Chair of Network Architectures and Services
School of Computation, Information, and Technology
Technical University of Munich

Containing Low Tail-Latencies in Packet Processing Using Lightweight Virtualization

Florian Wiedner, Max Helm, Alexander Daichendt,
Jonas Andre, and Georg Carle

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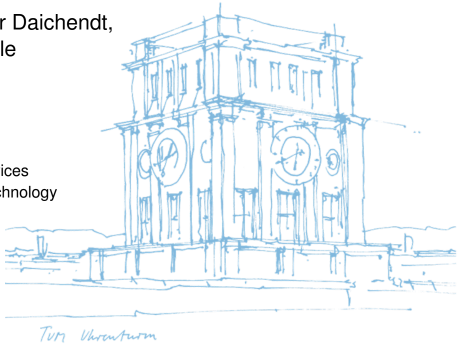

Motivation

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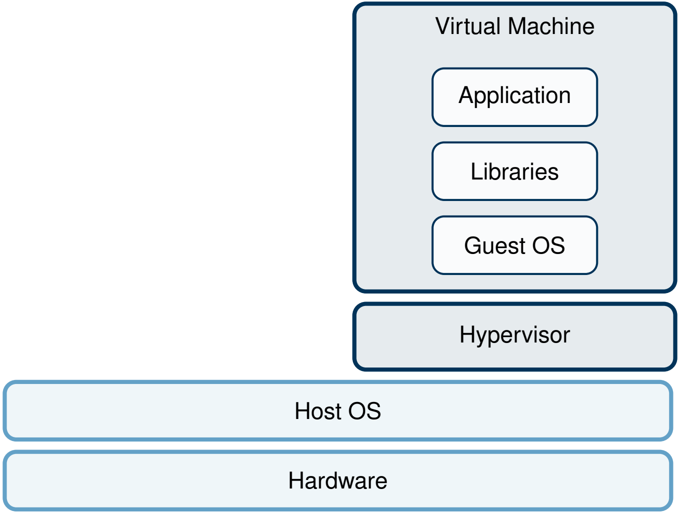
- Demand for resource sharing and on-demand provisioning is rising
- One hardware machine per customer and application is expensive
- Virtualization allows to share of systems and resources between customers/applications
- Can virtualized network applications achieve stable low latency in networking?

Virtualization: Virtual Machines vs. Container

Overview



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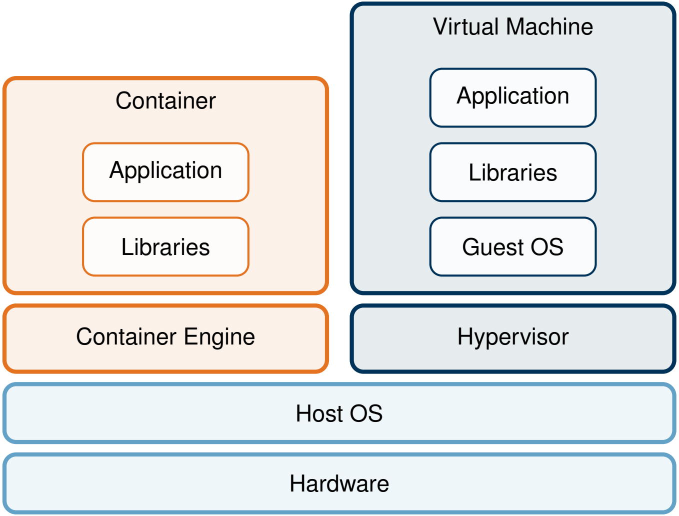

Research Goal and State-of-the-Art

Goal

Can container enhance resource-sharing when processing low-latency traffic?

- What is the state-of-the-art on using low-latency applications on virtualized systems?
- Are containers capable of processing traffic while holding low-latency requirements?
- Is tail-latency behavior differing between container, VMs, bare-metal, and kernel to user-mode processing?

Research Goal and State-of-the-Art

State-of-the-Art

	VMs		Container		Baremetal		Tail-latency
	Latency	Throughput	Latency	Throughput	Latency	Throughput	
Tran and Kim[1]	✗	✗	✗	✓	✗	✗	✗
Cha and Kim[2]	✗	✗	✗	✓	✗	✗	✗
Liu[3]	✓	✓	✗	✗	✗	✗	✗
Gallenmüller et al.[4]	✓	✓	✗	✗	✓	✓	✓

1 M.-N. Tran and Y. Kim, „Network Performance Benchmarking for Containerized Infrastructure in NFV environment“, in 2022 IEEE 8th International Conference on Network Softwarization (NetSoft), Jun. 2022, pp. 115–120.

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This paper	✓	✗	✓	✓	✓	✗	✓

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Low-Latency Optimizations

Low-latency software stack

How can we reduce latency spikes in virtualized systems?

mostly caused by interrupts

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Optimizations for VMs[a]

- Polling-based IO (DPDK)
- Disable Simultaneous Multithreading
- Disable energy-saving mechanism
- Statically allocate CPU cores for processes
- Interrupt affinity to core 0
- Isolate VM and packet processing from OS kernel

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Is the Kernel configuration influencing the latency?

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Vanilla kernel

- Debian Bullseye
- No changes, as provided by the Debian project

Real-Time (RT) kernel

- Debian Bullseye
- Real-time patches integrated
- Targeted to achieve deterministic behavior

NoHz kernel

- Debian Bullseye
- Real patches integrated
- NoHz kernel option enabled
- Allow to isolate cores with only one application running from timer interrupts

Low-Latency Optimizations

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Can container enhance resource-sharing when processing low-latency traffic?

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- × Is tail-latency behavior differing between container, VMs, bare-metal, and kernel to user-mode processing?

Experimental Setup

Workload and Scenario

- Use container (Linux Container (LXC)) as virtual network function
- Ingress and Egress hardware interface direct-attached to the container
- DPDK-based Libmoon l2-forwarding application
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- Traffic: UDP Traffic with 64 B-sized packets
- Duration: 160 s per measurement
- Rate: 1 Mpackets/s

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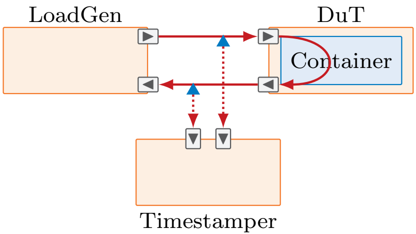

- Loadgen runs a packet generator (MoonGen) creating UDP packets
- Device under Test (DuT) runs Container/VMs/Packet Processing application
- Timestamper records DuT ingress/egress traffic (passive optical TAPs)

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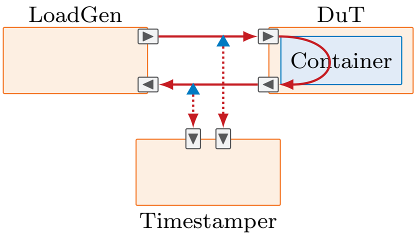

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DuT

- AMD EPYC 7551P 32-Core
- 2x X710 10GbE SFP+ NICs
- 128 GiB RAM

LoadGen

- Intel Xeon Silver 4116
- Intel 82599ES 10GbE SFP+ NIC
- 192 GiB RAM

Timestamper

- AMD EPYC 7542 32-Core
- Intel E810-XXVDA4 NIC
- 500 GiB RAM

Kernel Variants (optimized) [1 Mpackets/s]

Which of the available kernels provides most deterministic latency behavior on container?

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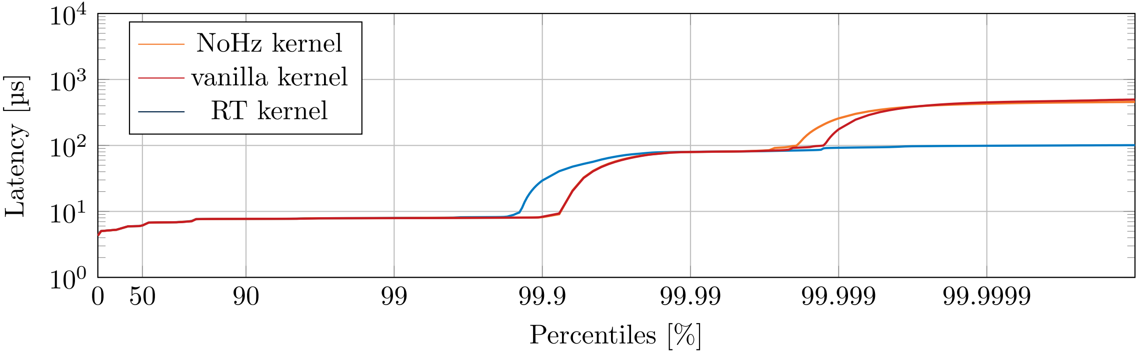

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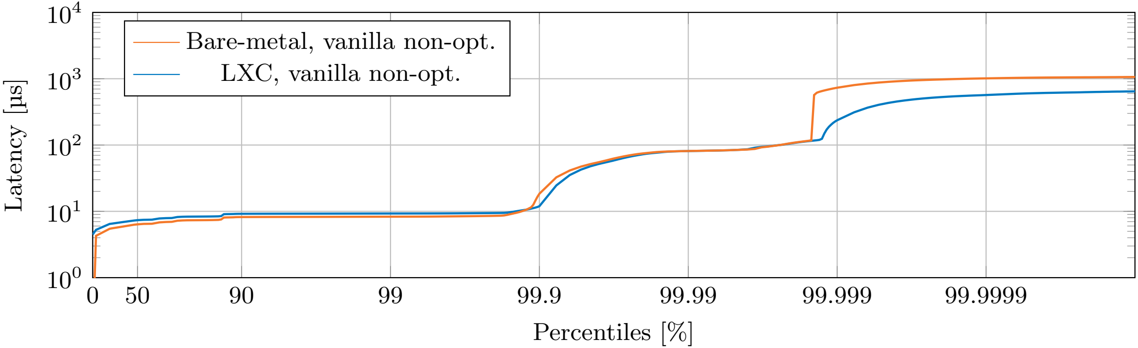
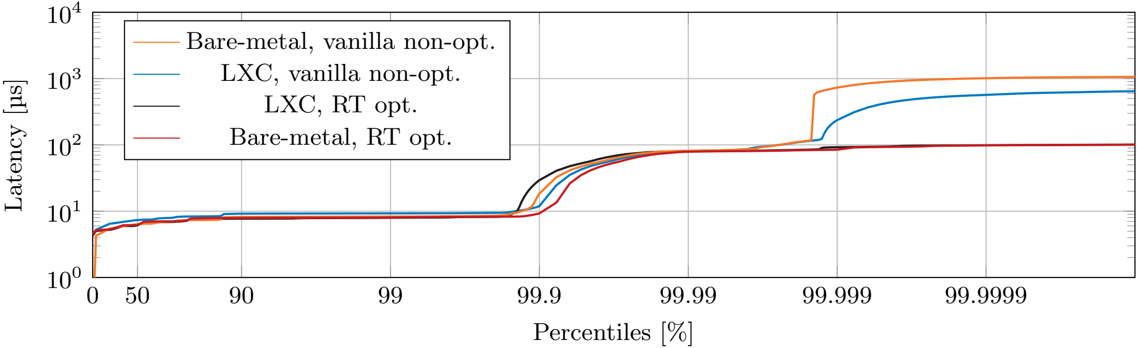


Container vs. Bare-metal [1 Mpackets/s]

Is packet processing on containers a disadvantage compared to bare-metal?



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Container vs. VMs [1 Mpackets/s]

Is packet processing on containers a disadvantage compared to VMs?

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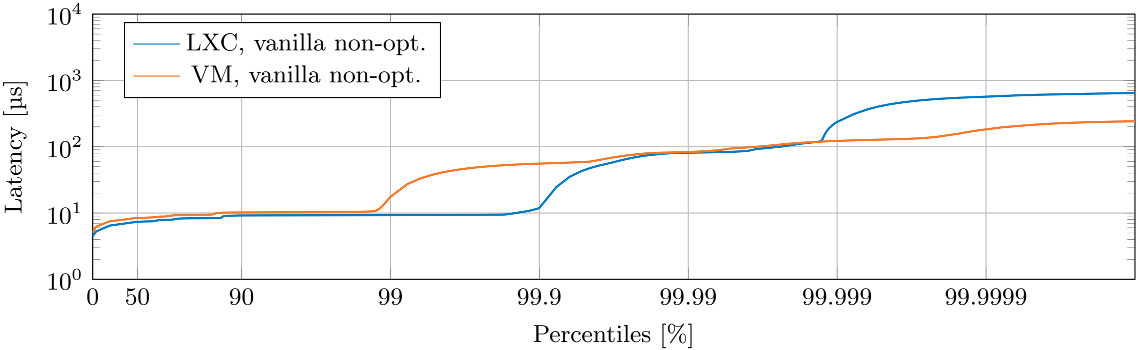

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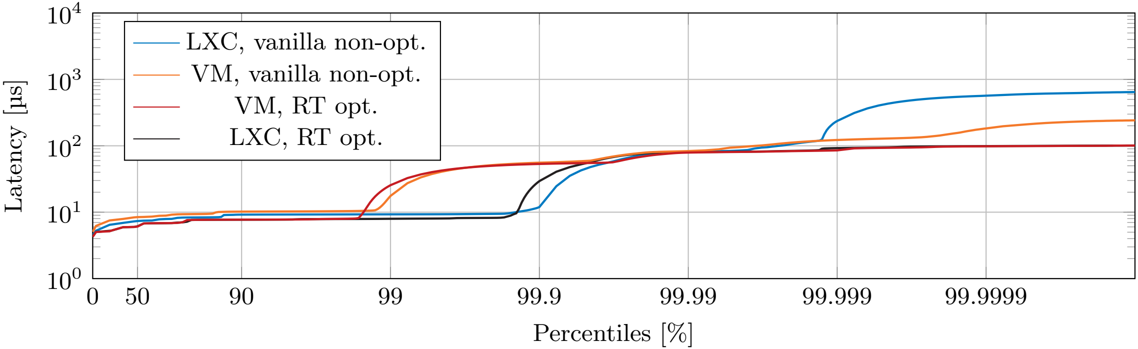

Container using DPDK vs Container Linux Kernel [1 Mpackets/s]

Is kernel-mode networking possible for low-latency on container?

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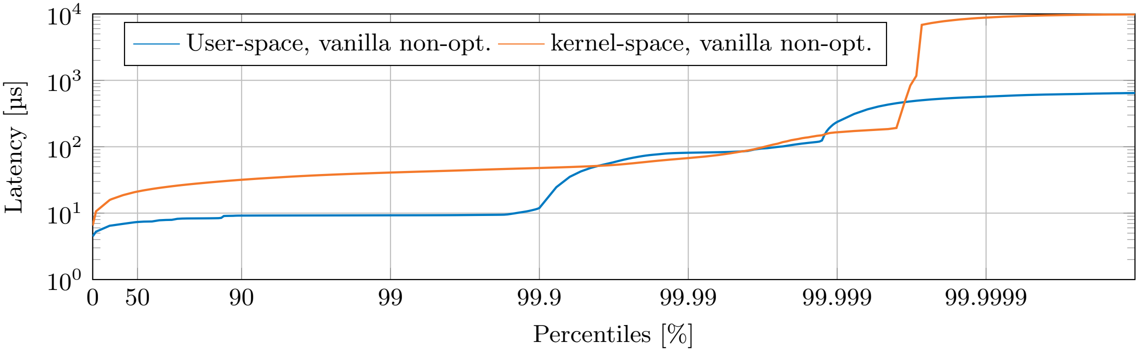

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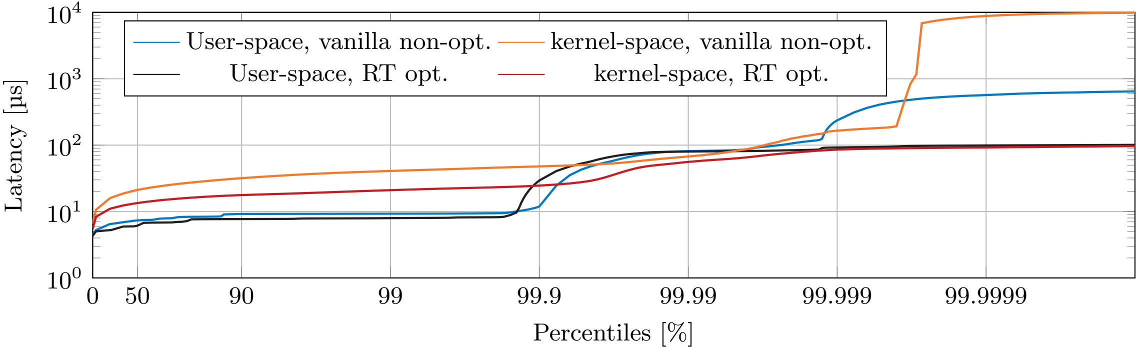

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Conclusion

Low Tail-Latencies in Packet Processing Systems with Lightweight Virtualization

- Using low-latency packet processing in container is possible
- Similar tail-latencies between container, bare-metal, and VMs
- More influence of shared OS in lightweight systems
- Extending state-of-the-art by adding baseline latency measurements

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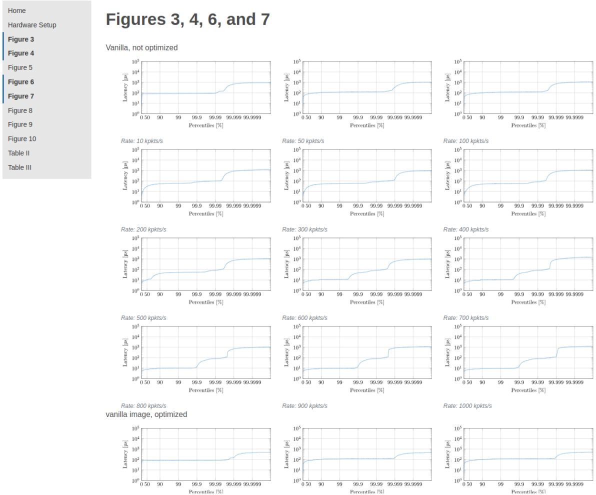
Paper

Measurement Data

- Available artifacts:
  - Evaluation scripts
  - Measurement data
- Website for reproducibility: https://wiednerf.github.io/containerized-low-latency/



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Backup

Used Frameworks

Linux Container (LXC) version 4 [5]

Kernel Virtual Machines (KVM) [6]

Backup

Plain Orchestrating Service [7]

- pos is . . .
  - a testbed orchestration service, and
  - an experiment methodology.
- Methodology makes experiments . . .
  - repeatable as everything is automated,
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- Control hardware machines and VMs using . . . :
  - IPMI as management protocol
  - virtualBMC for controlling VMs similar to hardware machines
  - DHCP for distributing IPs

Backup

VirtualLXCBMC

Challenge: No IPMI available for LXC container

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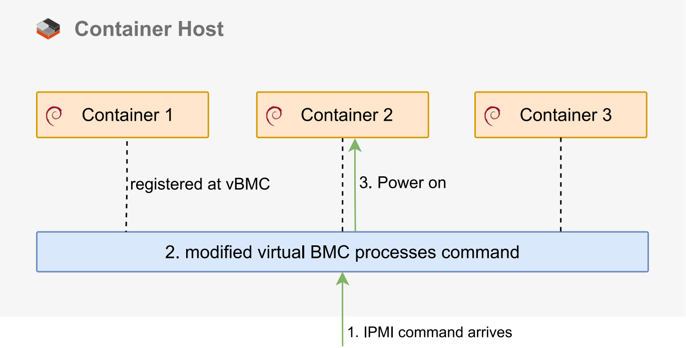
Solution: Fork VirtualBMC for LXC:

- Support starting and stopping container
- Status information of container



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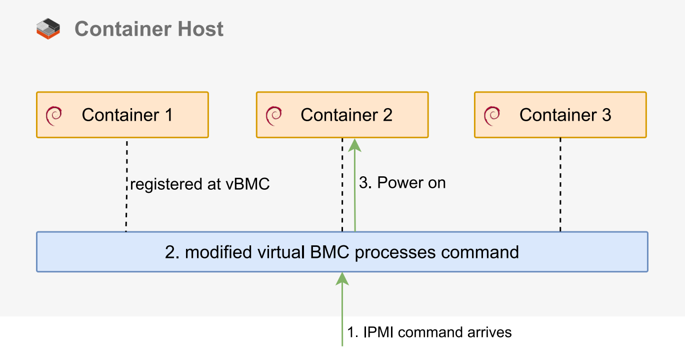
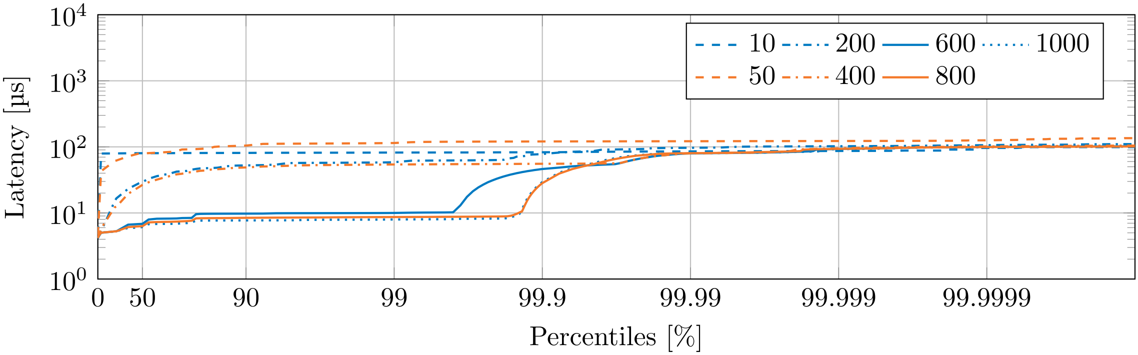
Published in
`https://github.com/tumi8/VirtualLXCBMC`



Backup

Rates on optimized system [kpackets/s]



Rates influence mostly the mean latency.

- The higher the rates, the lower the mean latency
- Tail-latency not significantly influenced