rkt-io

A Direct I/O Stack for Shielded Execution

https://github.com/Mic92/rkt-io

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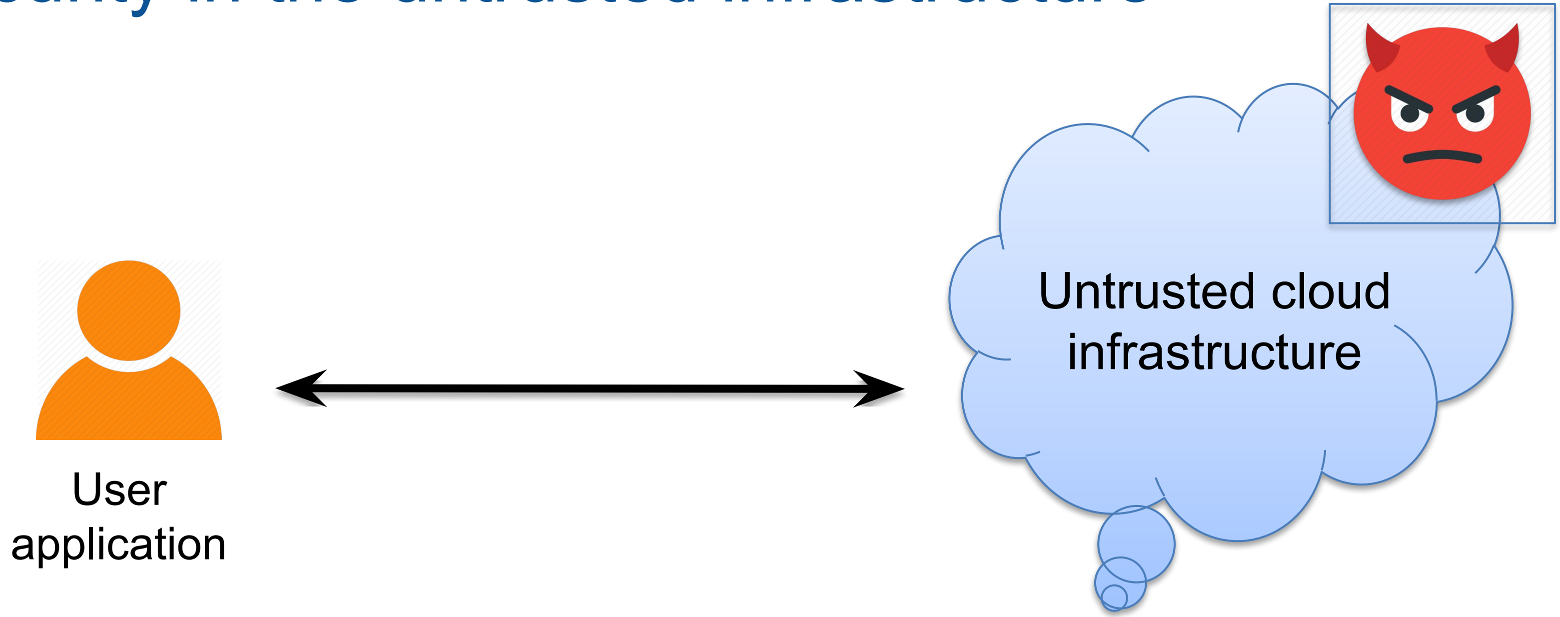
ACM EuroSys 2021

Security in the untrusted infrastructure



How do we ensure application security
in untrusted cloud environments?

Trusted computing

Hardware-assisted
trusted execution environments (TEEs)

intel SGX

arm

AMD

RISC-V

Keystone

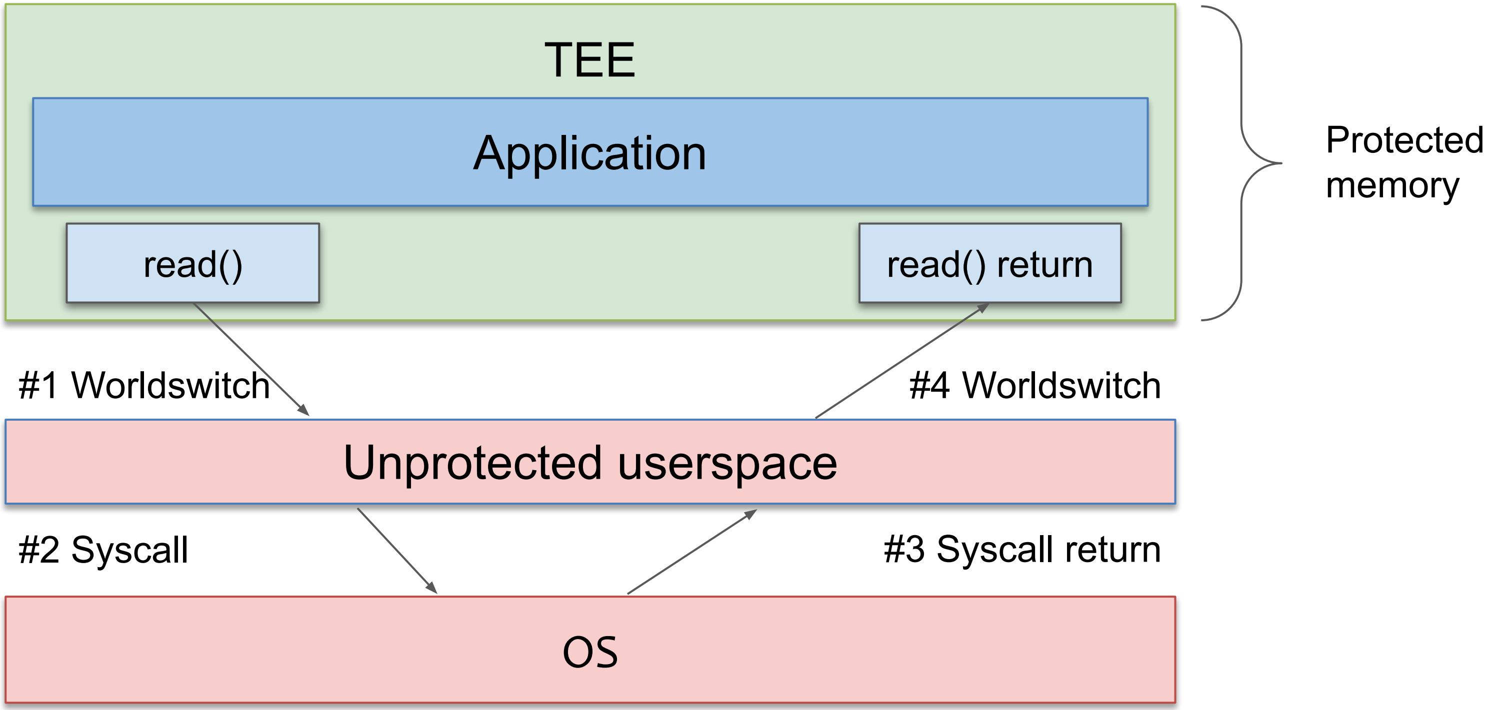
Google Cloud

Azure

Alibaba Cloud

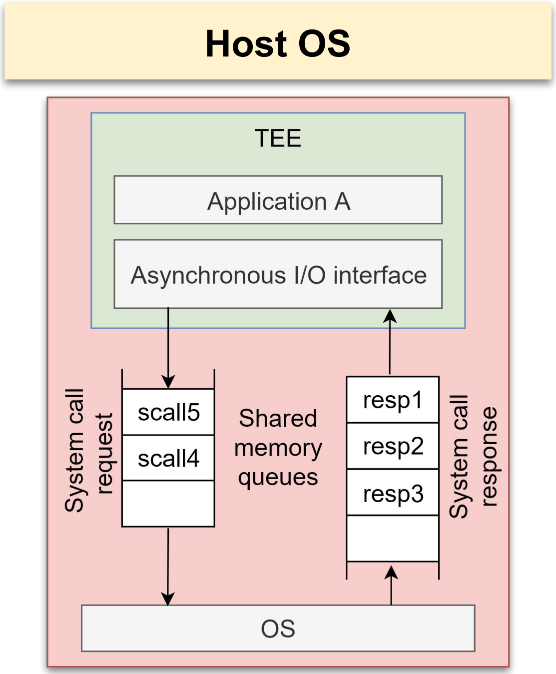
Offered by major cloud providers

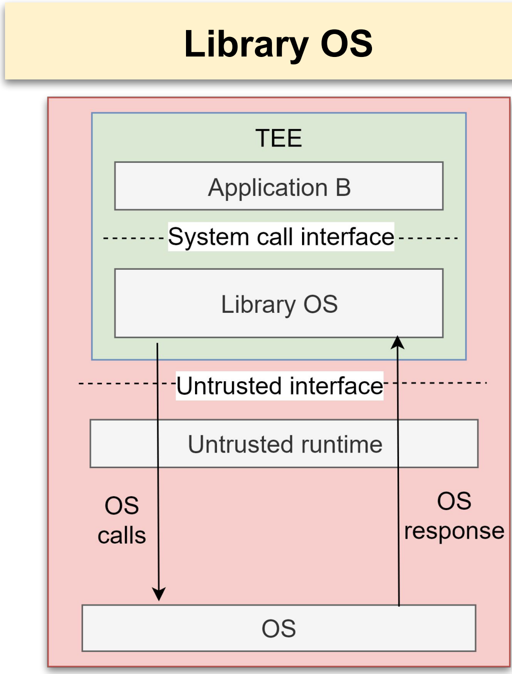
I/O in TEEs: “Strawman design”



Worldswitch is 5x slower than syscalls

Current I/O mechanisms: “Switchless design”





Switchless design avoid world-switches on the I/O path

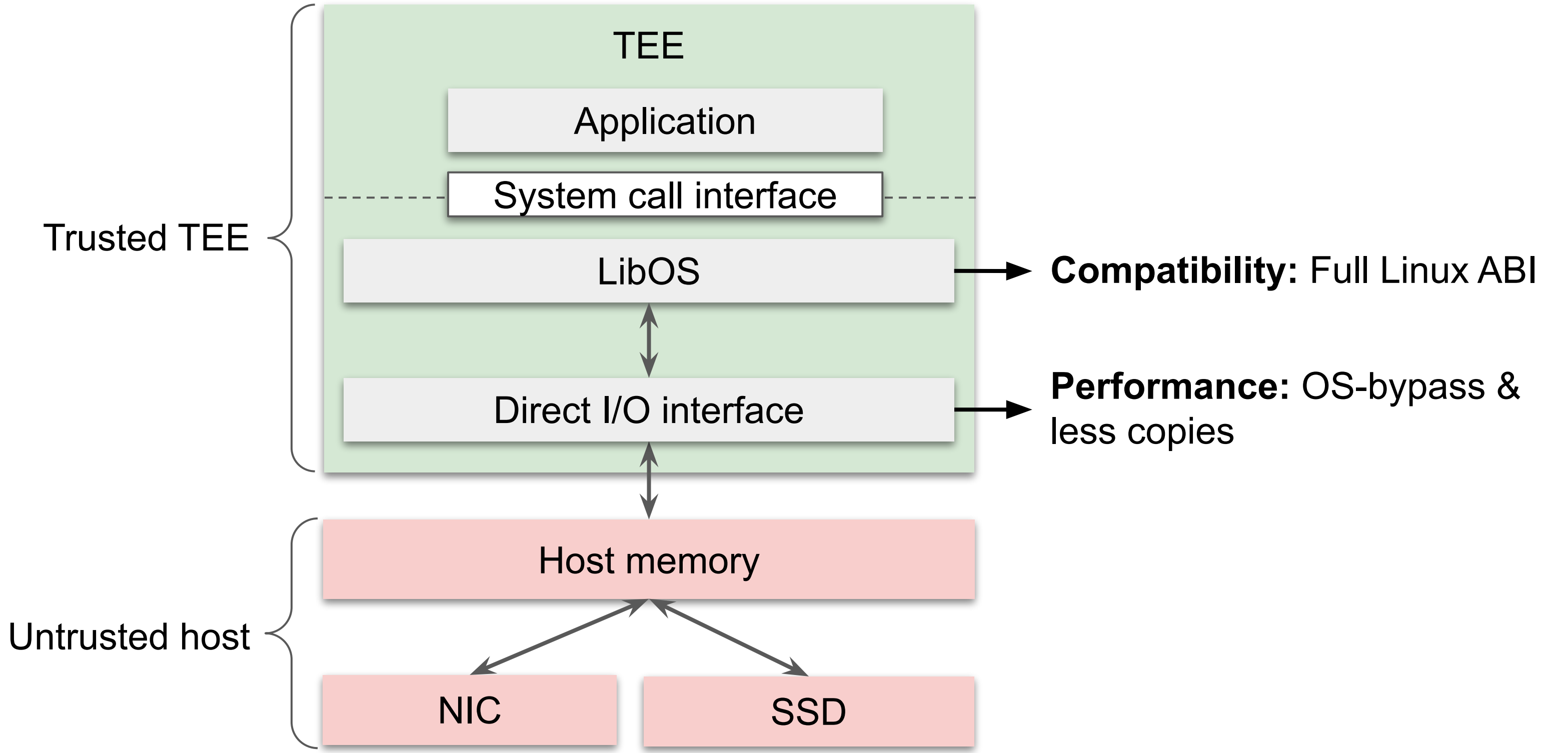
Limitations of switchless designs

- Performance
  - **OS bottlenecks:** The OS is still on the I/O path
  - **I/O threads:** Needs dedicated I/O threads, require tuning to find optimal number of threads
  - **Data copies:** Additional data copies between TEE ↔ IO threads ↔ OS

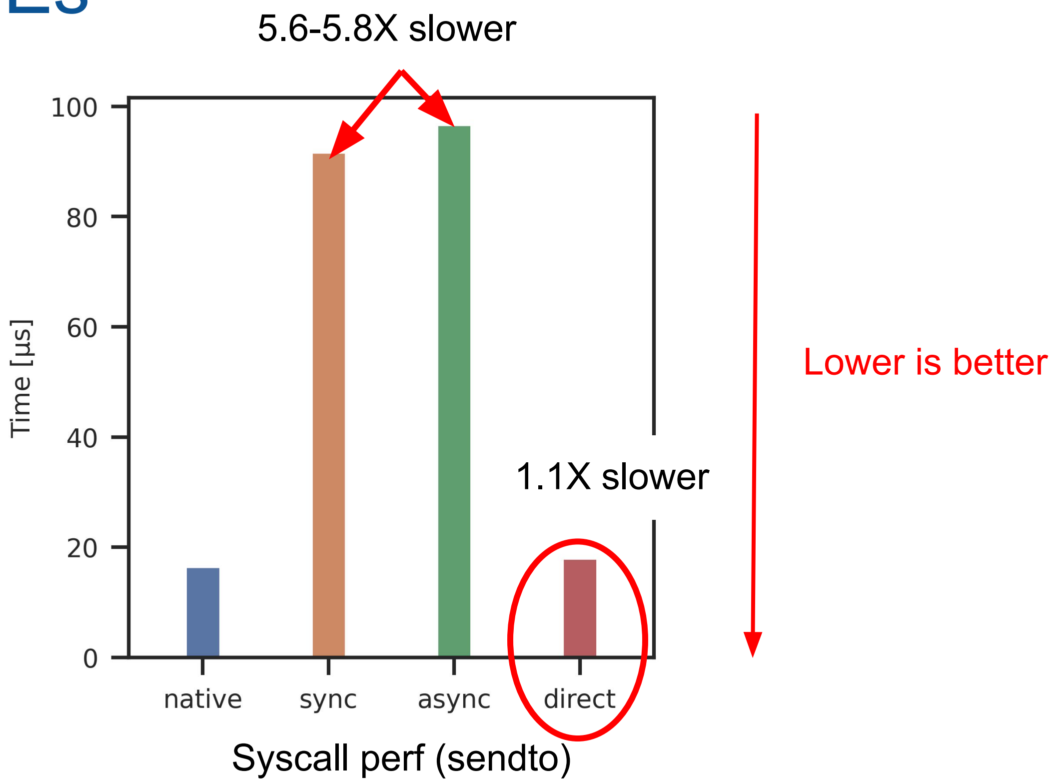
- Compatibility
  - LibOS-based approaches often only provide a subset of Linux ABI

rkt-io: A Direct I/O library for TEEs

rkt-io combines a library OS with direct I/O libraries



Direct I/O in TEEs



Direct I/O improves IO performance significantly

Design

Design principles

1

I/O stack interface

2

I/O event handling

3

I/O stack partitioning

1

I/O interface:

Host OS independence

1. Host OS independent I/O stack

Network:

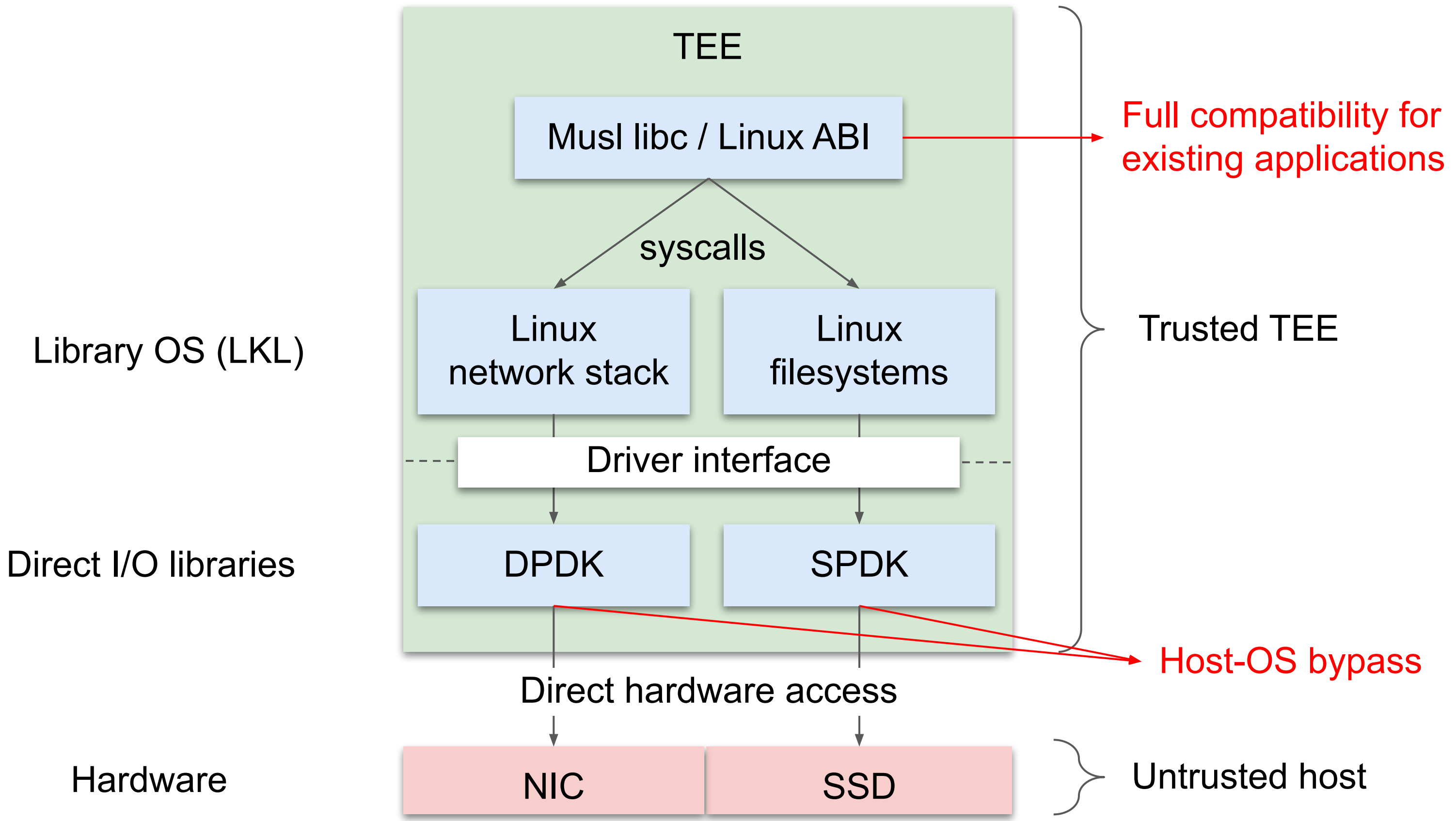
- DPDK (**D**ata **P**lane **D**evelopment **K**it)
- Direct access to fast network interface
- No TCP/IP stack
- No socket

Storage:

- SPDK (**S**torage **P**erformance **D**evelopment **K**it)
- Direct access to NVMe devices from userspace
- No filesystem
- No file abstraction

How to maintain compatibility with existing APIs?

rkt-io: Host OS independent I/O stack



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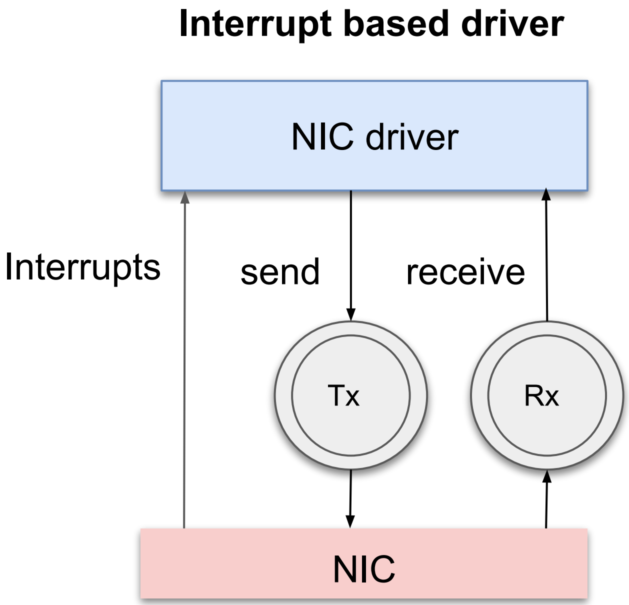
I/O event handling:

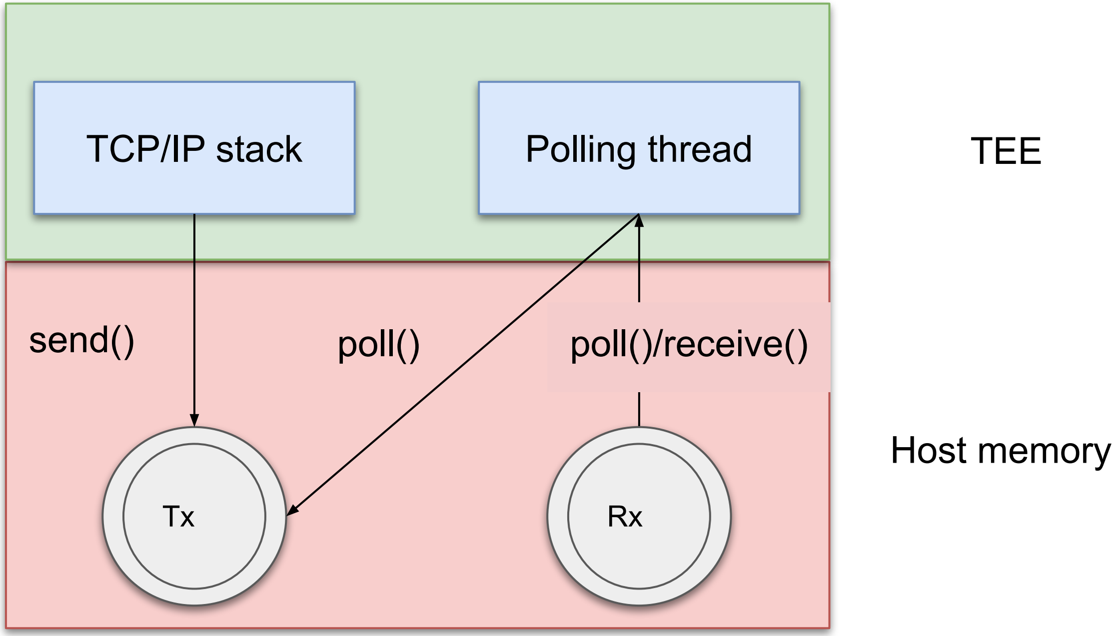
Polling-based approach

2. I/O event handling



Interrupts cause world switches in TEE!

2. Rkt-io's polling driver (for NIC)



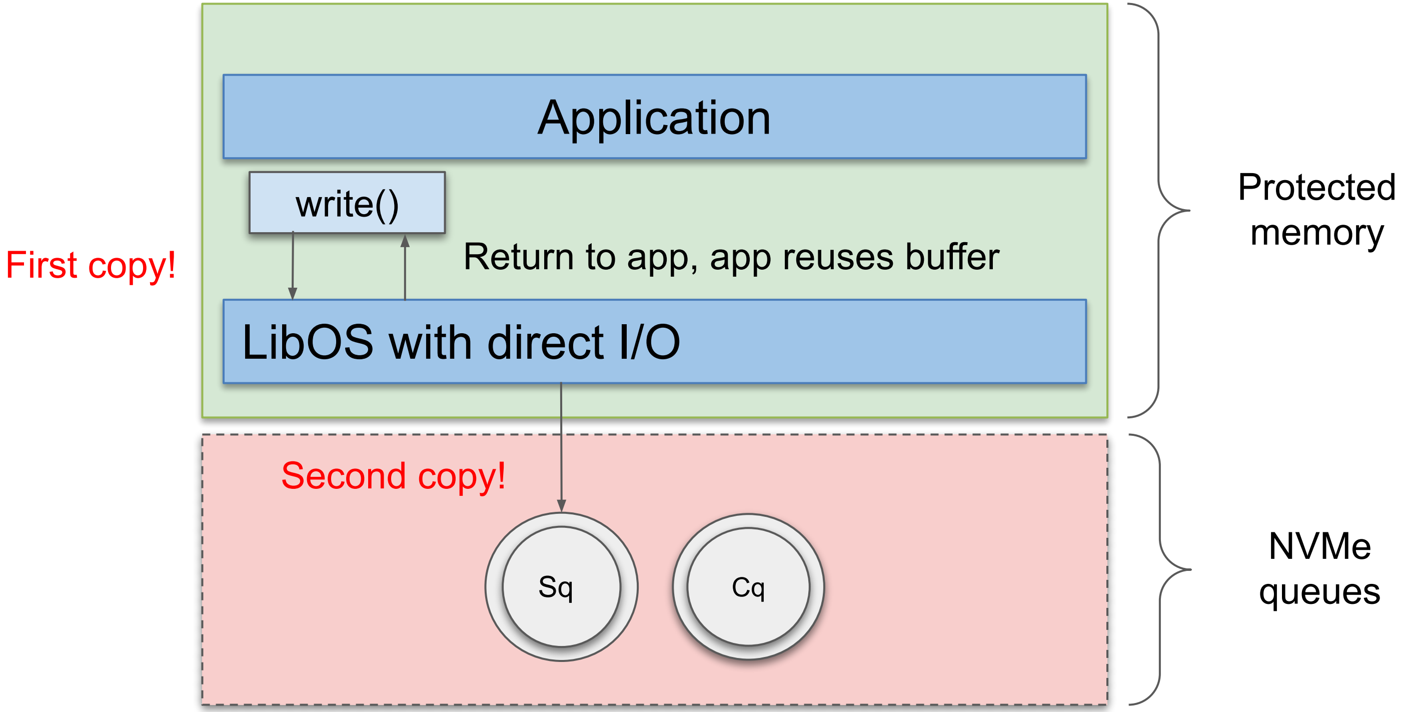
rkt-io uses device polling to handle the I/O events

3

I/O stack partitioning:

Control and data path partitioning

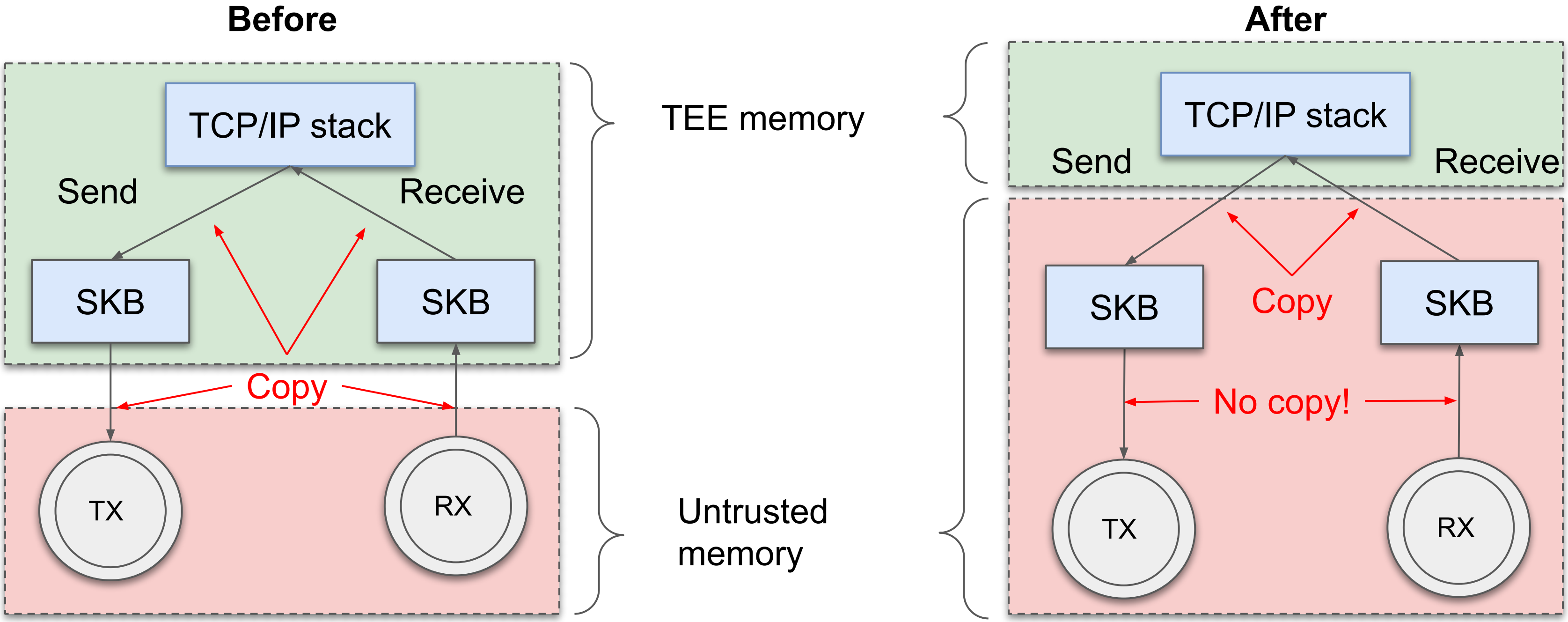
3. I/O stack partitioning for TEEs



How to avoid the second copy?

One-copy network/block device driver

SKB = Linux's internal buffer socket



Page cache/socket buffer are written to unencrypted memory

Usage

Usage

```
$ rkt-io-run ./app-disk.img /usr/bin/redis-server --bind 10.0.1.1
```

- Applications are packaged as encrypted, signed filesystem images
- Transparent substitution of musl libc at runtime
- I/O path is (optionally) encrypted:
    - Full disk encryption with cryptsetup
    - Layer-3 VPN with wireguard

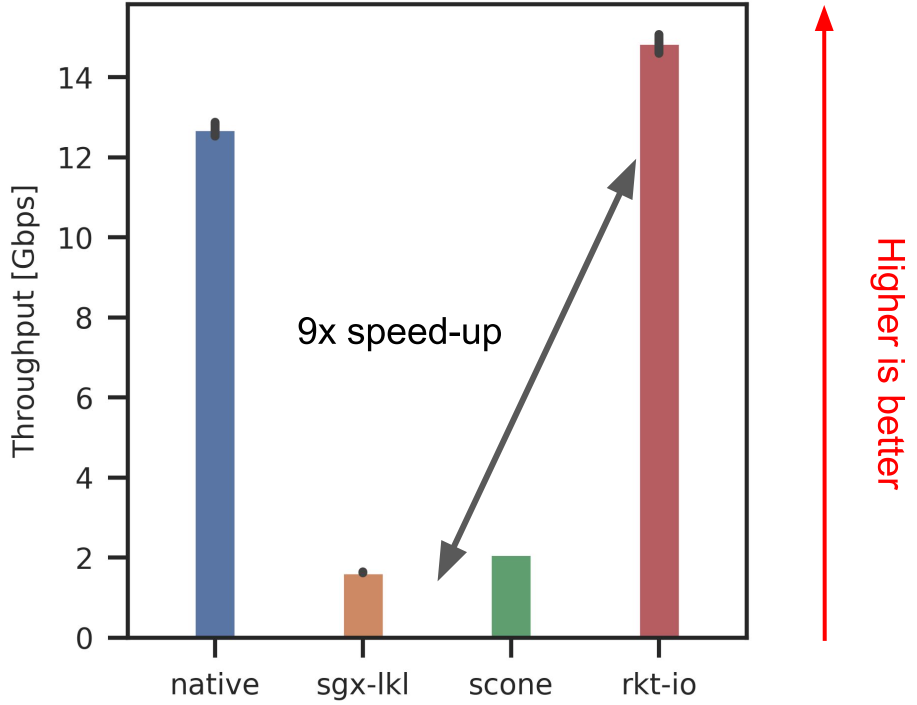
rkt-io enables applications to easily build with a commodity package manager

Evaluation

Evaluation: Benchmarks and applications

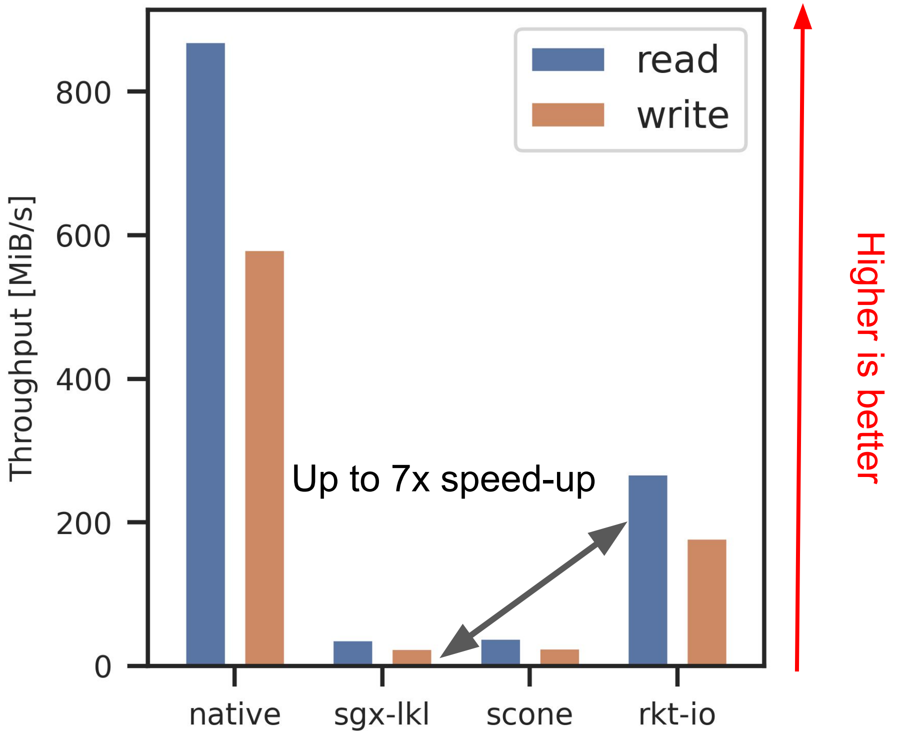
- Synthetic benchmarks:
  - Storage (fio) and network (iPerf)
- Real-world applications:
  - Sqlite (Speedtest), nginx (wrk), Redis (YCSB), MySQL (Sysbench)
- Baselines
  - **Non-secure:** Native Linux
  - **Secure:** SCONE (host OS) & SGX-LKL (library OS)

Network stack: iPerf



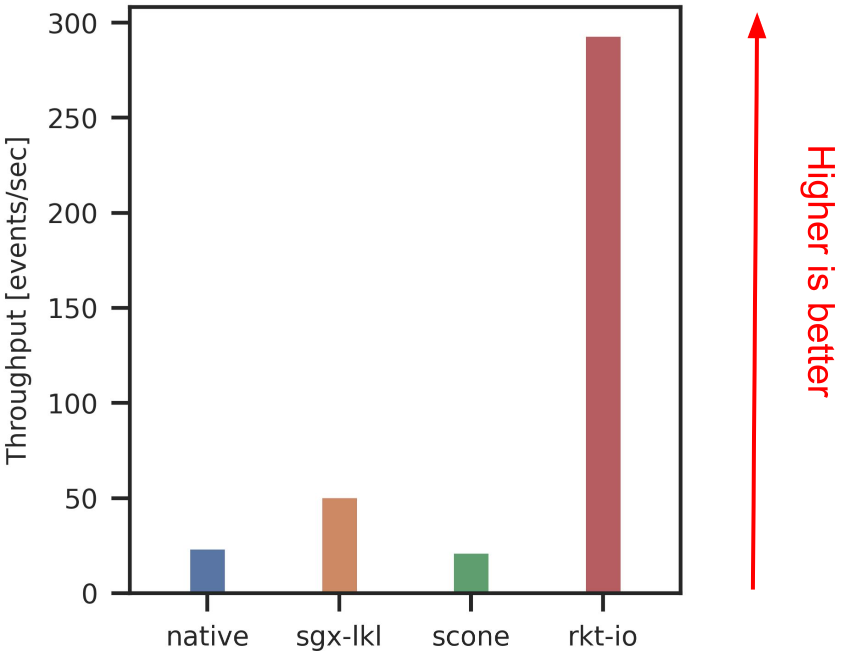
Rkt-io provide hight iPerf network throughput due to NIC offloading

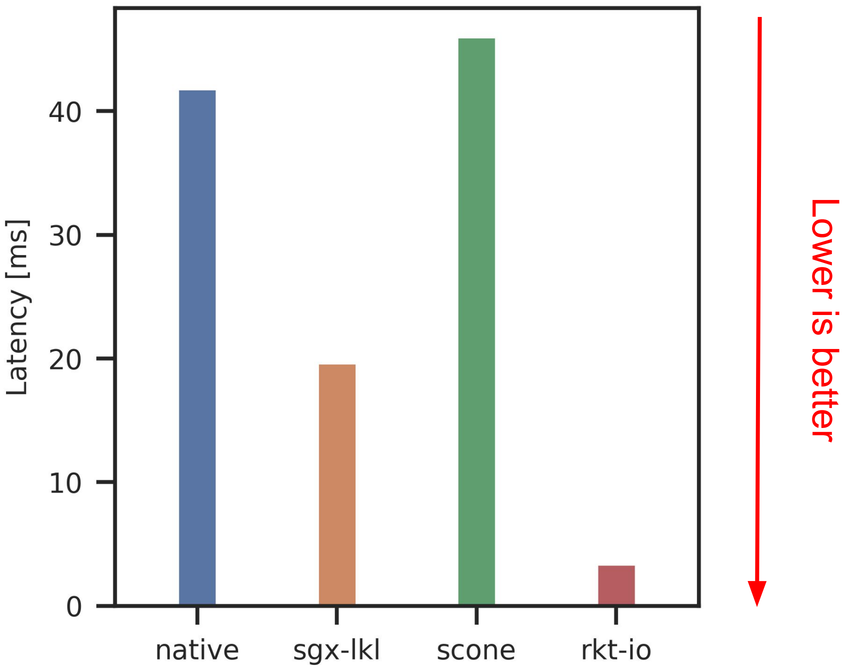
Storage stack: fio (random read-write)



Disk throughput ahead to other frameworks but behind native (smaller page cache)

Evaluation: MySQL (sysbench)





Both SGX-LKL and rkt-io are faster than native

Analysis of futexes in MySQL

Top 5	Syscall	Count	Time (μs)	Total (%)
#1	futex	64	4.20e+07	69.4
#2	read	24728	9.40e+06	15.5
#3	select	9	8.99e+06	14.8
#4	fsync	436	6.03e+04	0.1
#5	write	8243	3.48e+04	0.06

Breakdown of Top-5 syscalls in MySQL native execution

MySQL performance benefits from LibOS futexes / context switching

Summary

- Current SGX-implementation are not designed for high-performance I/O
    - **OS bottlenecks:** The OS is still on the I/O path
    - **I/O threads:** Require tuning to find optimal number of I/O threads
    - **Data copies:** Additional data copies between TEE ↔ IO threads ↔ OS
- rkt-io provides
    - Transparent and fast access to the I/O devices
    - Linux ABI-compatibility for applications in TEEs

Performant + Secure + Transparent

Try it out!

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