



It's Time to Debloat the Cloud with Unikraft

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The Private/Public Cloud

200

Cloud computing with AWS

Amazon Web Services (AWS) is the world's most comprehensive and broadly adopted **cloud** platform, offering over 200 fully featured **services** from data centers globally.



Multitude of services

Bad for the environment



We need to debloat our VMs

We need to stop idle VMs

The Problem Part 1: Size

Wasted Resources

**Your virtual
machine**

Made of...

Your application

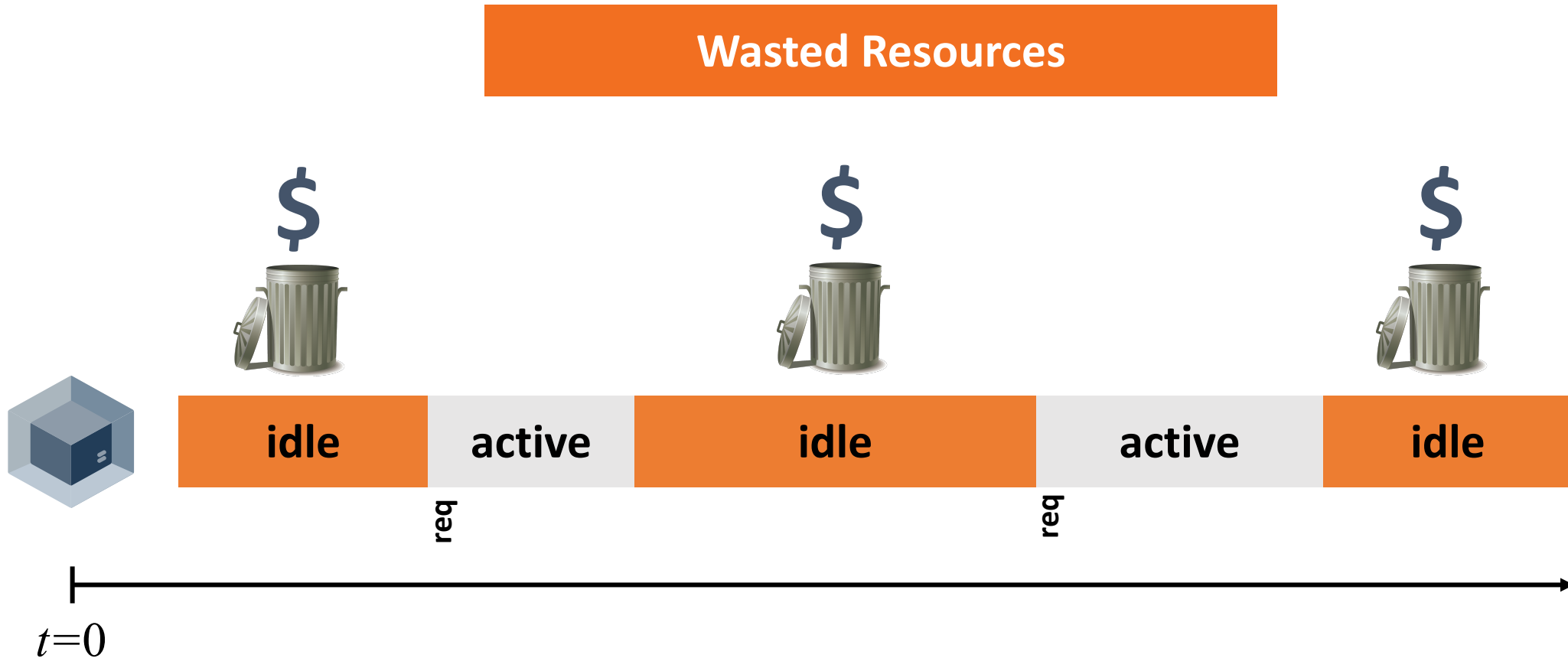
Unused

Unused

Unused



The Problem Part 2: Time



Specialization = High Efficiency

Unikernels = Specialized Virtual Machines

- GOALS**
- **Easy to build and run**
 - **Easy or no app porting**
 - **Great performance**

Unikernel Power



Fast start/stop/migration times

- 10s of milliseconds or less (and as little as 2.3ms)
REFS: LigthVM [Manco SOSP 2017], Jitsu [Madhvapeddy, NSDI 2015]



Low memory footprint

- Few MBs of RAM or less
*REFS: ClickOS [Martins NSDI 2014], Unikraft [Kuenzer, Eurosys 2021. **Best Paper Award**]*



High density

- 8k guests on a single x86 server
REFS: LigthVM [Manco SOSP 2017]



High Performance

- ~300K reqs/sec nginx with a single guest CPU
*REFS: Unikraft [Kuenzer, Eurosys 2021. **Best Paper Award**], Elastic CDNs [Kuenzer VEE 2017]*

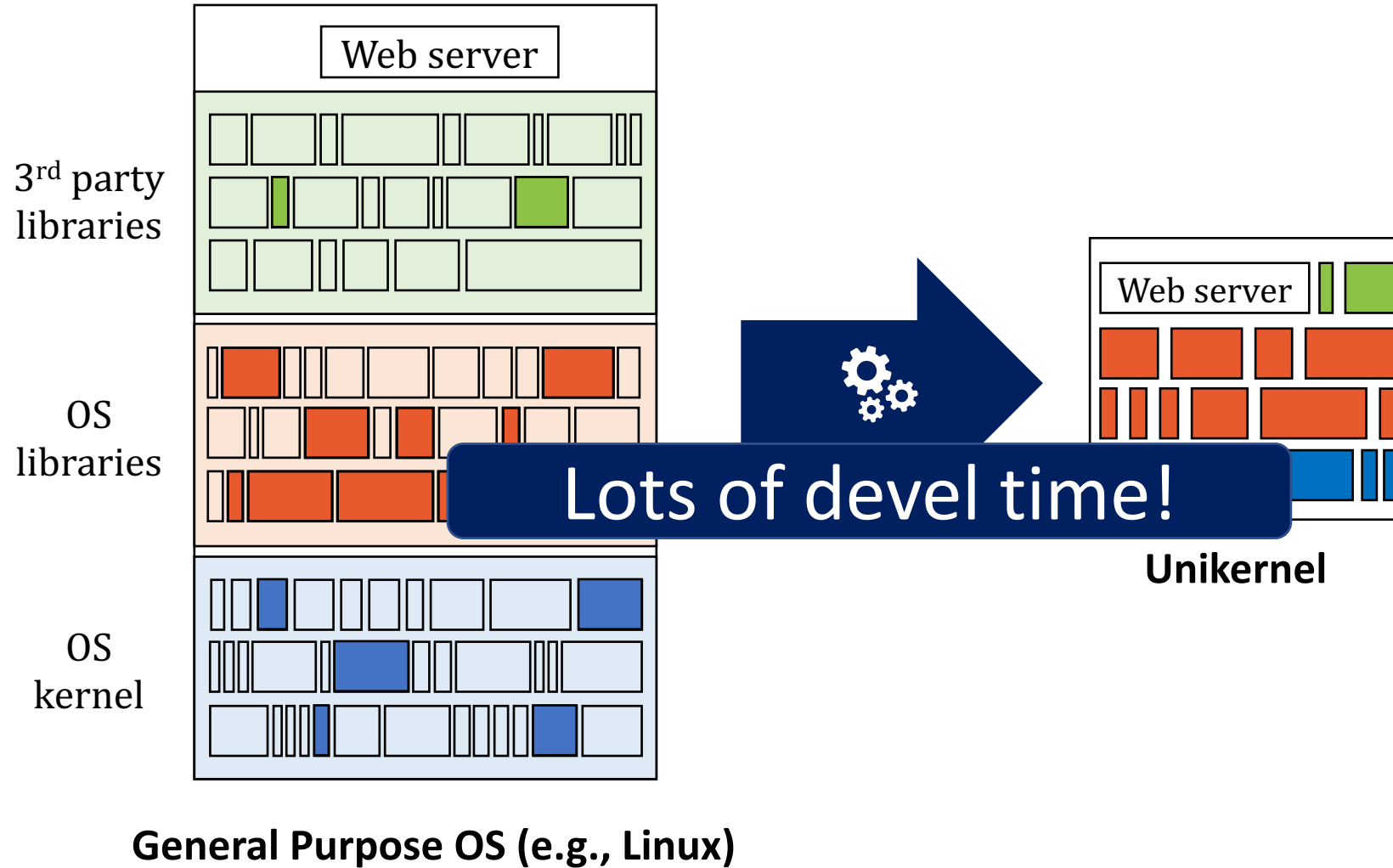


Security Features

- Small trusted compute base
- Strong isolation by hypervisor
- Per-library isolation

REFS: FlexOS [Lefeuvre HotOS 2021], CubicleOS [Sartakov ASPLOS 2021])

Unikernels in One Slide



How do we *transparently* build
efficient and POSIX-compliant
unikernels?

Design Principles

1. Fully **modular** kernel
2. Provide high performance **specialized APIs**

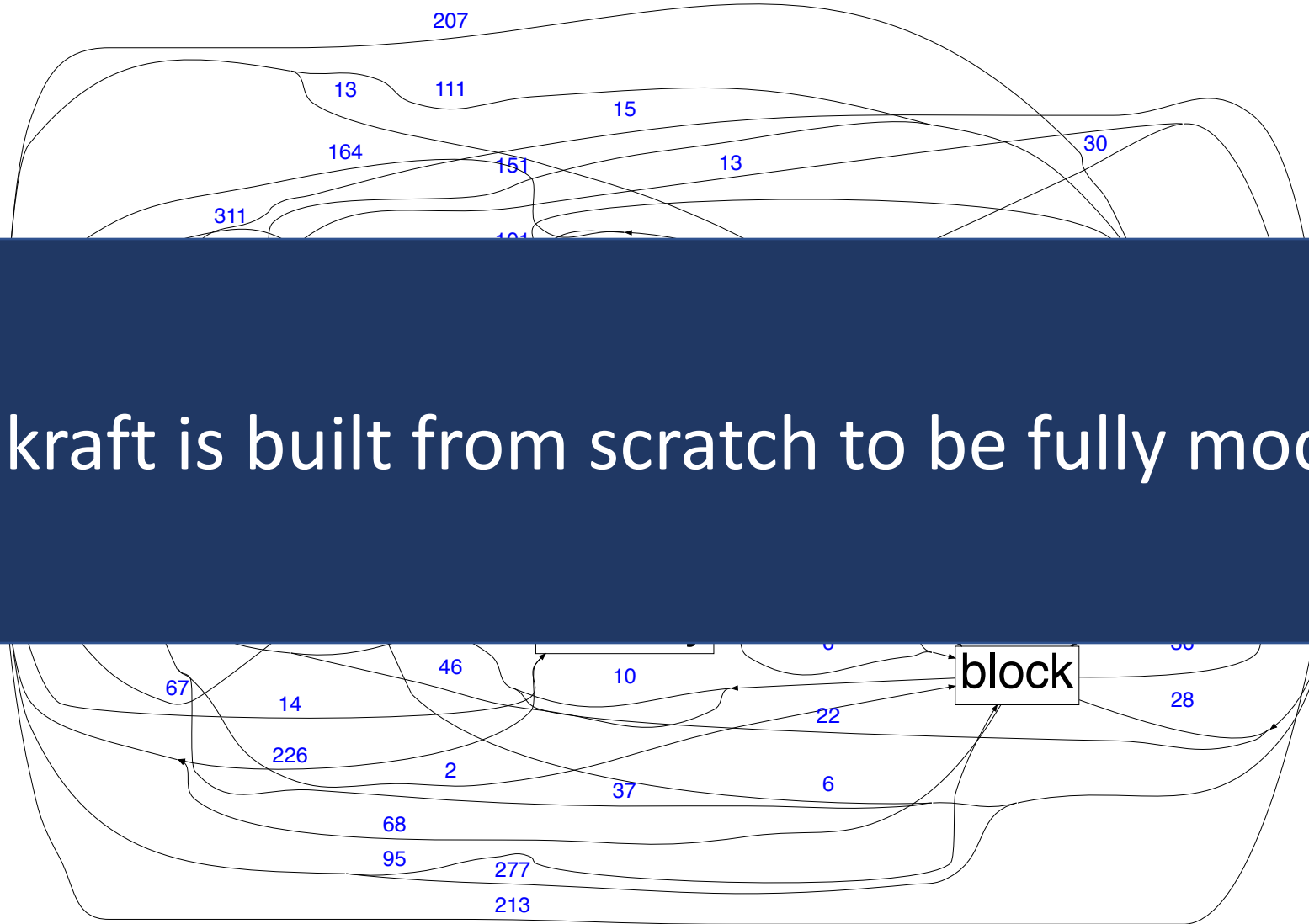
Design Principles

1. Fully **modular** kernel

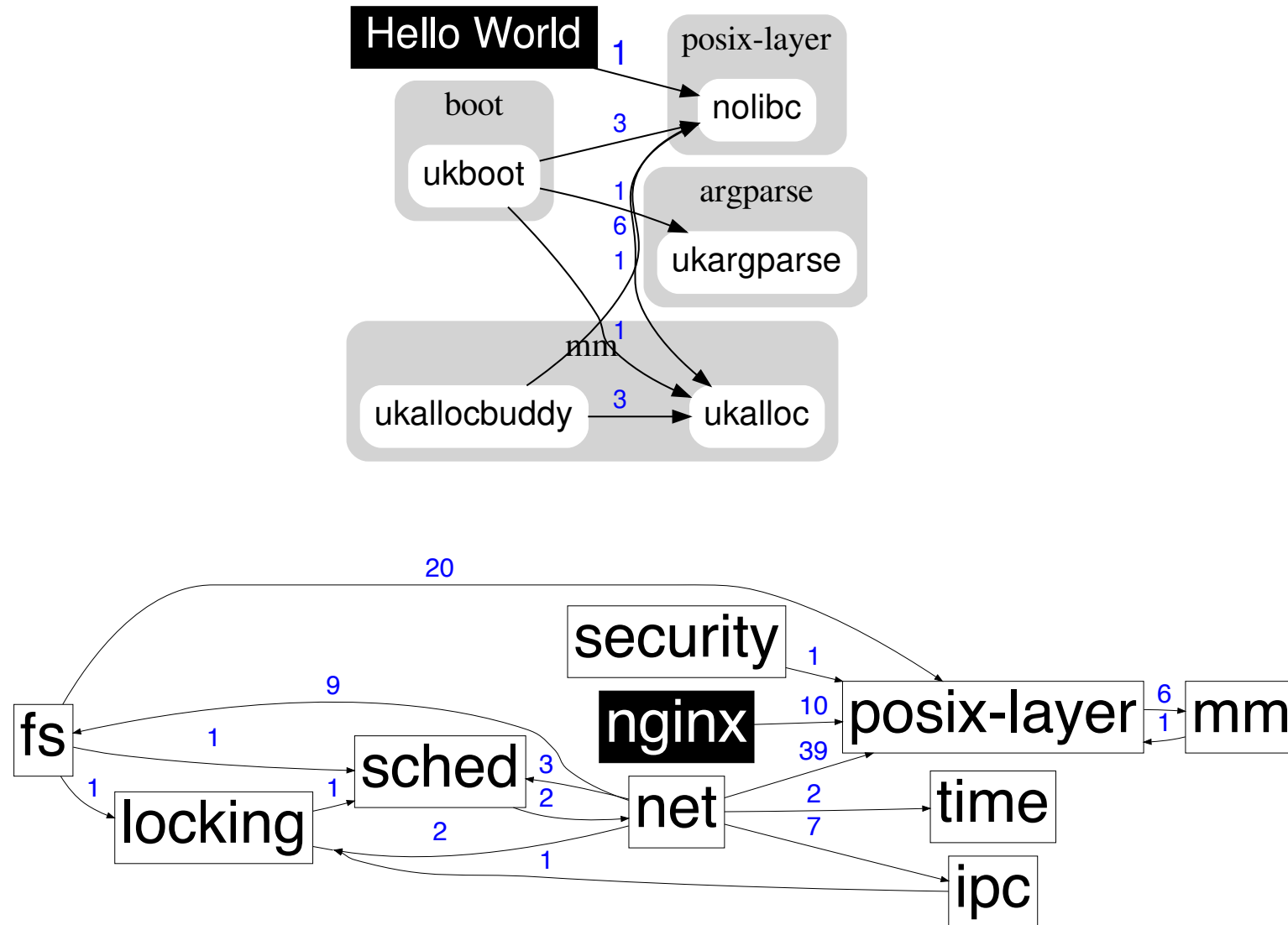
2. Provide high performance **specialized APIs**

Why not Linux?

Unikraft is built from scratch to be fully modular



With Unikraft



Doing it with existing unikernels?

(1) Require significant expert work to build

Unikraft is built from scratch (with borrowing)

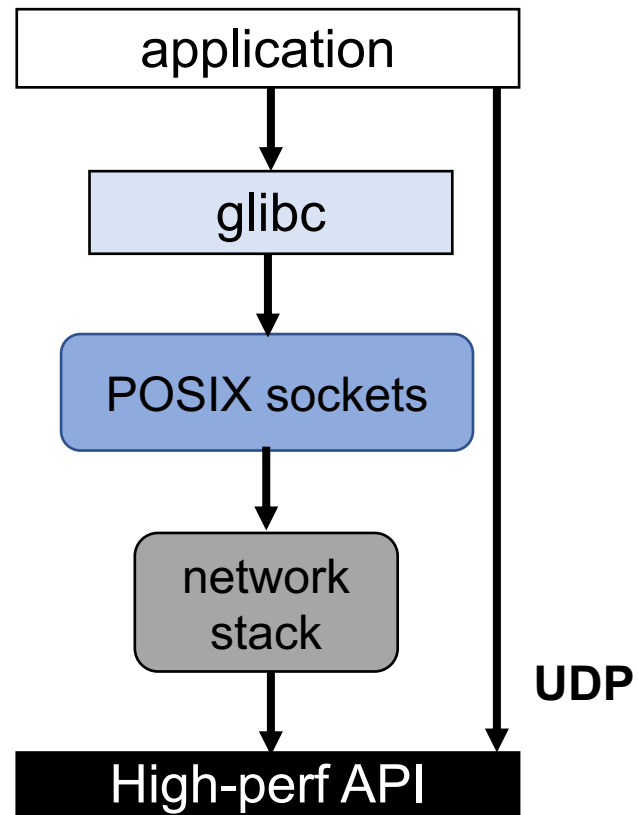
(3) The (uni)kernels are *still* monolithic

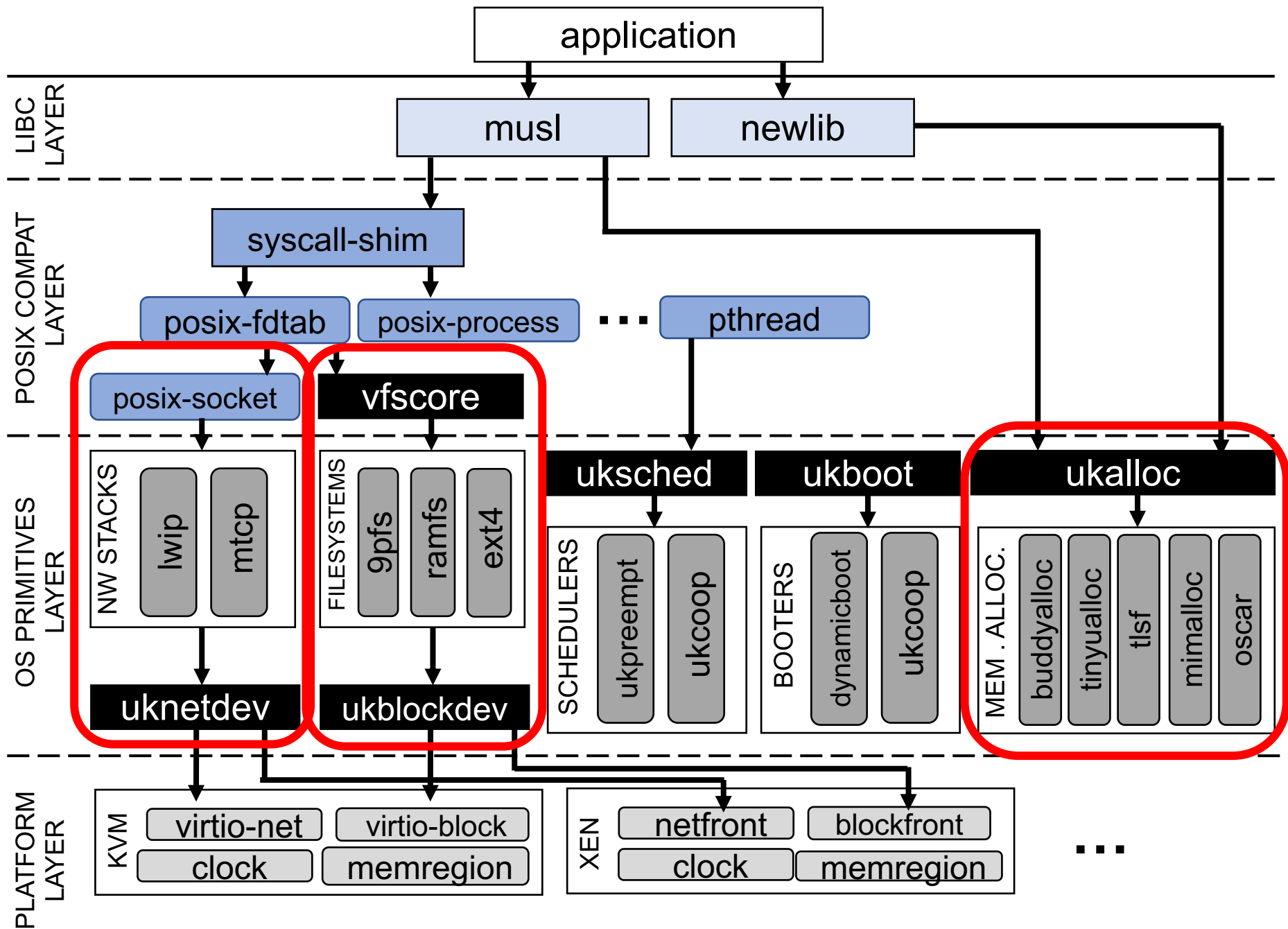
Design Principles

1. Fully modular kernel

2. Provide high performance **specialized APIs**

Specialized API Example





GOALS

- **Easy to build and run**
- Easy or no app porting
- Great performance

root@kraft:~#



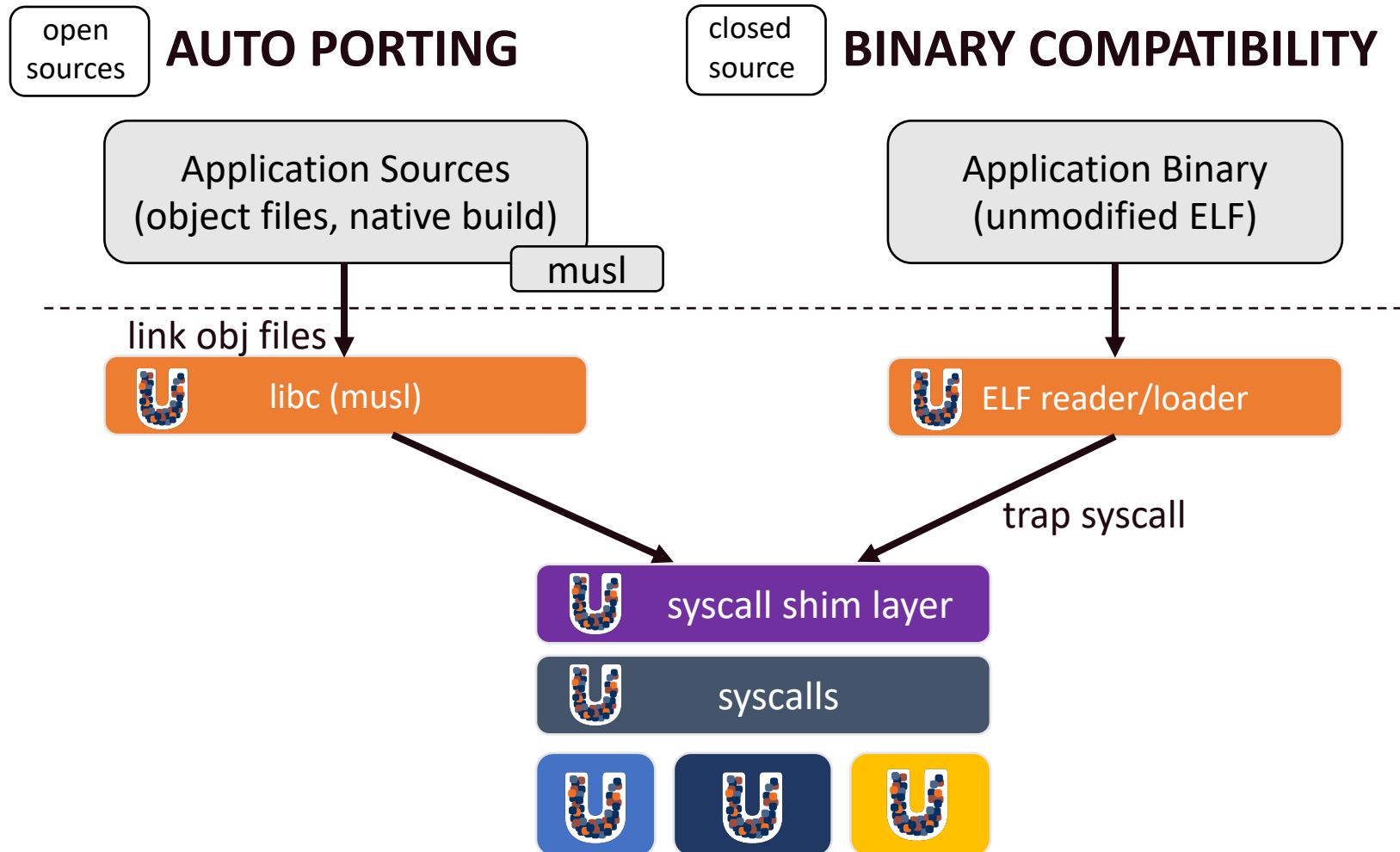
[0] 0: bash*

kraft NGINX demo

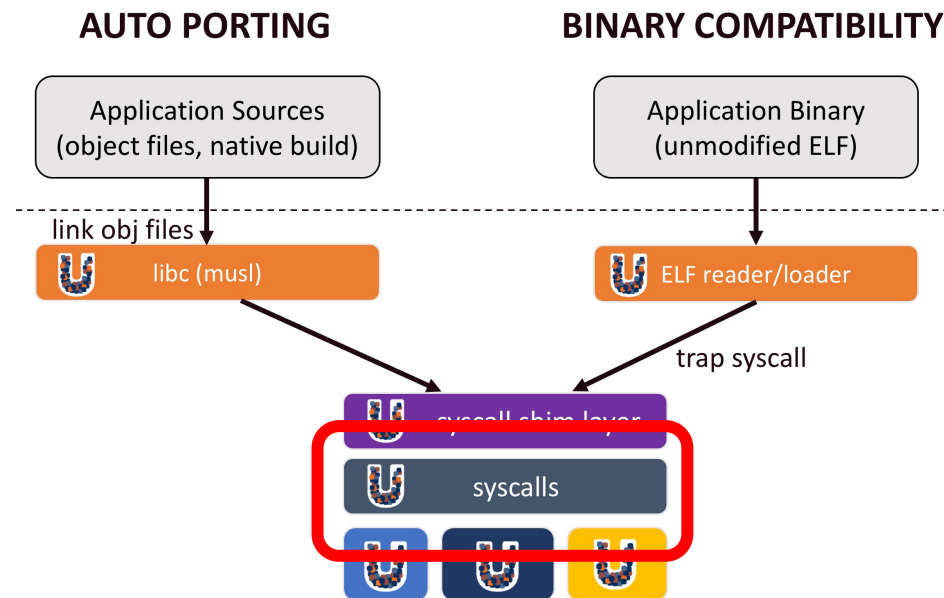
GOALS

- Easy to build and run
- **Easy or no app porting**
- Great performance

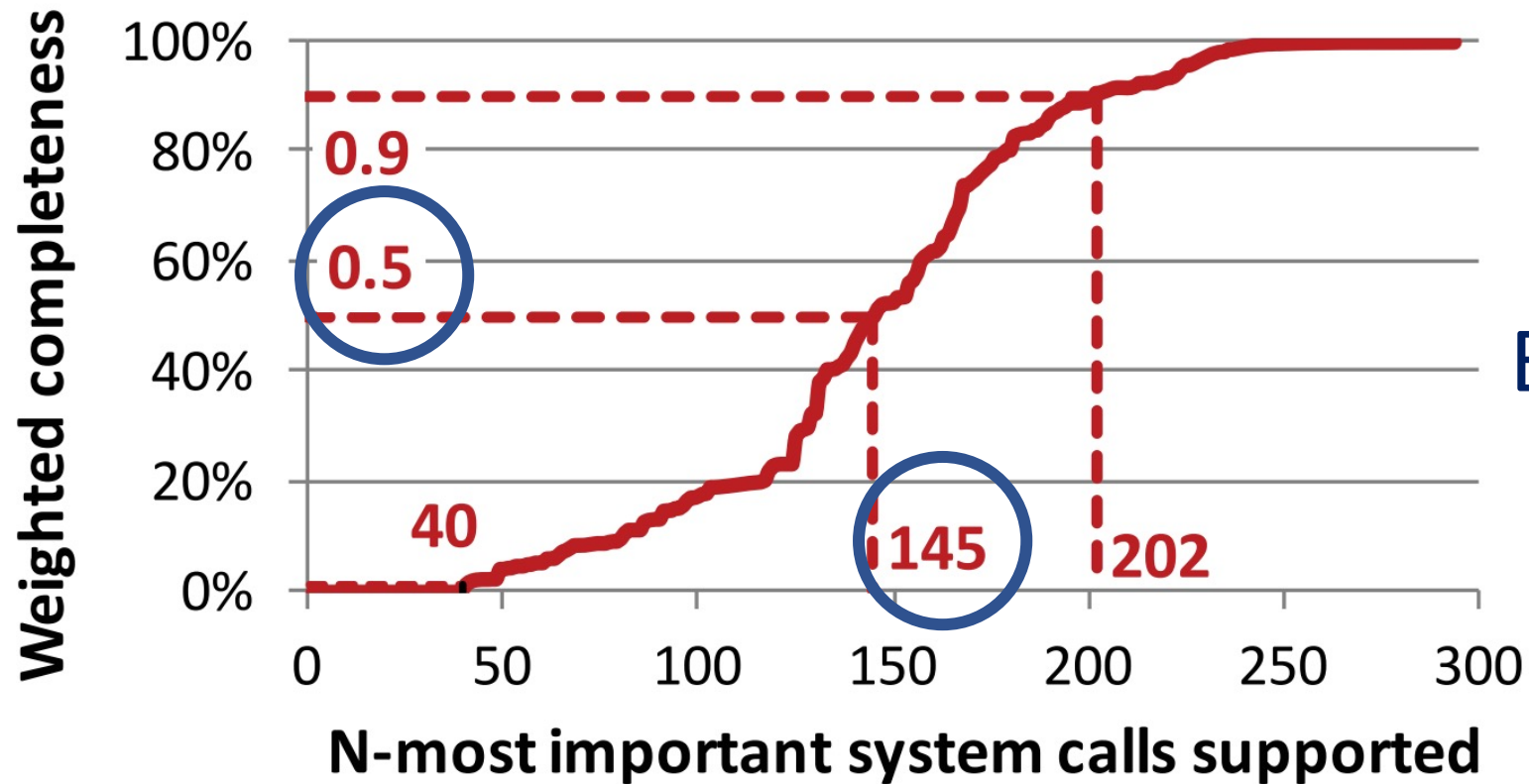
POSIX Compatibility – Two Approaches



What about syscall support?



Syscall Support



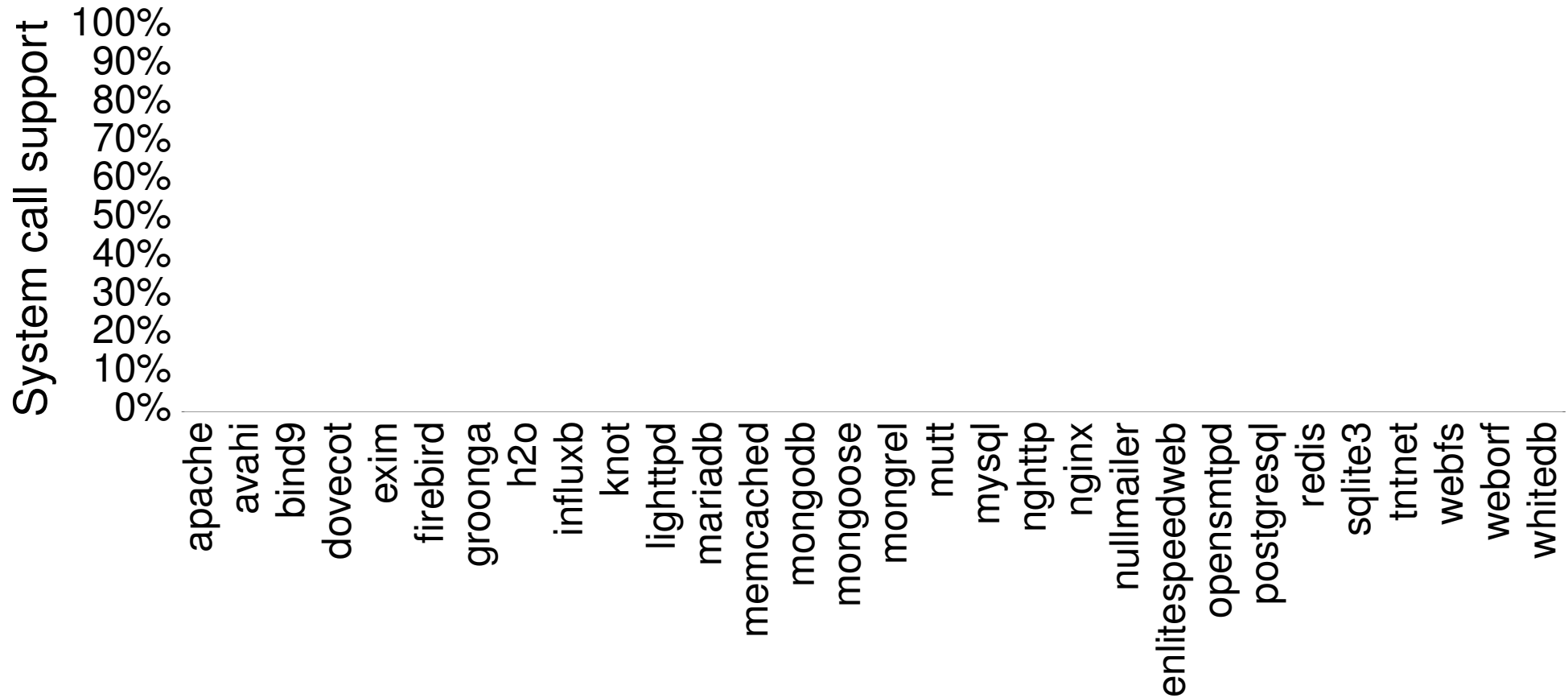
Eurosys 2016

146 syscalls currently supported

Linux: ~350 syscalls

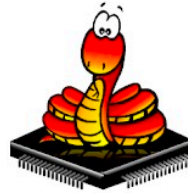
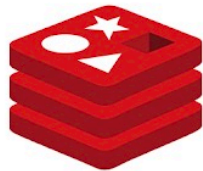
Syscall Support

Top 30 Debian Popcon Apps



146 syscalls currently supported

What Unikraft Supports (sample)



(ongoing)



(ongoing)

GOALS

- Easy to build and run
- Easy or no app porting
- **Great performance**

Does autoporting sacrifice performance?

SQLite: Manual vs. Auto Port



Autoporting doesn't negatively affect performance

0

time for 60K insertions

Transparent Benefits – Boot, Memory, Size, Throughput

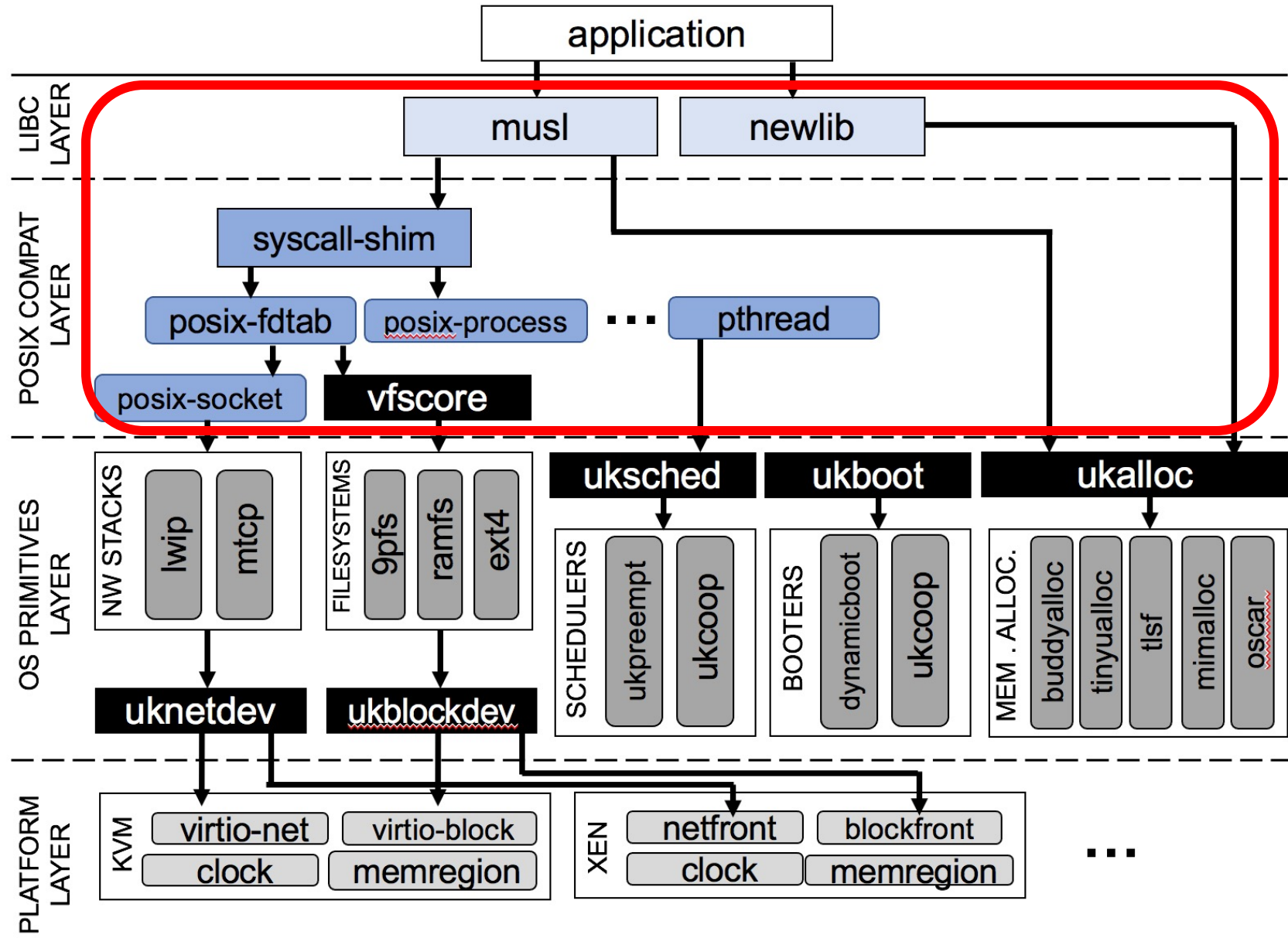
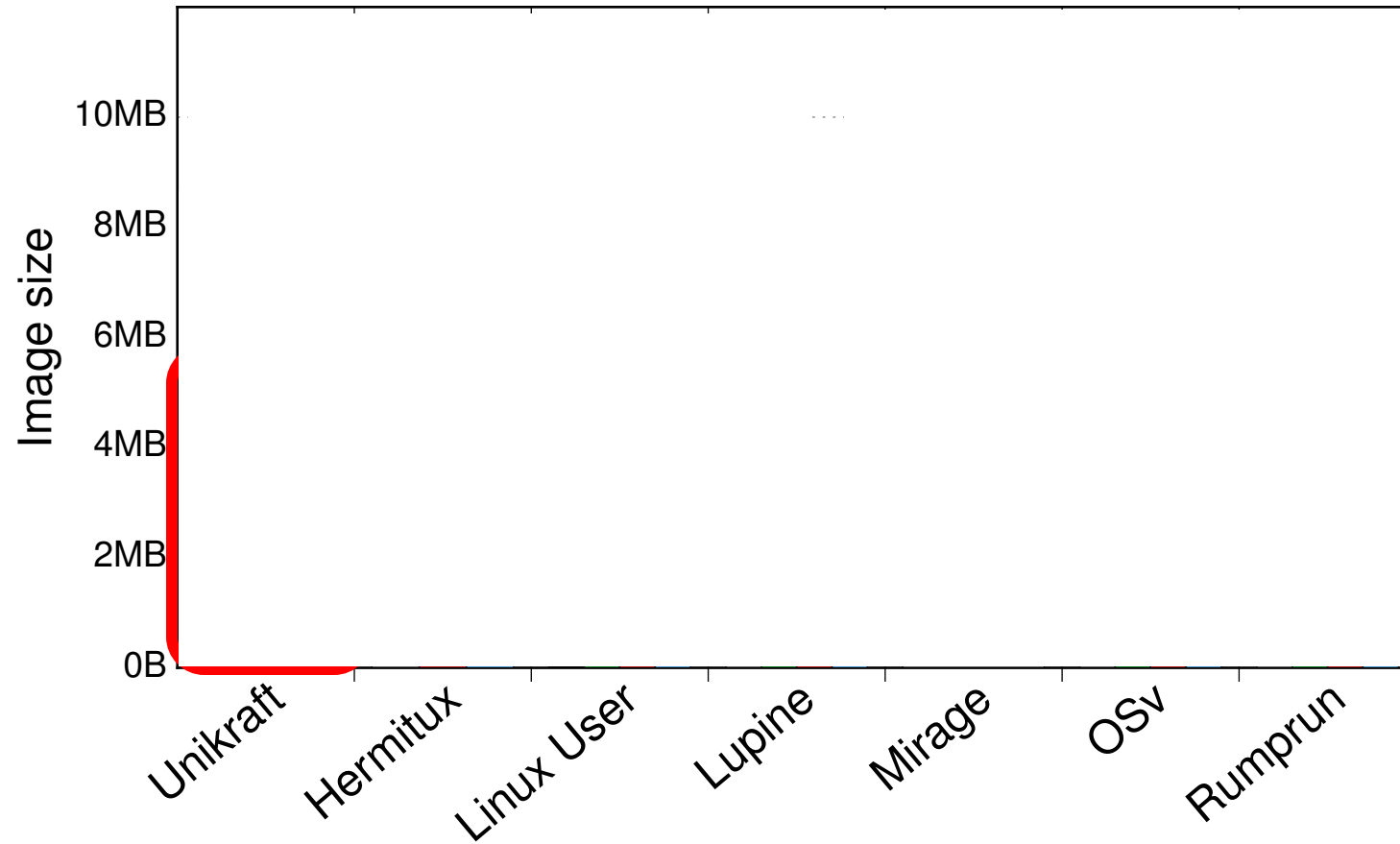
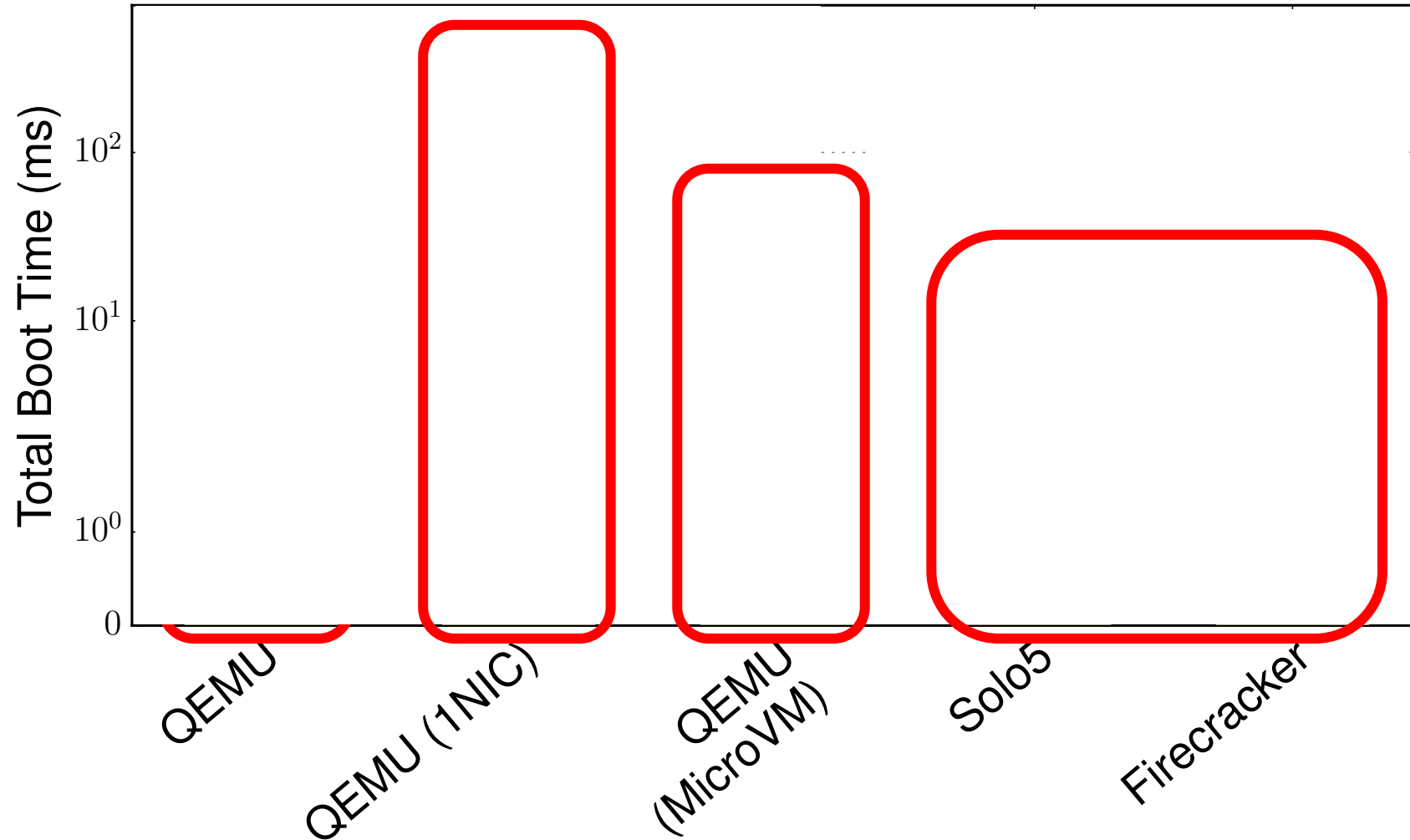


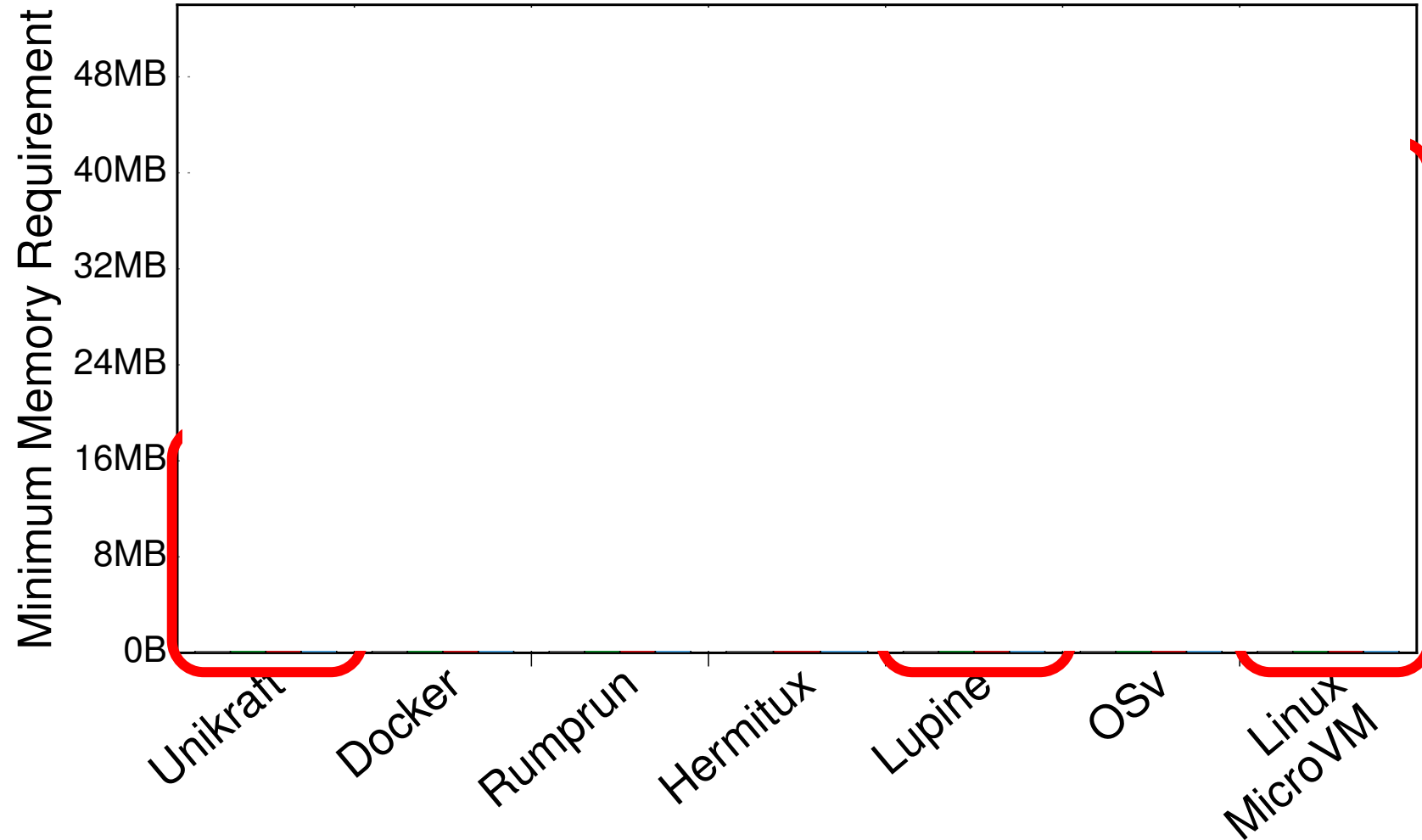
Image Sizes vs. other Projects



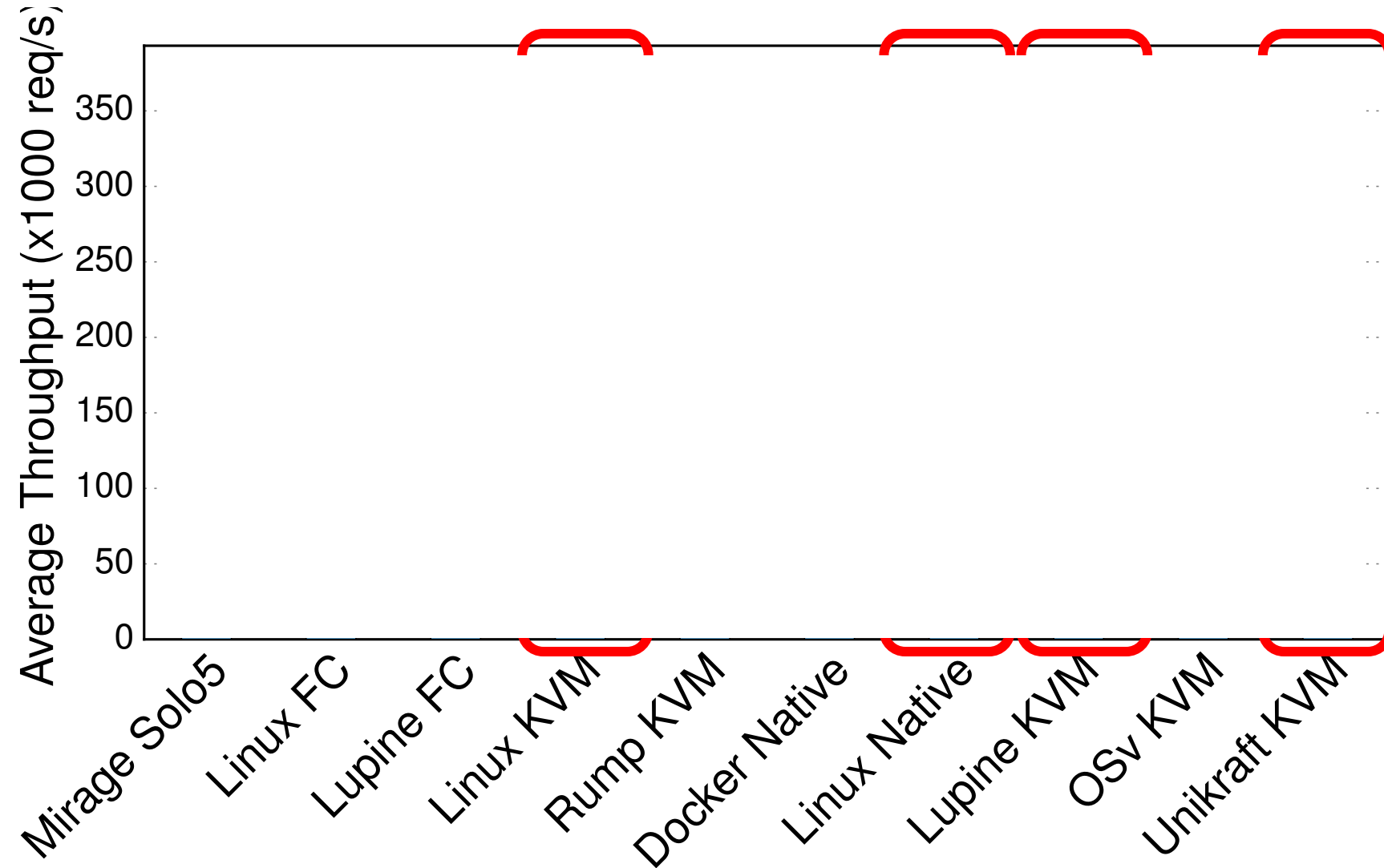
Unikraft Boot Times



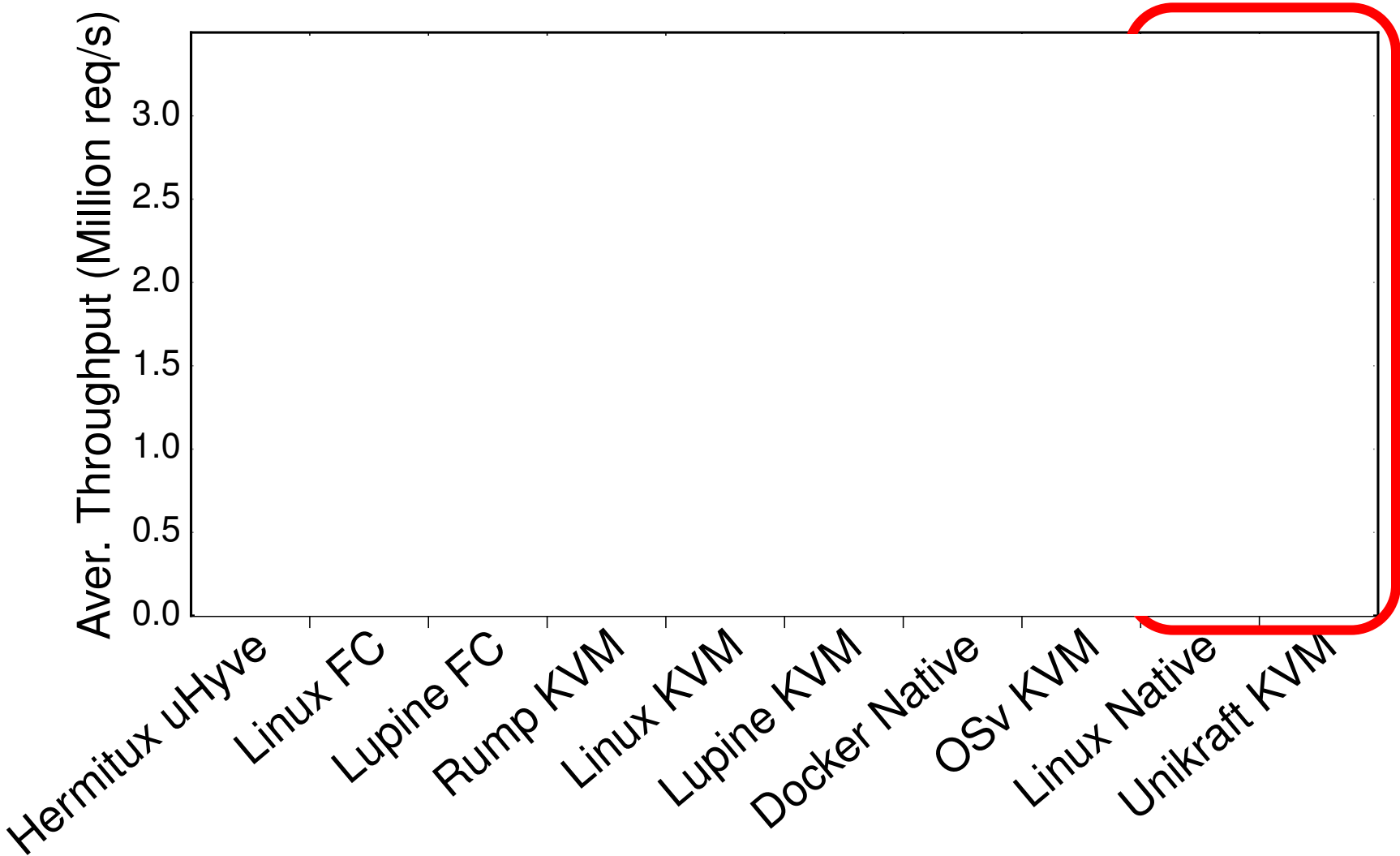
Minimum Memory Requirements



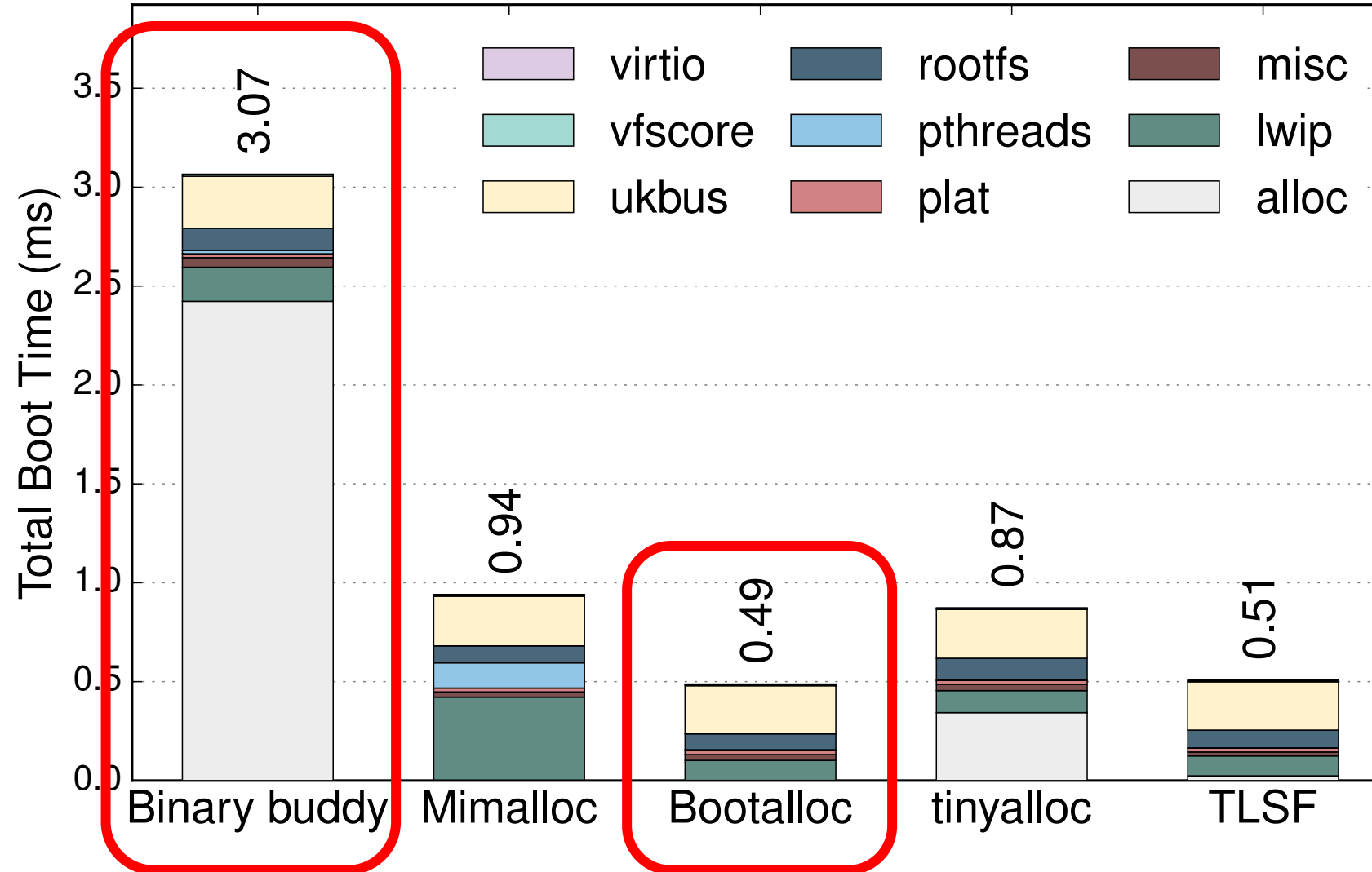
nginx Throughput



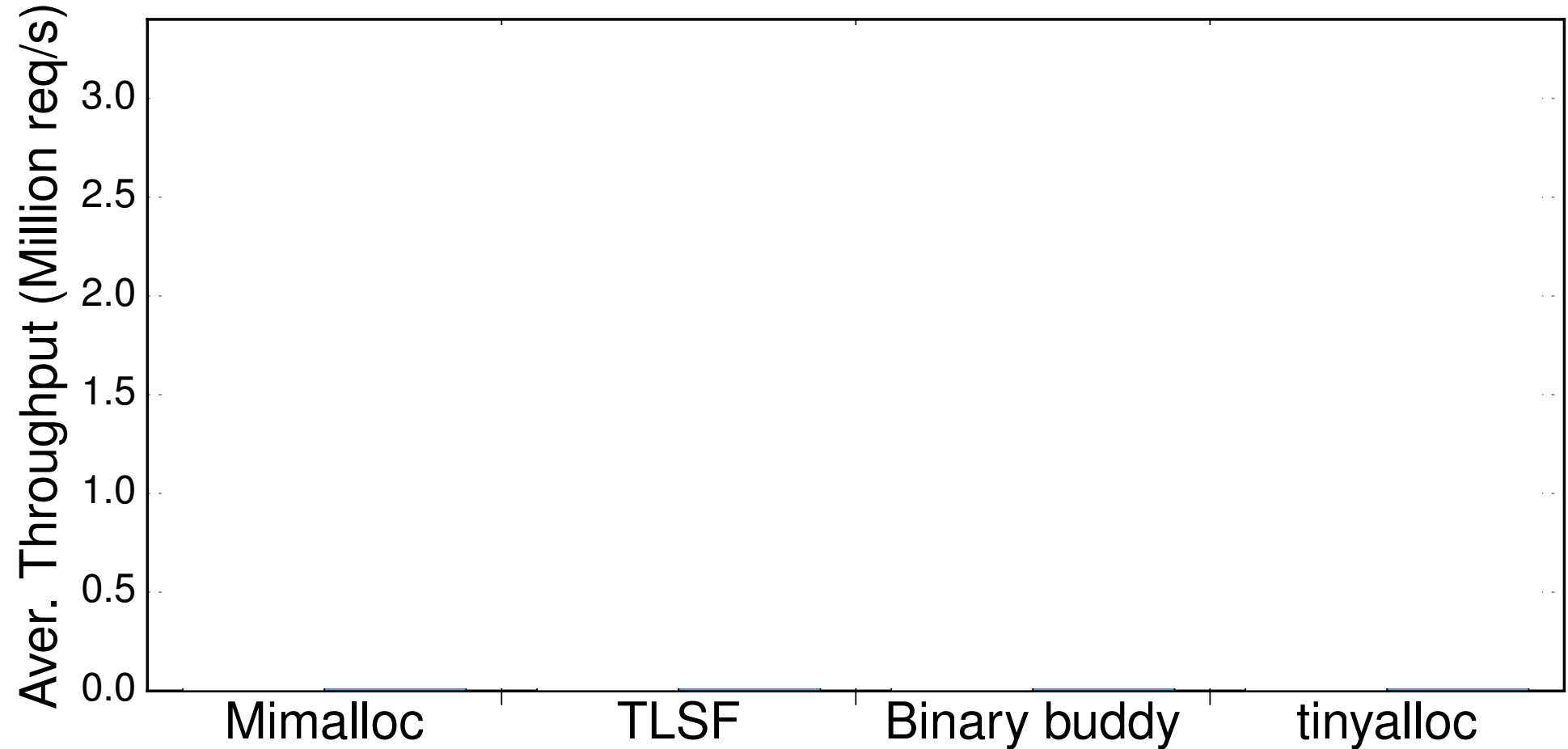
Redis Performance



Boot Times - Different Allocators

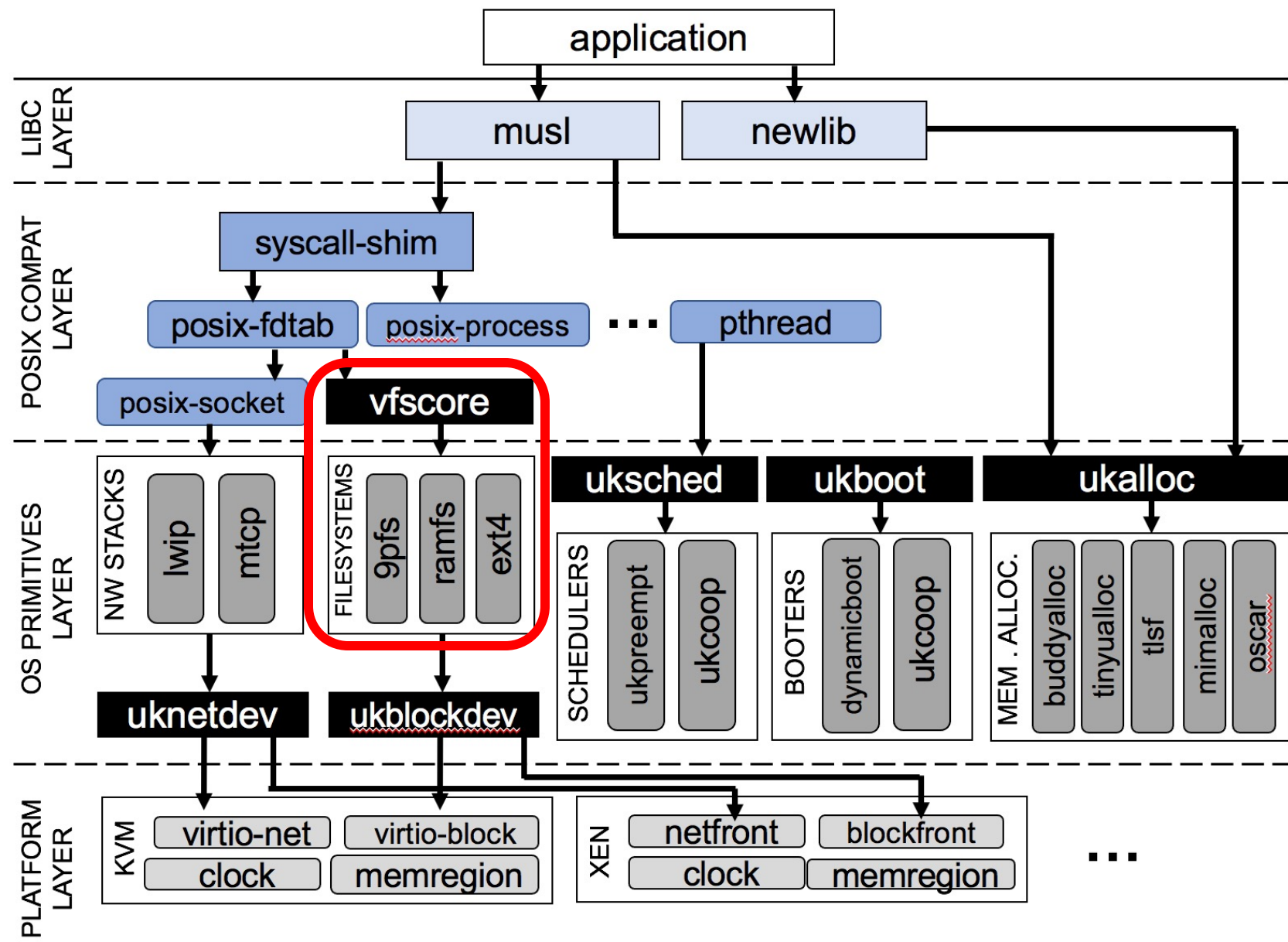


Redis Throughput Different Allocators

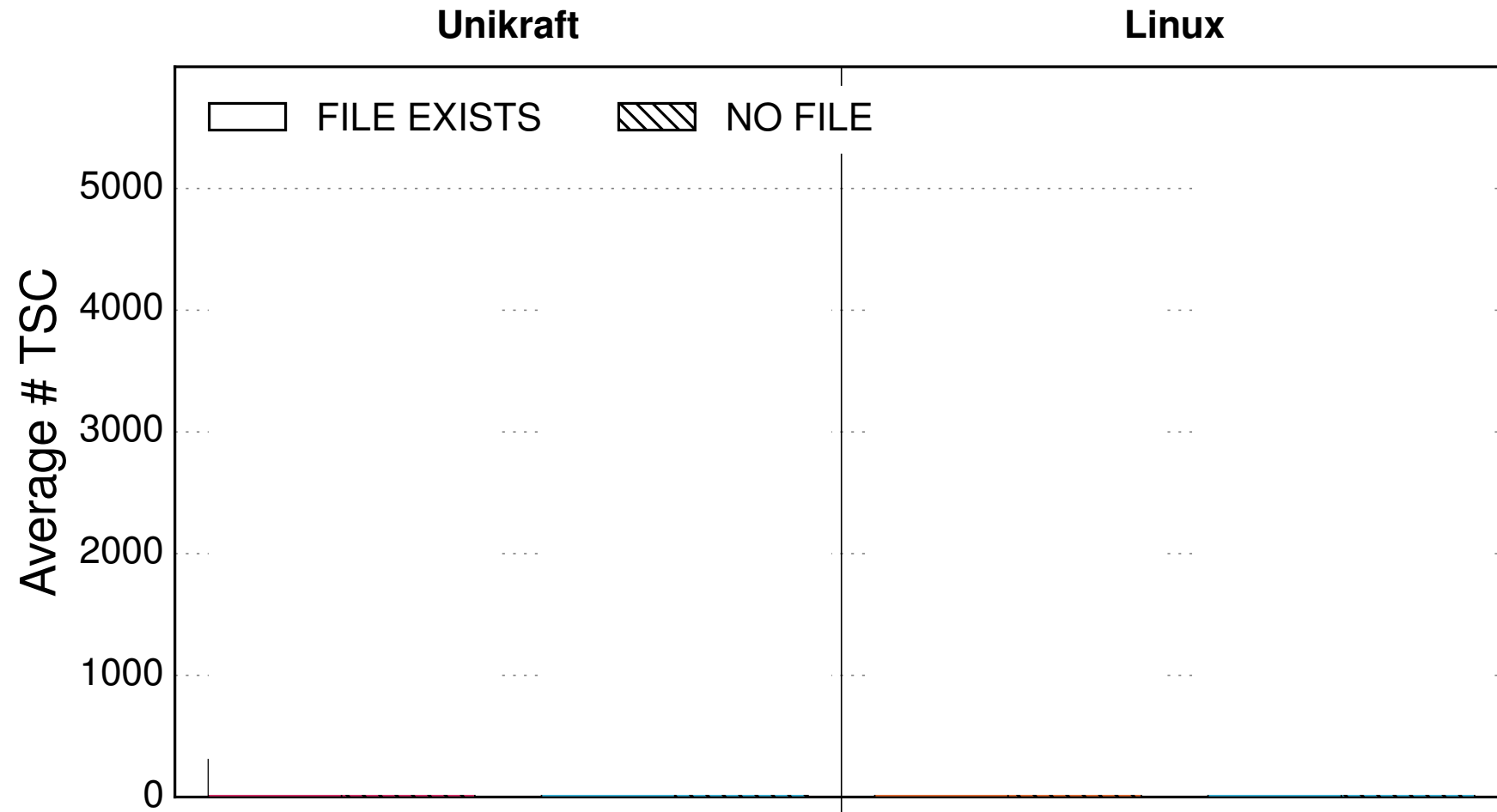


Specialized APIs

Specialization Benefits – Filesystem Performance



Filesystem Specialization – SHFS





on the



Popular Categories



Operating Systems



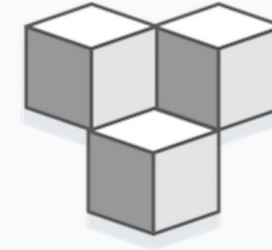
Security



Networking



Storage



View all categories



Data Analytics



Dev Ops



Machine Learning



Data Products

Explore solutions by topic area and use case



Business Applications

Find, buy, and deploy SaaS solutions to drive your business forward.

[LEARN MORE](#)



Data & analytics

Gain the decision-making power and insights to act in real time.

[LEARN MORE](#)



DevOps

Design and deploy reliable, secure modern applications and infrastructure.

[LEARN MORE](#)



Infrastructure software

Move, modernize, and manage your IT Infrastructure.

[LEARN MORE](#)

AMIs | EC2 M x

AWS Marketp x

aws baremeta x

EC2 Bare Met x

Xen - Debian x

WelcomePage - / x

AntBuildLinux - A x

AntBootLinux - A x

+ x

← → ↺ 🏠

🔒 https://eu-central-1.console.aws.amazon.com/ec2/v2/home?r 80% ... 📄 ⚙️ ⭐

📁 📄 ⌚ 📄 📄 📄 📄 📄 📄 📄 📄

aws Services ▾

🔔 Sharan Santhanam ▾ Frankfurt ▾ Support ▾

EC2 Dashboard New

Events New

Tags

Limits

▼ Instances

Instances New

Instance Types

Launch Templates

Spot Requests

Savings Plans

Reserved Instances

Dedicated Hosts New

Capacity Reservations

▼ Images

AMIs

▼ Elastic Block Store

Volumes

Snapshots

Lifecycle Manager

▼ Network & Security

Security Groups New

Elastic IPs New

Launch

EC2 Image Builder

Actions ▾

Owned by me ▾ 🔍 Filter by tags and attributes or search by keyword ?

❑

Narr ▾

AMI Name ▴

AMI ID ▾

Source ▾

Owner ▾

Visibility ▾

Status ▾

Creation Date ▾

Platform ▾

Root Device

<input type="checkbox"/>		nginx-uk-xenp...	ami-0a9f5e25c1fdb87b3	unikraft/nginx-uk-xenpv-160621146...	885001117030	Private	available	November 24, 2020 at 10:5...	Other Linux	instance-st
<input type="checkbox"/>		nginx-xenpv-b...	ami-0e154db3beb237414	unikraft/nginx-xenpv-busypoll-1606...	885001117030	Private	available	November 24, 2020 at 6:53:...	Other Linux	instance-st
<input type="checkbox"/>		nginx-xenpv-b...	ami-07df06fb4aa1f9013	unikraft/nginx-xenpv-busypoll-1606...	885001117030	Private	available	November 24, 2020 at 7:47:...	Other Linux	instance-st
<input type="checkbox"/>		nginx-xenpv-b...	ami-087eaadbff8656045	unikraft/nginx-xenpv-busypoll-1606...	885001117030	Private	available	November 24, 2020 at 8:01:...	Other Linux	instance-st
<input checked="" type="checkbox"/>		nginx-xenpv-b...	ami-04dbbb39b6ff603df	unikraft/nginx-xenpv-busypoll-1606...	885001117030	Private	available	November 24, 2020 at 11:0...	Other Linux	instance-st

Image: ami-04dbbb39b6ff603df

Details

Permissions

Tags

AMI ID

Owner

Status

Creation date

Architecture

Image Type

Description

Root Device Type

Kernel ID

Block Devices

ami-04dbbb39b6ff603df 📄

885001117030

available

November 24, 2020 at 11:01:23 PM UTC+1

x86_64

machine

-

instance-store

aki-931fe3fc

-

AMI Name

Source

State Reason

Platform details

Usage operation

Virtualization type

Root Device Name

RAM disk ID

Product Codes

nginx-xenpv-busypoll-1606255273

unikraft/nginx-xenpv-busypoll-1606255273.img.manifest.xml

-

Linux/UNIX

RunInstances

paravirtual

-

-

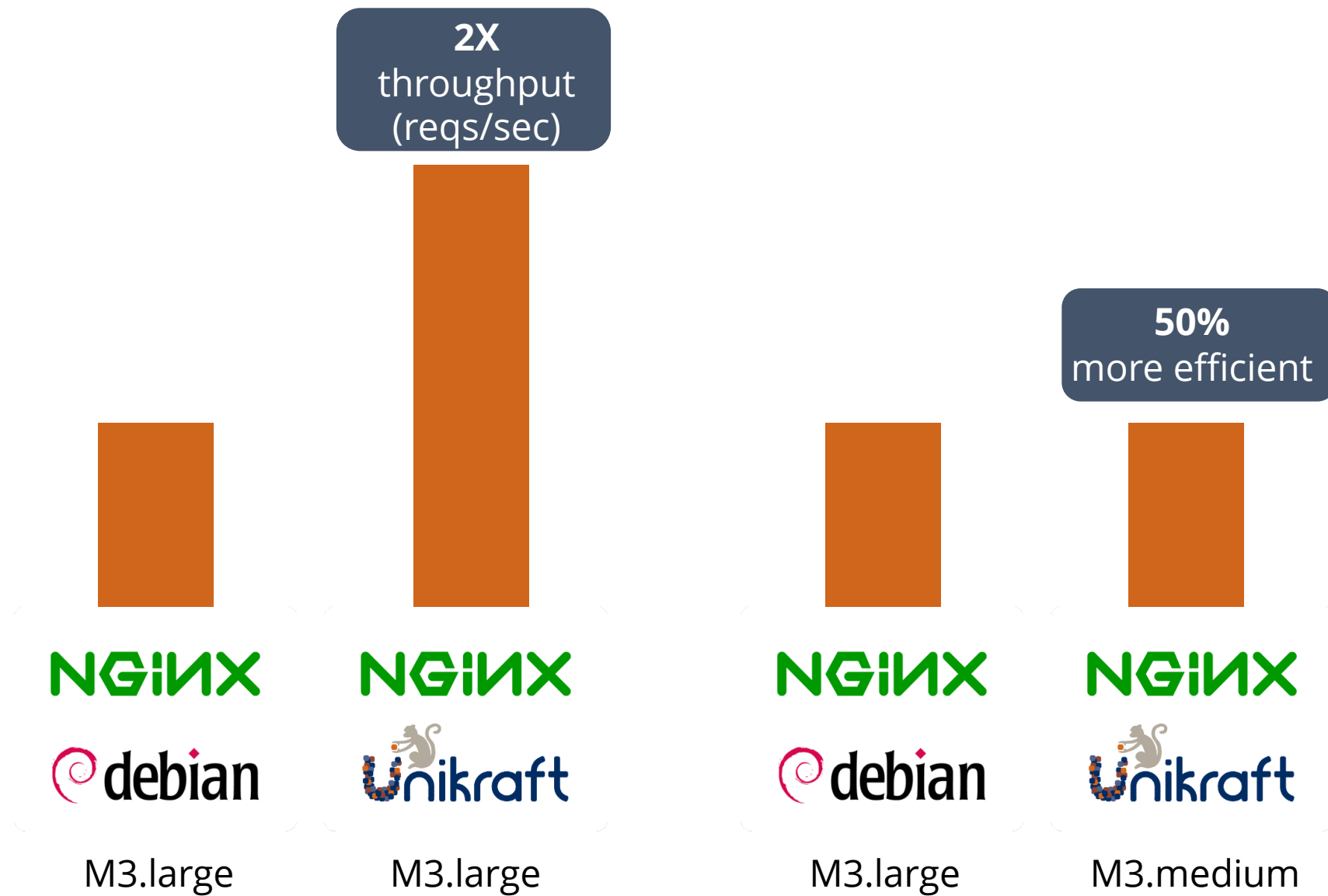
-

Edit

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Terms of Use





Estimating your costs

Our bill in dollars:

- \$87.70 Linux/Debian
- \$43.80 Unikraft

=

50%
savings

Estimated infrastructure cost

\$0.067 EC2/hr >

Free Trial

Try one unit of this product for 30 days. There will be no software charges for that unit, but AWS infrastructure charges still apply. Free Trials will automatically convert to a paid subscription upon expiration and you will be charged for additional usage above the free units provided.

<input type="radio"/>	t3a.2xlarge	\$0.34	\$0.301	\$0.641
<input checked="" type="radio"/>	m3.medium <small>★Vendor Recommended</small>	\$0.34	\$0.067	\$0.407
<input type="radio"/>	m3.large	\$0.34	\$0.133	\$0.473
<input type="radio"/>	m3.xlarge	\$0.34	\$0.266	\$0.606
<input type="radio"/>	t3.xlarge	\$0.34	\$0.573	\$0.873



Xen-based



Google Cloud Platform

KVM-based



KVM-based



Hyper-V (upcoming)

```
SeaBIOS (version 1.8.2-20190620_103534-google)
Total RAM Size = 0x0000000026600000 = 614 MiB
CPUs found: 1    Max CPUs supported: 1
found virtio-scsi at 0:3
virtio-scsi vendor='Google' product='PersistentDisk' rev='1' type=0 removable=0
virtio-scsi blksize=512 sectors=2097152 = 1024 MiB
drive 0x000f2770: PCHS=0/0/0 translation=lba LCHS=1024/32/63 s=2097152
Booting from Hard Disk 0...
[ 0.914853] ERR: [libkvmvirtio] virtio_bus.c @ 143 : Failed to find the driver for the virtio device 0x1fc008 (id:8)
[ 0.920038] ERR: [libkvmvirtio] virtio_pci.c @ 391 : Failed to register the virtio device: -14
[ 0.923965] ERR: [libkvmpci] pci_bus.c @ 215 : PCI 00:03.00: Failed to initialize device driver
en0: Added
en0: Interface is up
Welcome to
 _ _ _ _ _
/ _ _ _ _ \
/ _ _ _ _ \
\ _ _ _ _ /
Iapetus 0.3.1~94e6454-custom
Listening on port 8888...
```

Unikraft on GCP

Ecosystem - kraft

Define, configure, build and run Unikraft unikernels.

- Easily manage multiple libraries from different sources
- Quickly access updates and change between versions
- Automatically download application source dependencies

System Status			
CPU	RAM	Network	Time
12%	9.7 GB	1.0 kB↓ 2.0 kB↑	29.4., 9:43 PM

UNIKRAFT			
NAME	VERSION	RELEASED	LAST CHECKED
unikraft	0.5	4 hours ago	1 hour ago

PLATFORMS			
NAME	VERSION	RELEASED	LAST CHECKED
gcp	0.5	06 Feb 21	1 hour ago
digitalocean	0.5	06 Feb 21	1 hour ago
solo5	0.5	06 Feb 21	1 hour ago
aws	0.5	6 days ago	1 hour ago
firecracker	98327b0	23 Oct 20	1 hour ago

LIBRARIES			
NAME	VERSION	RELEASED	LAST CHECKED
eigen	0.5	06 Feb 21	1 hour ago
libunwind	0.5	06 Feb 21	1 hour ago
lwip	0.5	5 hours ago	1 hour ago
pthreadpool	0.5	06 Feb 21	1 hour ago
psimd	0.5	06 Feb 21	1 hour ago
click	0.4	05 Feb 21	1 hour ago
pthread-embedded	0.5	6 days ago	1 hour ago
gcc	0.5	06 Feb 21	1 hour ago
zlib	0.5	06 Feb 21	1 hour ago
googlebenchmark	0.5	06 Feb 21	1 hour ago
nginx	0.5	06 Feb 21	1 hour ago
openssl	0.5	06 Feb 21	1 hour ago
newlib	0.5	16 Apr 21	1 hour ago
libucontext	0.5	06 Feb 21	1 hour ago
libuuid	0.5	06 Feb 21	1 hour ago
libfxdiv	0.5	06 Feb 21	1 hour ago
compiler-rt	0.5	06 Feb 21	1 hour ago
libcxxabi	0.5	06 Feb 21	1 hour ago
googletest	0.5	06 Feb 21	1 hour ago
pcre	0.5	06 Feb 21	1 hour ago
intel-intrinsics	0.5	06 Feb 21	1 hour ago
libfp16	0.5	06 Feb 21	1 hour ago
libcxx	0.5	06 Feb 21	1 hour ago
lua	0.5	06 Feb 21	1 hour ago
http-parser	0.5	06 Feb 21	1 hour ago
axtls	0.5	06 Feb 21	1 hour ago
bzip2	0.5	06 Feb 21	1 hour ago
python3	0.4	23 Oct 20	1 hour ago
wamr	0.5	06 Feb 21	1 hour ago
libgo	0.5	06 Feb 21	1 hour ago

--More--

Retrieve stable and latest versions with pre-built source files

(no need to compile everything from scratch)


releases.unikraft.org/unikraft/apps/nginx/staging/

Unikraft Releases

These are the official releases of Unikraft for Debian-based distributions and binary releases of popular unikernels. For more information on how to use Unikraft, please visit our [Getting Started](#) guide or the official [Documentation](#).

[Home](#) / [unikraft](#) / [apps](#) / [nginx](#) / staging

File Name ↓	File Size ↓	Date ↓
Parent directory/	-	-
app-nginx@staging~kvm-x86_64.tar.gz	228.0 MiB	2021-Apr-28 07:00
app-nginx@staging~kvm-x86_64.tar.gz.sha256sum	104 B	2021-Feb-04 18:30



Powered by
Unikraft

About the Project



Open Source License
Unikraft Core Team
The Xen Project
The Linux Foundation
NEC Laboratories Europe GmbH
UNICORE Project

Website

[Data Privacy Statement](#)
[Datenschutzerklärung](#)
[Corporate Information \(Impressum\)](#)

Write us

unikraft@listserv.neclab.eu

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And Much More!

```
11% 13 GB 0.0 kB↓ 3.1 kB↑ 01.5., 8:26 PM
Usage: kraft [OPTIONS] COMMAND [ARGS]...

Options:
  --version          Show the version and exit.
  -C, --no-color     Do not use colour in output logs.
  -T, --timestamps  Show timestamps in output logs.
  -Y, --yes         Assume yes to any binary prompts.
  -v, --verbose     Enables verbose mode.
  -h, --help        Show this message and exit.

Commands:
  build      Build the application.
  clean      Clean the application.
  configure  Configure the application.
  fetch      Fetch library dependencies.
  init       Initialize a new unikraft application.
  lib        Unikraft library commands.
  list       List architectures, platforms, libraries or applications.
  menuconfig Open the kconfig menu editor
  package    Package unikernel image.
  prepare    Runs preparations steps on libraries.
  push       Push OCI image.
  run        Run the application.
  up         Configure, build and run an application.

Influential Environmental Variables:
  UK_WORKDIR The working directory for all Unikraft
              source code [default: ~/.unikraft]
  UK_ROOT    The directory for Unikraft's core source
              code [default: $UK_WORKDIR/unikraft]
  UK_LIBS    The directory of all the external Unikraft
              libraries [default: $UK_WORKDIR/libs]
  UK_APPS    The directory of all the template applications
              [default: $UK_WORKDIR/apps]
  KRAFTRC    The location of kraft's preferences file
              [default: ~/.kraftrc]

Help:
  For help using this tool, please open an issue on Github:
  https://github.com/unikraft/kraft
root@demo:/usr/src/kraft#
```

Towards Seamless Integration & Deployment

KUBERNETES



Deploy extremely
efficient Unikraft images
seamlessly on your
Kubernetes cluster

ongoing

PROMETHEUS



Monitor your Unikraft
instances through a
standard monitoring
platform

ongoing

BOSH

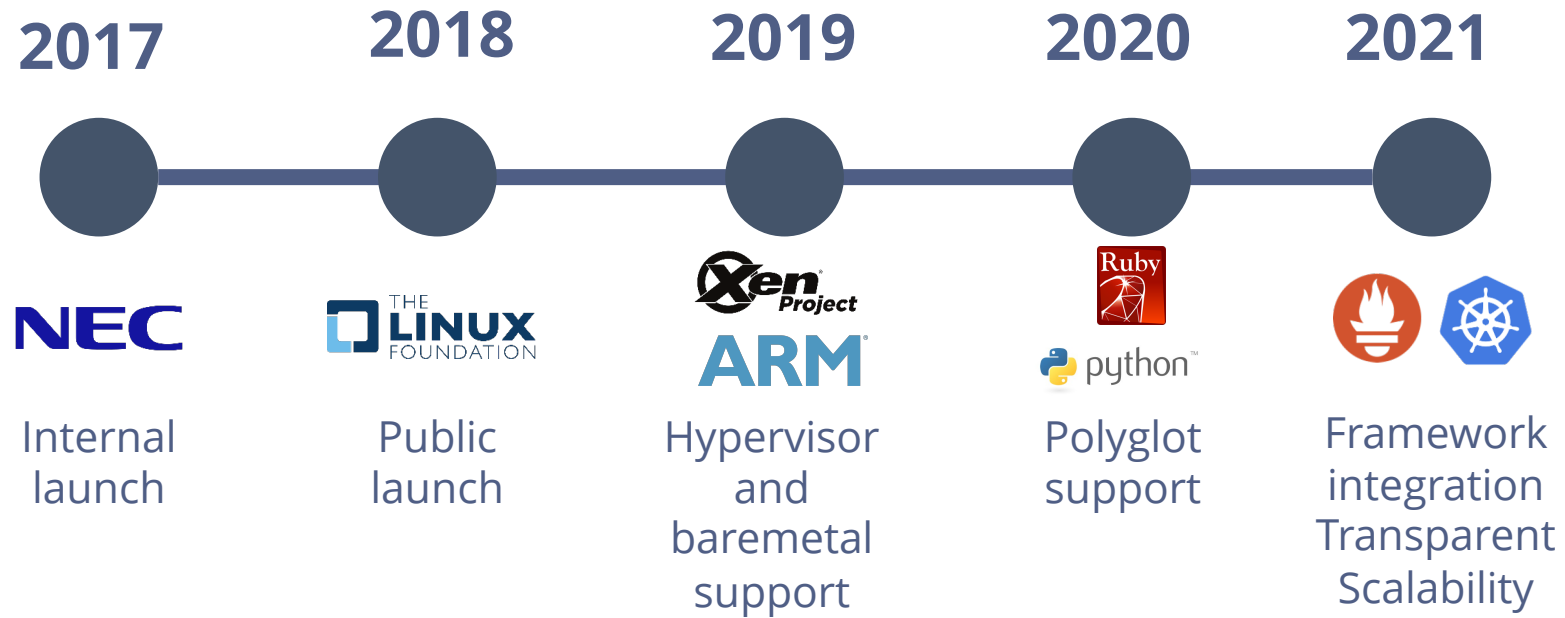


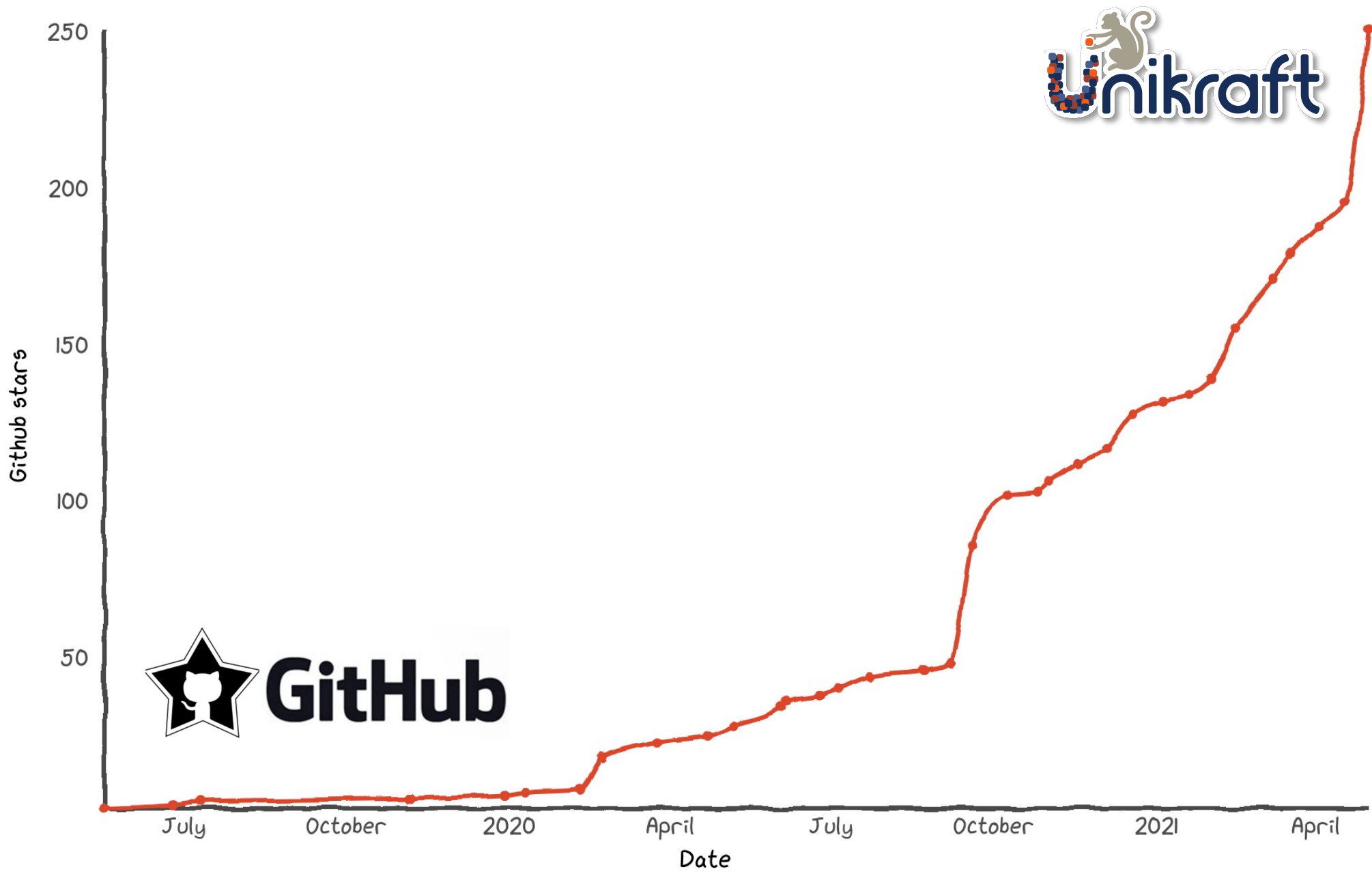
Perform your Unikraft
builds directly via
your Cloud Foundry
infrastructure

planned

Open Source Project

Project History





GitHub



Unikraft: Fast, Specialized Unikernels the Easy Way

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NEC Laboratories Europe GmbH

Vlad-Andrei Bădoiu*
University Politehnica of Bucharest

Hugo Lefeuvre*
The University of Manchester

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NEC Laboratories Europe GmbH

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Lancaster University

Gauthier Gain*
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Costi Răducanu
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University Politehnica of Bucharest

Felipe Huici
NEC Laboratories Europe GmbH

Abstract

Unikernels are famous for providing excellent performance in terms of boot times, throughput and memory consumption, to name a few metrics. However, they are infamous for making it hard and extremely time consuming to extract such performance, and for needing significant engineering effort in order to port applications to them. We introduce Unikraft, a novel micro-library OS that (1) fully modularizes OS primitives so that it is easy to customize the unikernel

[65], or providing efficient container environments [62, 76], to give some examples. Even in the hardware domain, and especially with the demise of Moore's law, manufacturers are increasingly leaning towards hardware specialization to achieve ever better performance; the machine learning field is a primary exponent of this [30, 32, 34].

In the virtualization domain, unikernels are the golden standard for specialization, showing impressive results in terms of throughput, memory consumption, and boot times,

All our experiments are open and reproducible:

github.com/unikraft/eurosys21-artifacts



The screenshot shows the GitHub repository page for `unikraft/eurosys21-artifacts`. The browser address bar shows the URL `github.com/unikraft/eurosys21-artifacts`. The repository page includes a navigation bar with links like "Why GitHub?", "Team", "Enterprise", "Explore", "Marketplace", and "Pricing". Below the navigation bar, the repository name is displayed along with statistics: 6 stars and 1 fork. The "Code" tab is selected, showing the "master" branch with 1 branch and 1 tag. A "Go to file" button and a green "Code" button are visible. The main content area displays the "README.md" file, which contains the title "Unikraft EuroSys'21 Artifacts" and a description of the repository. The "About" section on the right provides more context about the artifacts and the paper. A list of tags is shown, including `linux`, `nginx`, `redis`, `debian`, `dppk`, `sqlite`, `mirageos`, `osv`, `rumprun`, `unikraft`, `unikernels`, and `eurosys21`. The "Contributors" section shows 7 contributors.

Why GitHub? Team Enterprise Explore Marketplace Pricing Search Sign in Sign up

unikraft / eurosys21-artifacts Notifications Star 6 Fork 1

<> Code Issues Pull requests Actions Projects Security Insights

master 1 branch 1 tag Go to file Code

README.md

Unikraft EuroSys'21 Artifacts

This repository contains the artifacts, including experiments and graphs, for the paper:

Unikraft: Fast, Specialized Unikernels the Easy Way

Abstract: Unikernels are famous for providing excellent performance in terms of boot times, throughput and memory consumption, to name a few metrics. However, they are infamous for making it hard and extremely time consuming to extract such performance, and for needing significant engineering effort in order to port applications to them. We introduce Unikraft, a novel micro-library OS that (1) fully modularizes OS primitives so that it is easy to customize the unikernel and include only relevant components and (2) exposes a set of composable, performance-oriented APIs in order to make it easy for developers to obtain high performance.

Our evaluation using off-the-shelf popular applications such as NGINX, SQLite, and Redis

About

Artifacts, including experiments and graphs, for the paper:
"Unikraft: Fast, Specialized Unikernels the Easy Way"
(EuroSys'21).

linux nginx redis debian
dppk sqlite mirageos osv
rumprun unikraft unikernels
eurosys21

Readme

Contributors 7

7 contributors



High performance POSIX unikernels are now a reality!

Info: <https://unikraft.org/>

Code: <https://github.com/unikraft>

Reproduce: <https://github.com/unikraft/eurosys21-artifacts>

felipe.huici@neclab.eu