Virtual Open Systems

A performance benchmarking analysis of Hypervisors, Containers and Unikernels on ARMv8 and x86 CPUs

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Authorship and sponsorship

Virtual Open Systems is a high-tech software company active in open source virtualization solutions and custom services for complex mixed-criticality automotive systems, NFV networking infrastructures, mobile devices and in general for embedded heterogeneous multicore systems around new generation processor architectures.

This work is done in the context of the H2020 “Next Generation Platform as a Service” project (www.ngpaas.eu).

Agenda

- Objectives
- Evaluated Solutions
  - Virtual Machines
  - Containers
  - Unikernels
- Benchmark configuration
- Benchmark results
- Conclusion

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Objectives

- Software Defined Network (**SDN**) and Network Function Virtualization (**NFV**) technologies are emerging in the Edge Computing
- Efficient virtualization technologies are becoming crucial
- New lightweight techniques (Containers, Unikernels) have emerged
- This work focuses on **comparing the performance of open-source virtualization technologies** on X86 and ARMv8

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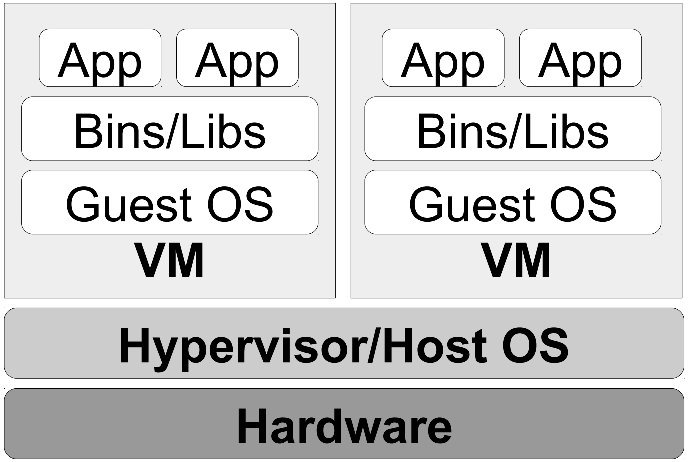
Virtual Machines (VMs)

- Virtualization is a technology that allows to create multiple environments or dedicated resources from a single, physical hardware system.

- Software called a hypervisor connects directly to that hardware and allows to split one system into separate environments called Virtual Machines (**VMs**)

- Hypervisor solution benchmarked is **KVM**



App App

Bins/Libs

Guest OS

VM

App App

Bins/Libs

Guest OS

VM

Hypervisor/Host OS

Hardware

VM-based architecture

Kernel Virtual Machine (KVM)

- KVM is a full virtualization solution
- It makes **Linux Kernel** act as a Type-1 hypervisor
- KVM relies on user space tools like Quick Emulator (QEMU)
- QEMU is used to emulate and provide device abstractions
- KVM also provides support for paravirtual devices through **Virtio**, for better performance

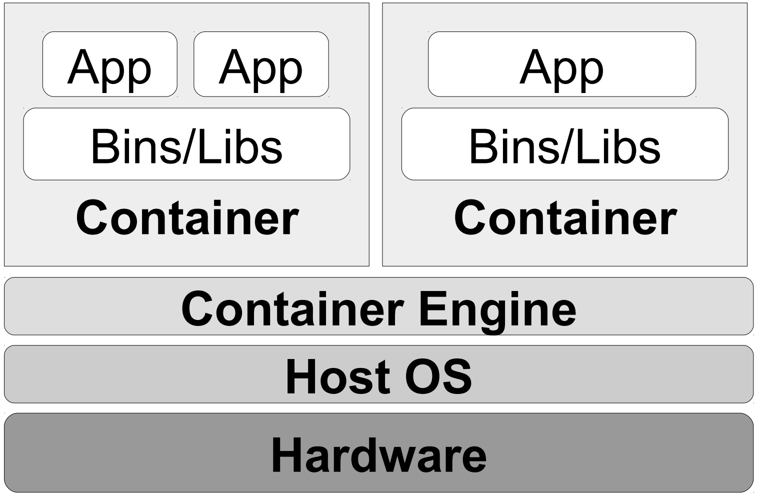
Containers

- **Containers** are a virtualization method for deploying and running distributed applications without launching an entire VM for each application.

- They depend on sharing the same base OS among themselves

- Loosely isolated

- Container engines benchmarked are **Docker** and **rkt**.



Container-based architecture

Docker

- Most popularly used container engine

- **Easy deployment** and management of cloud applications

- **Stable support** for different for various architectures and different applications

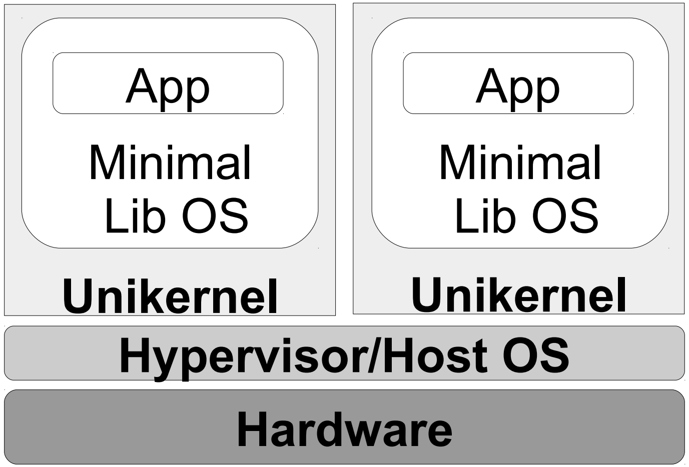
- Uses *libcontainer* to take advantages of Linux *namespaces* and *cgroups*

CoreOS rkt

- **rkt** (pronounce *rocket*) has a **security-minded** approach as its primary distinguishing feature from Docker
- Has support for all ”Docker Images”
- Has security features like:
  - Fetching container images as a non-root user
  - Option to use KVM or VM based isolation as stage 1
  - Support for SVirt in addition to a default SELinux policy

Unikernels

- **Unikernels** are specialized, single-address-space machine images constructed using library operating systems.
- Built by combining only the specialized application image and OS software parts required to support it
- Size of the traditional VMs is reduced
- Also use an **Hypervisor** (such as KVM), there are actually also VMs!
- Unikernel solutions benchmarked are **Rumprun** and **OSv**



Unikernel-based architecture

Rumprun

- The **Rumprun** unikernel is based on the driver components of **rump kernels**

- Rump Kernel is derived by picking the desired components from the **NetBSD** anykernel

- Execute existing **POSIX** applications on KVM or Xen

- Doesn’t support *exec()* and *fork()* system calls

OSv

- **OSv** uses the concept of a **library OS** to provide a Lightweight OS

- Application threads and the kernel share the same address space to reduce overhead

- Only stable architecture supported is x86, so far

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Benchmarking Tools

- CPU performance
  - Benchmarked using **SysBench**
- Memory bandwidth
  - Benchmarked using **STREAM**
- Network Bandwidth
  - Benchmarked using **Iperf**

Benchmarking Configuration

- **x86 64 bit platform**
  - Two Intel Xeon Processors E5-2623 v4
  - 8 cores @2.60GHz
  - Intel VT-x hardware virtualization extension
  - 32GB of DDR4 RAM

- **ARMv8 platform**
  - One Cavium ThunderX rev1 processor
  - 48 cores @2GHz
  - Hardware assisted virtualization extension
  - 128GB of DDR4 RAM

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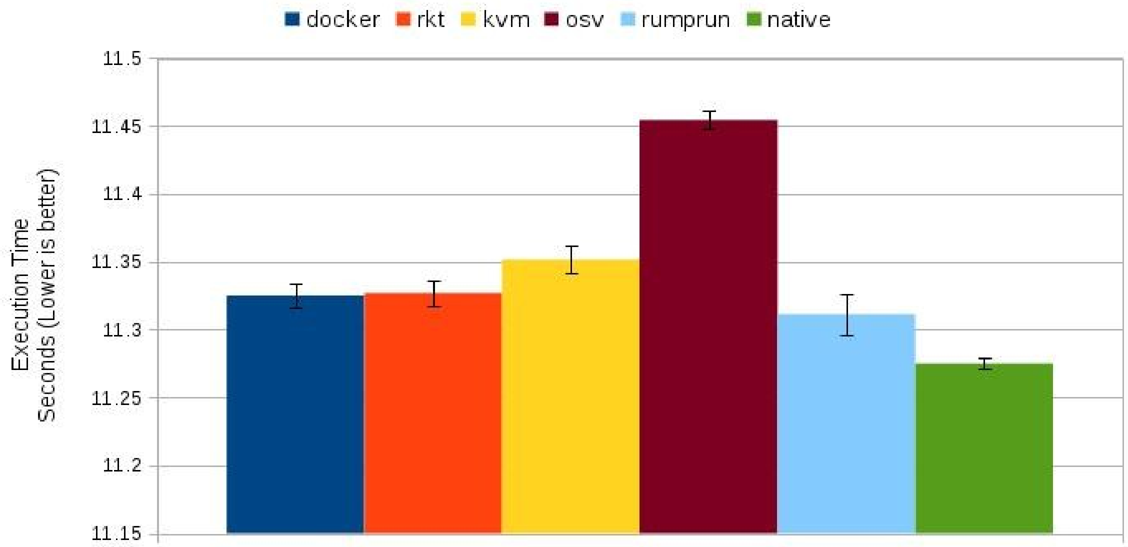
CPU performance comparison

SysBench on an x86 server



- Rumprun provides near native performance

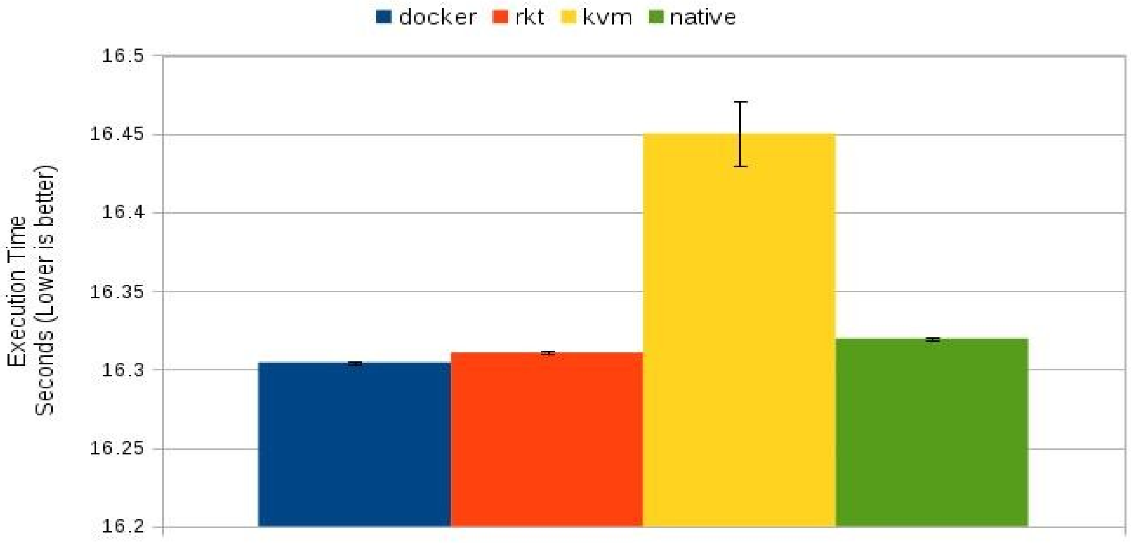
- Containers have 0.45% overhead

- KVM has 0.7% overhead

- OSv has the worst performance with 1.6% overhead

CPU performance comparison

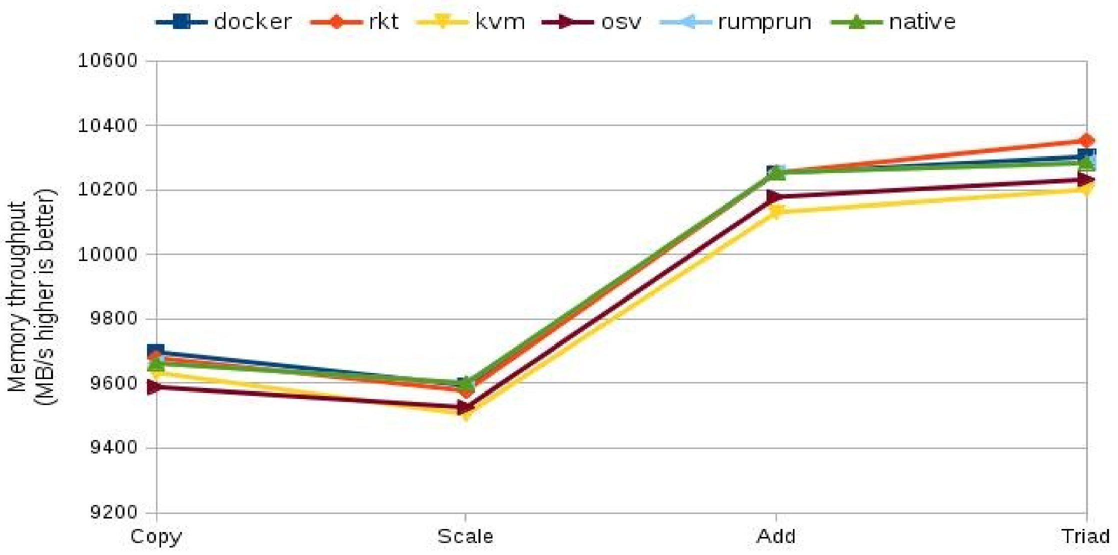
SysBench on an ARMv8 server



- KVM has a overhead of 0.8%
- Containers produce **near-native performance**
- Containers have very stable performance with negligible standard deviation

Memory Bandwidth comparison

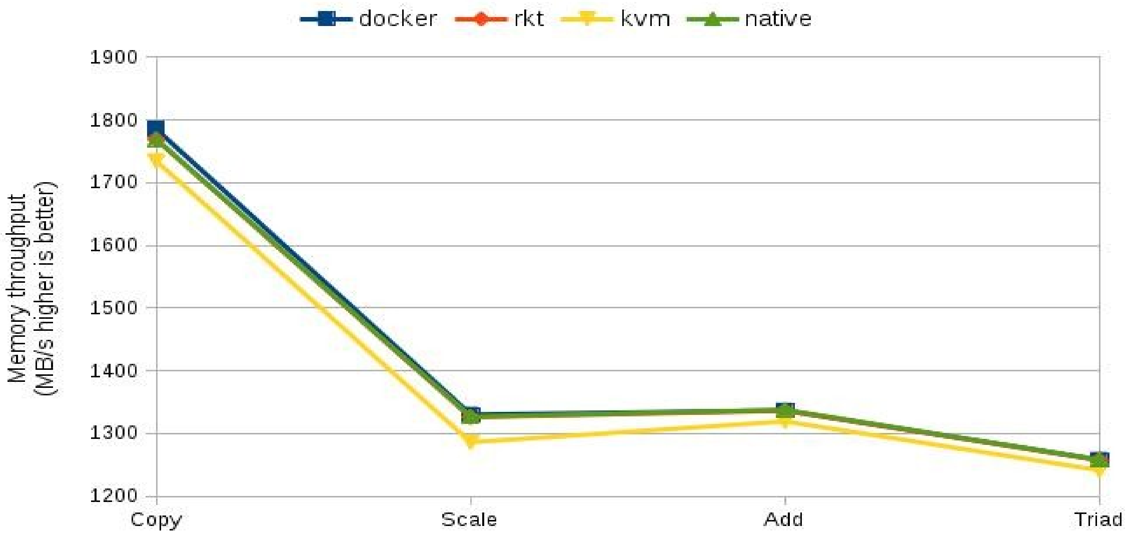
STREAM on an x86 server with 1 thread



- ➢ Docker, rkt and Rumprun have negligible overhead
- ➢ OSv has a small overhead range of 0.6%-1.3%
- ➢ KVM has the maximum overhead range of 0.6%-1.6%

Memory Bandwidth comparison

STREAM on an ARMv8 server with 1 thread

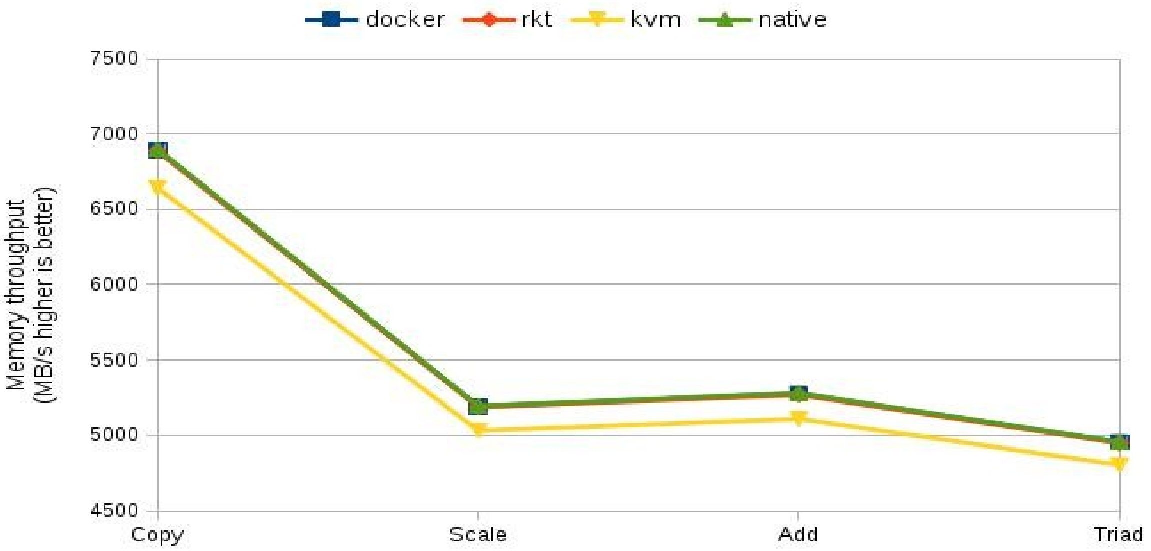


- KVM has overhead of about 2% for Copy and about 3% for Scale operations

- Containers induce no overhead

Memory Bandwidth comparison

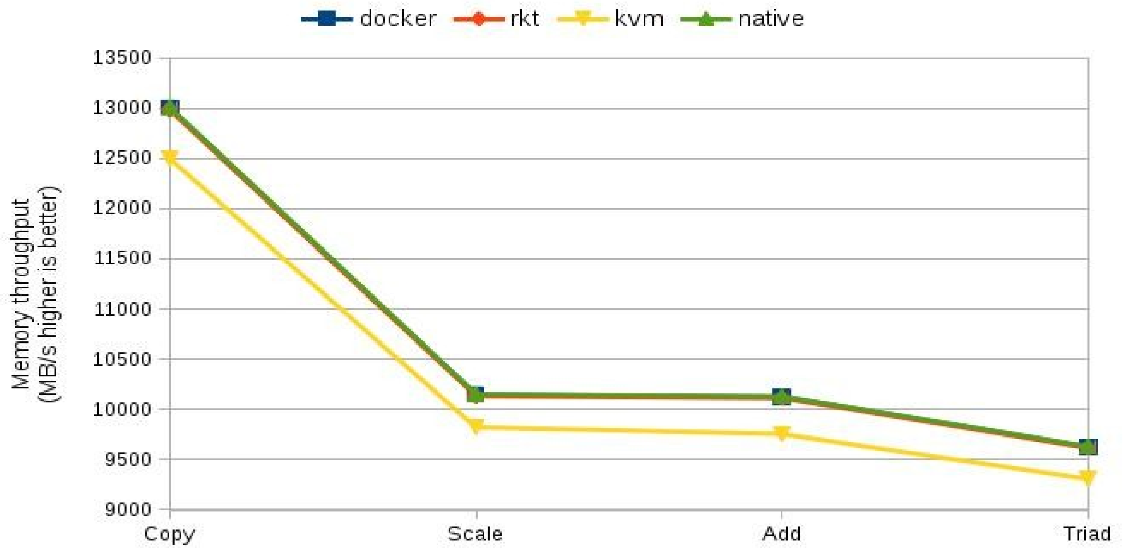
STREAM on an ARMv8 server with 4 threads



- ➢ KVM overhead scales to above 3% in all the cases
- ➢ Containers induce no overhead

Memory Bandwidth comparison

STREAM on an ARMv8 server with 8 threads

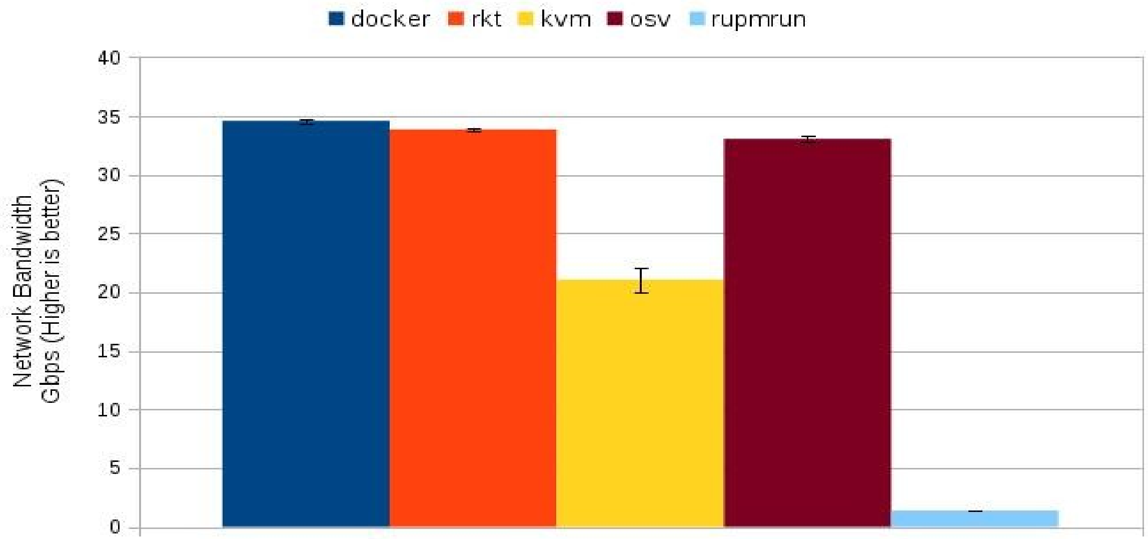


- KVM overhead slightly increases further to 4%

- Containers continue to produce near-native performance

Network Bandwidth comparison

Iperf on an x86 server



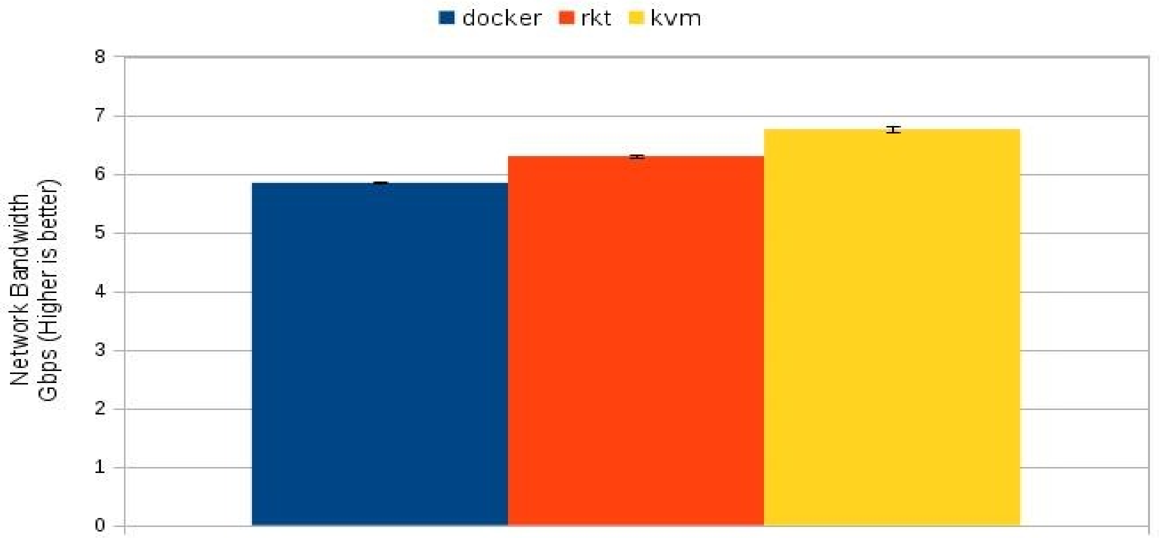
- Docker, rkt and OSv provide the highest performance

- KVM comparatively is 80% less efficient

- Rumprun has terrible performance issues with a max bandwidth of just 1.37 Gbps

Network Bandwidth comparison

Iperf on an ARMv8 server



- **KVM performs better** than both the container engines
- Docker comparatively has a performance overhead of almost 15.6%
- rkt shows an overhead of 7.2% compared to KVM

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Conclusion

- **Unikernels** are still quite young and not production ready (no ARMv8 stable support), but are very promising

- **Containers** are generally the fastest and the easiest to deploy

- **KVM VMs** provide small CPU and memory overhead with a strong isolation

Future Work

- Extend to benchmarking other metrics like:
  - Security
  - Scalability

- Benchmark Unikernels on ARMv8 once they are fully compatible and stable

- Benchmark performance by launching containers inside VMs

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THANK YOU!

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