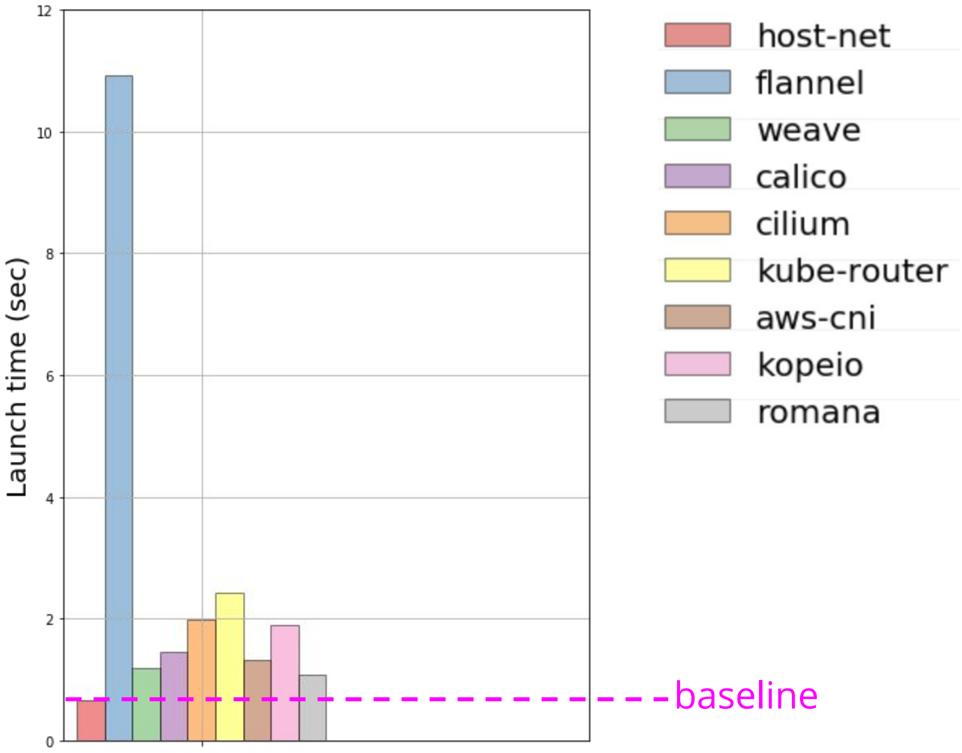
Network Launch Time

Steps

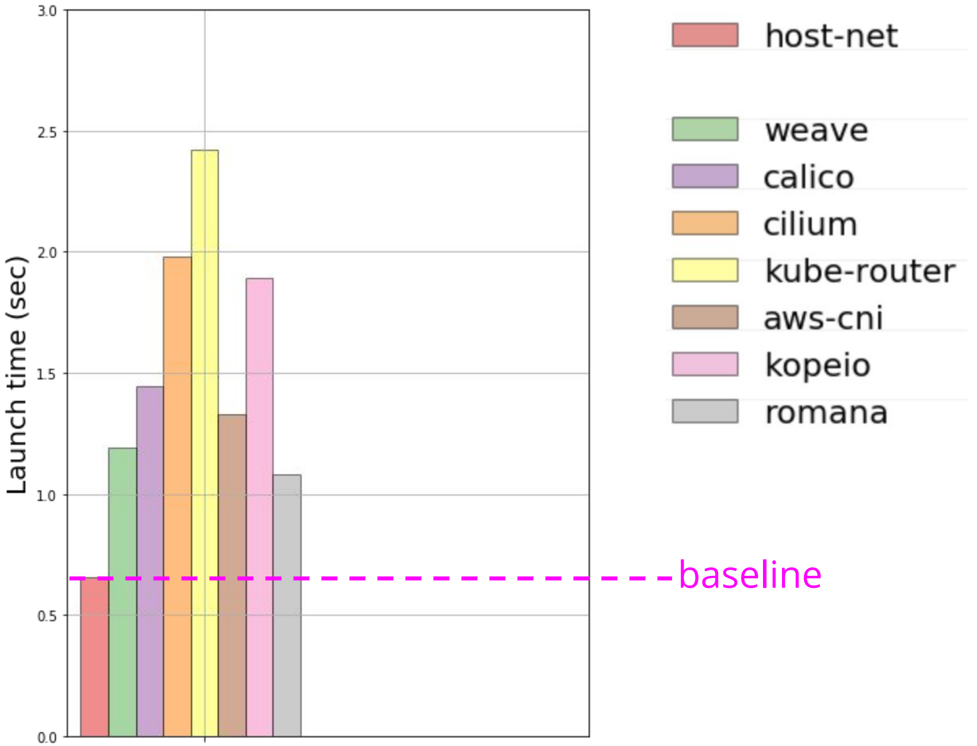


- Deploy Nginx pod in Node A
- Watch kubelet events on container create
- Stopwatch until pinging from Node B

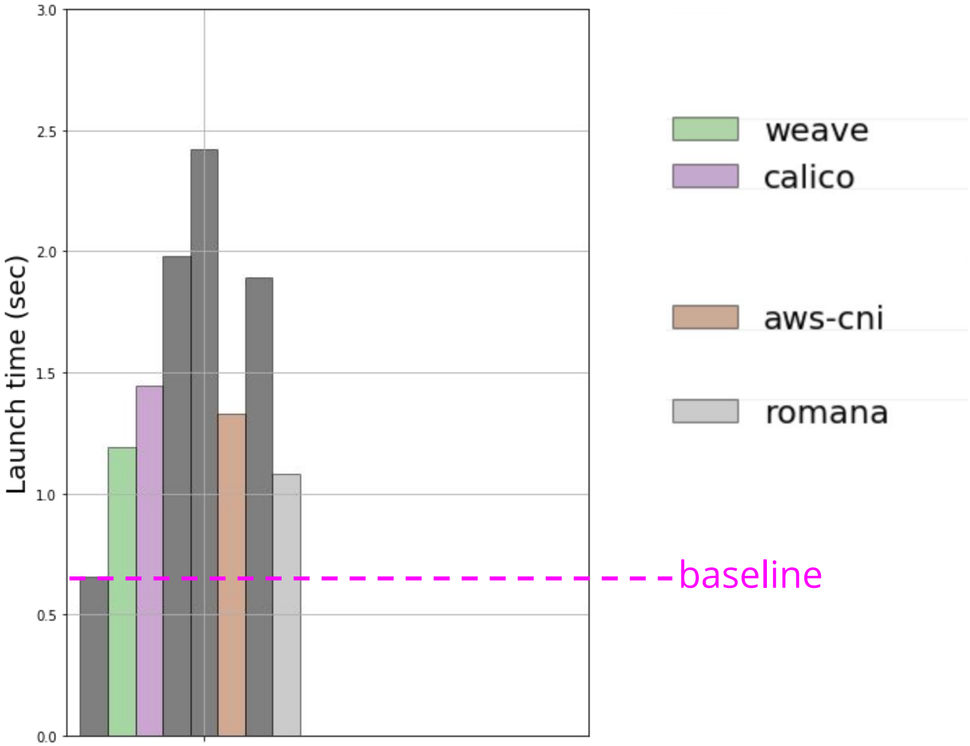
Network launch time



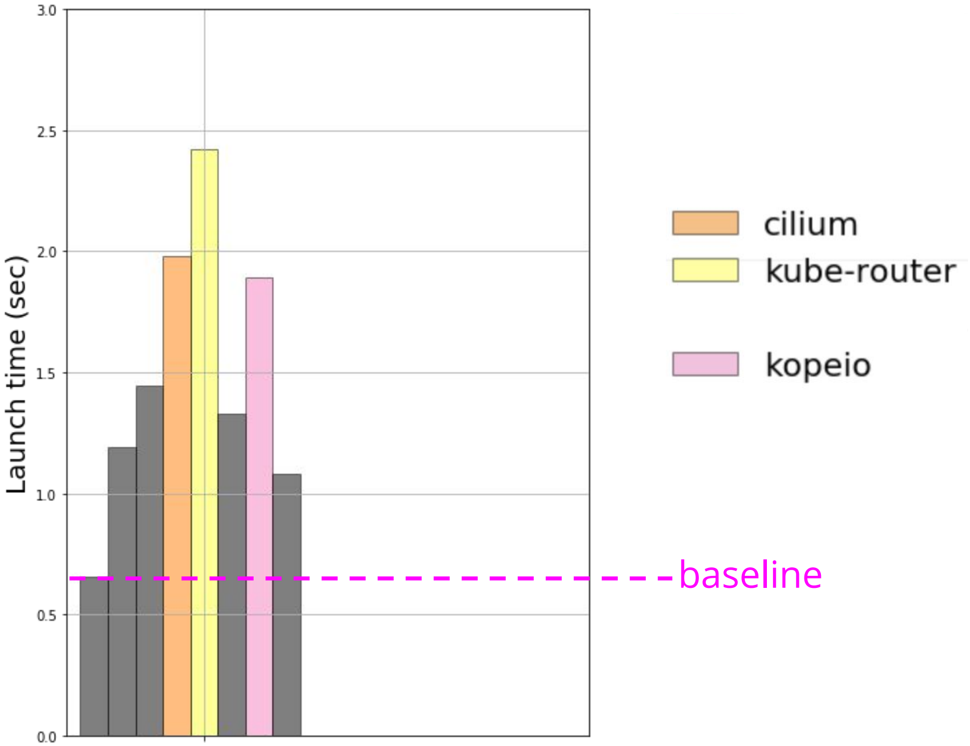
Network launch time



Network launch time



Network launch time



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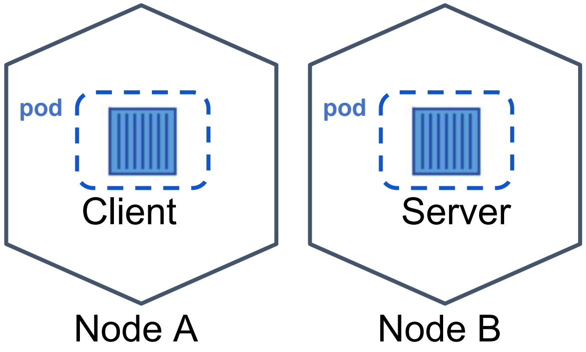
Experiment #5

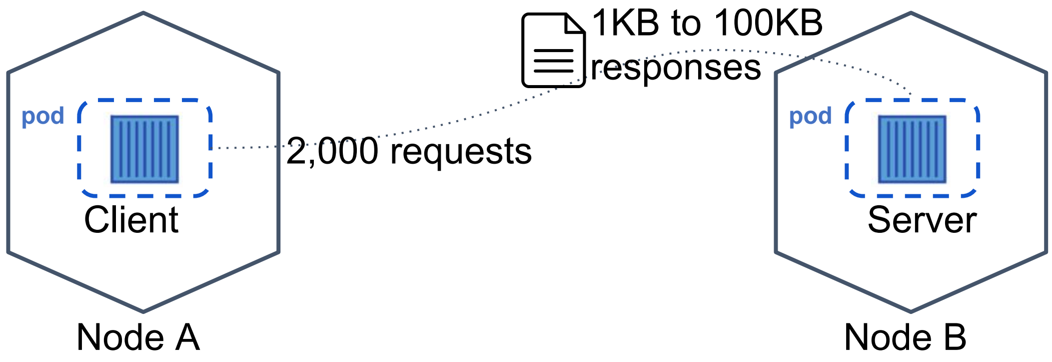
Network Policies

Steps



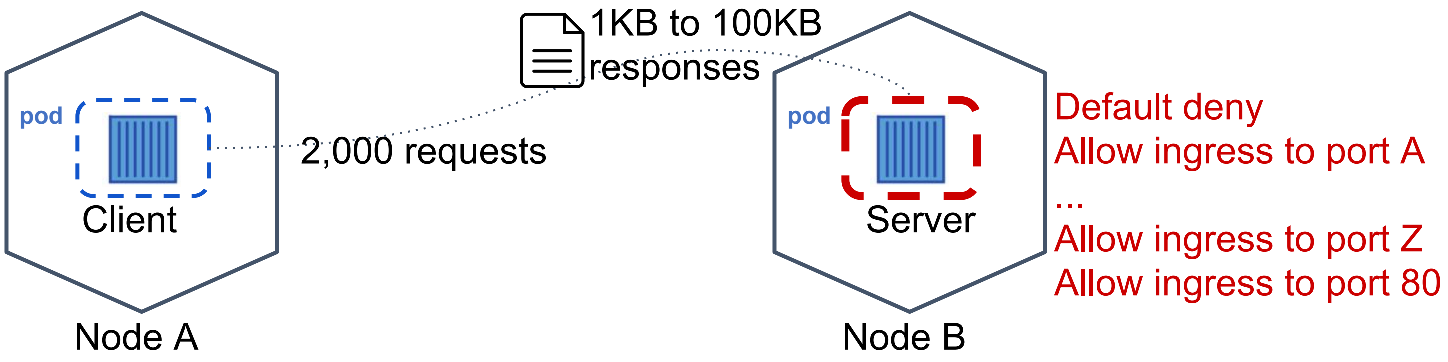
- Client pod in Node A
- Server pod in Node B

Steps



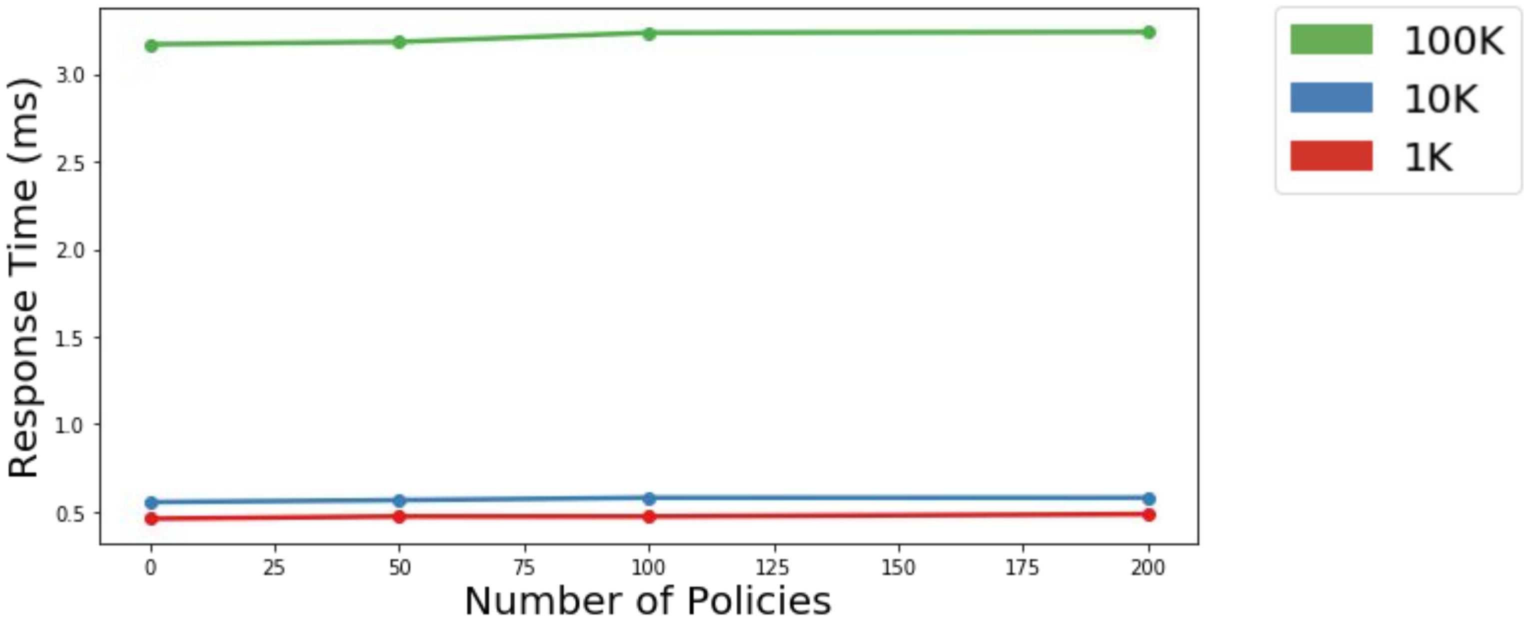
- Client pod sends 2,000 HTTP requests
- Varied response size from 1KB to 100KB
- Disabled persistent connection

Steps

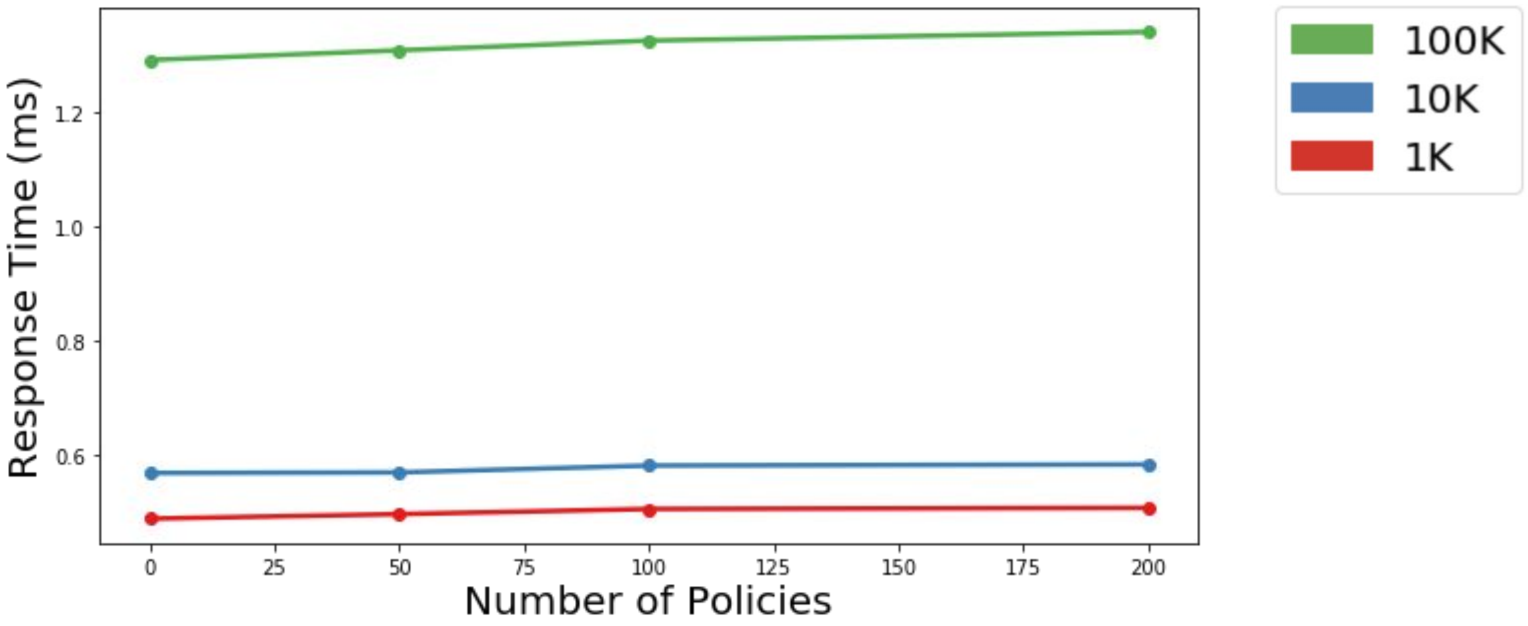


- Varied network policy from 0 to 200 policies

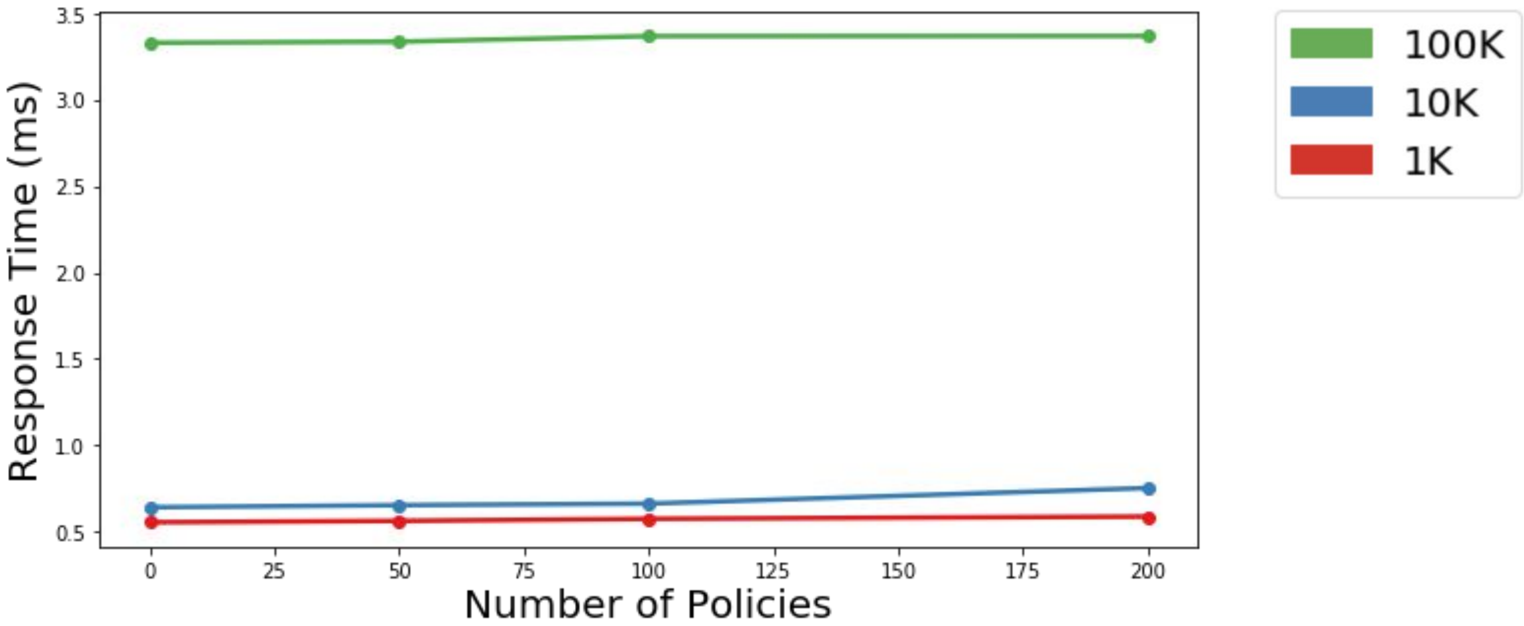
Network Policy (Calico)



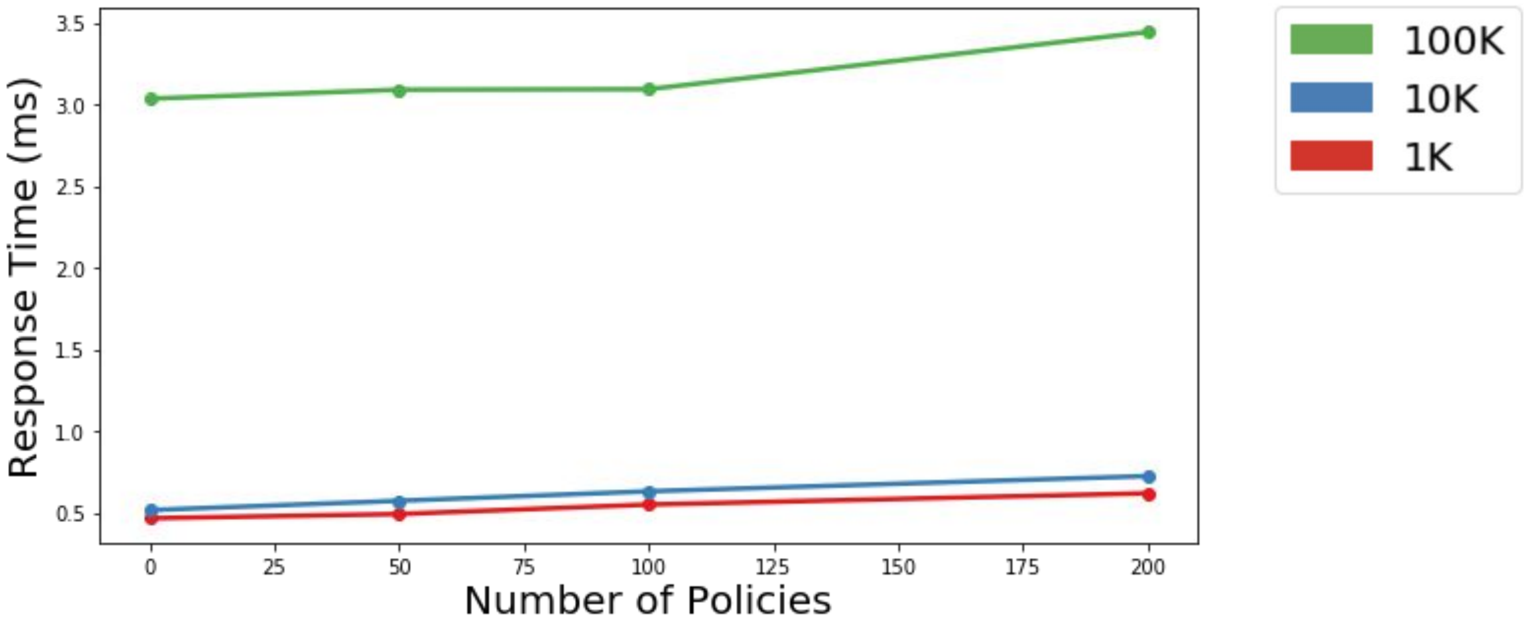
Network Policy (Weave)



Network Policy (Cilium)



Network Policy (Kube-Router)



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Takeaways

Takeaways

CNI

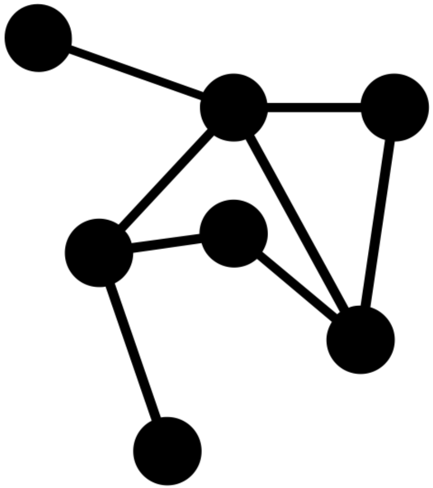
Very challenging to pick appropriate CNI plugins

Tradeoffs between **performance, security, isolation**

Takeaways

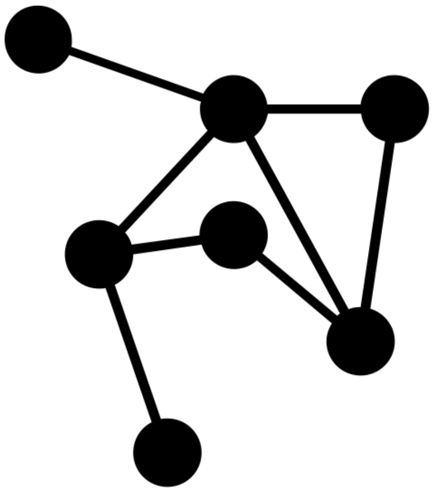
In general, with default config,
Flannel, Weave, Romana achieves better network performance than the others

Takeaways



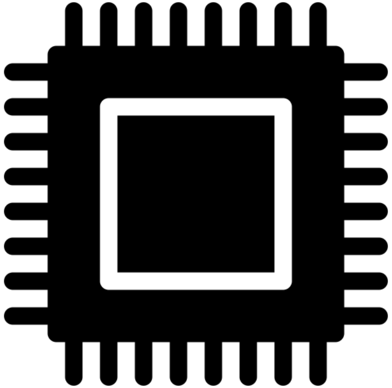
Most CNI plugins get much **larger throughput** to **TCP** than **UDP** workloads

Takeaways



Most CNI plugins **scaled more** in **UDP**
with **considerable loss**

Takeaways



Most CNI plugins introduce **CPU overhead** with **Weave** and **Cilium** being largest

Takeaways

Most CNI plugins add **reasonable delay** to **launch containers**, except **Flannel**

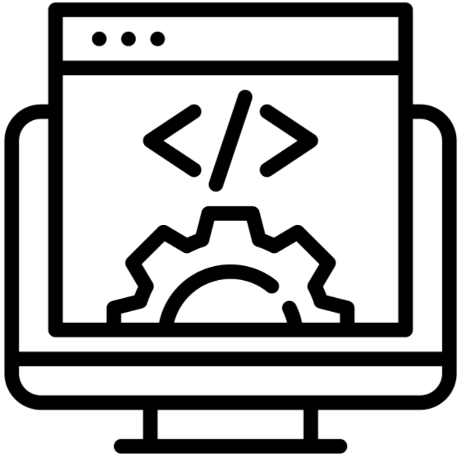
Takeaways

Most CNI plugins introduce **small delay** as number of **policies increases**

Next

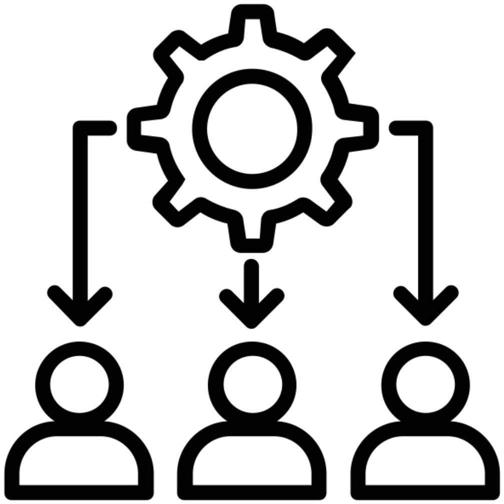
Need more **comprehensive analysis**
on the experiment results

Next



Perform specific **configuration**
to allow **better performance** on some CNI Plugins

Next



More types of experiments
on **concurrent requests** and **workload interference**

References

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