Can We Containerize Internet Measurements?

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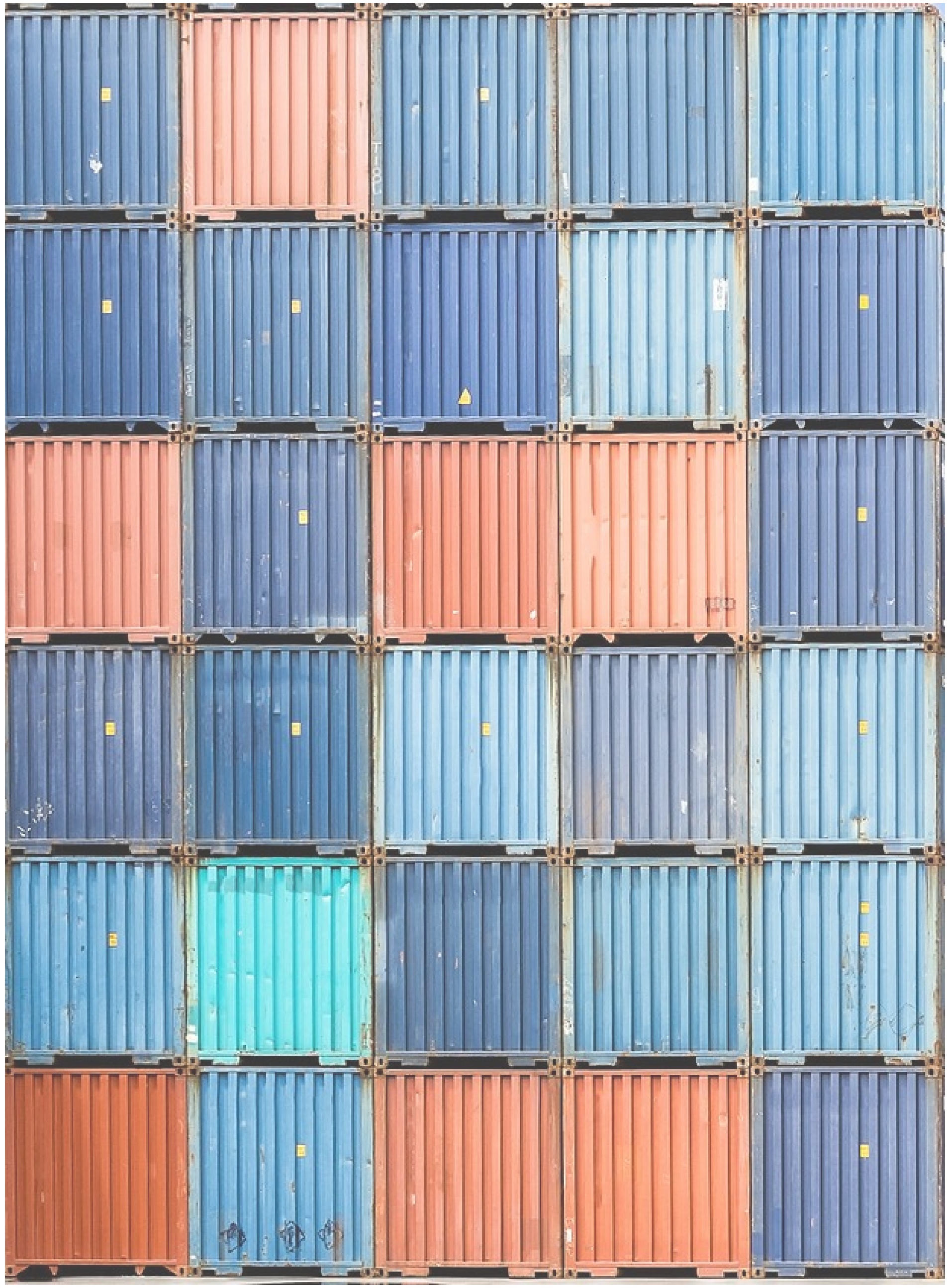
Outline

- **Containerized measurement issues**
- Proposed solution: MACE
- Evaluation of MACE

Containers

- Lightweight virtualization mechanism
  - Package, deploy, isolate



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  - Package, deploy, isolate
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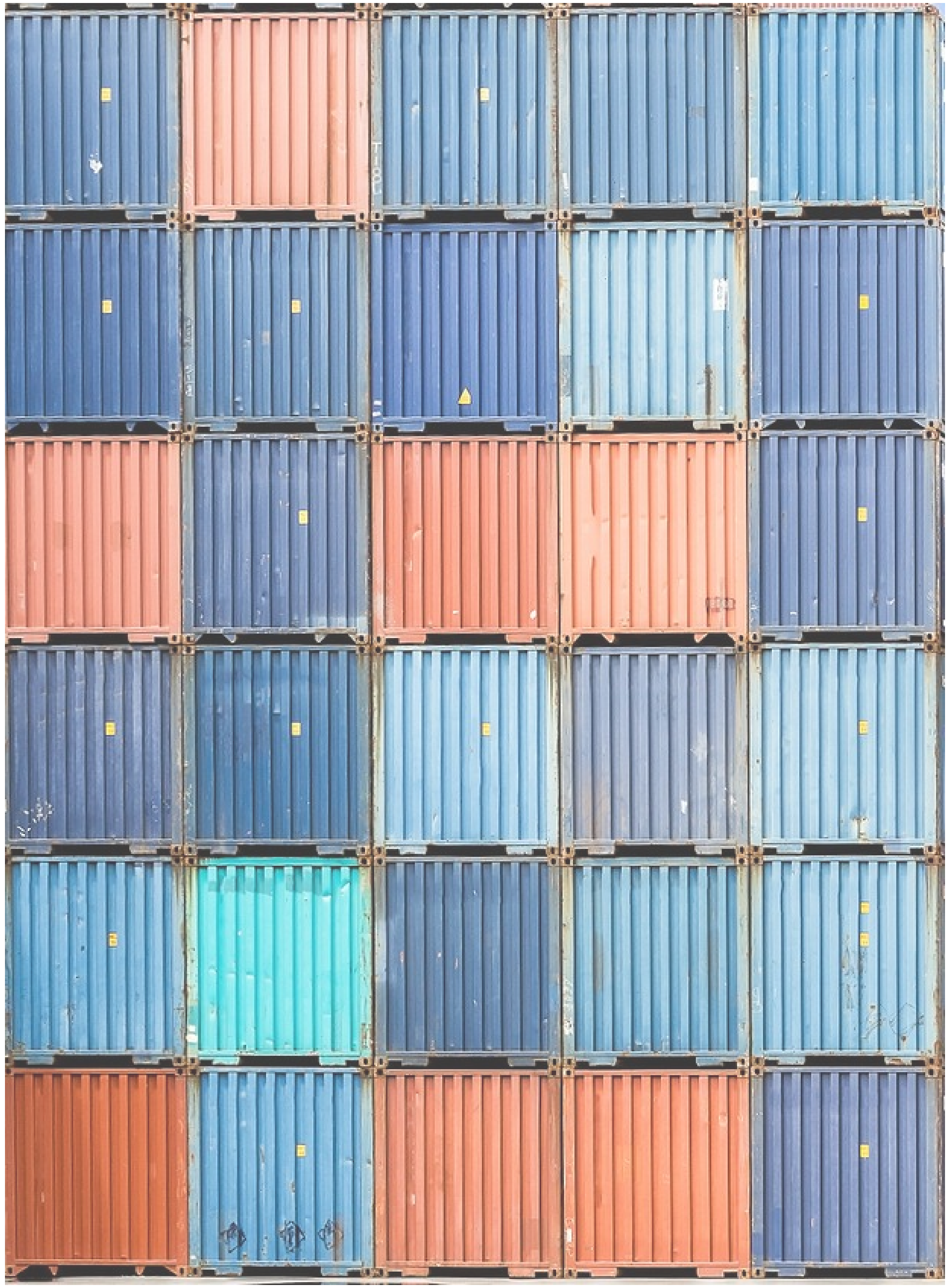
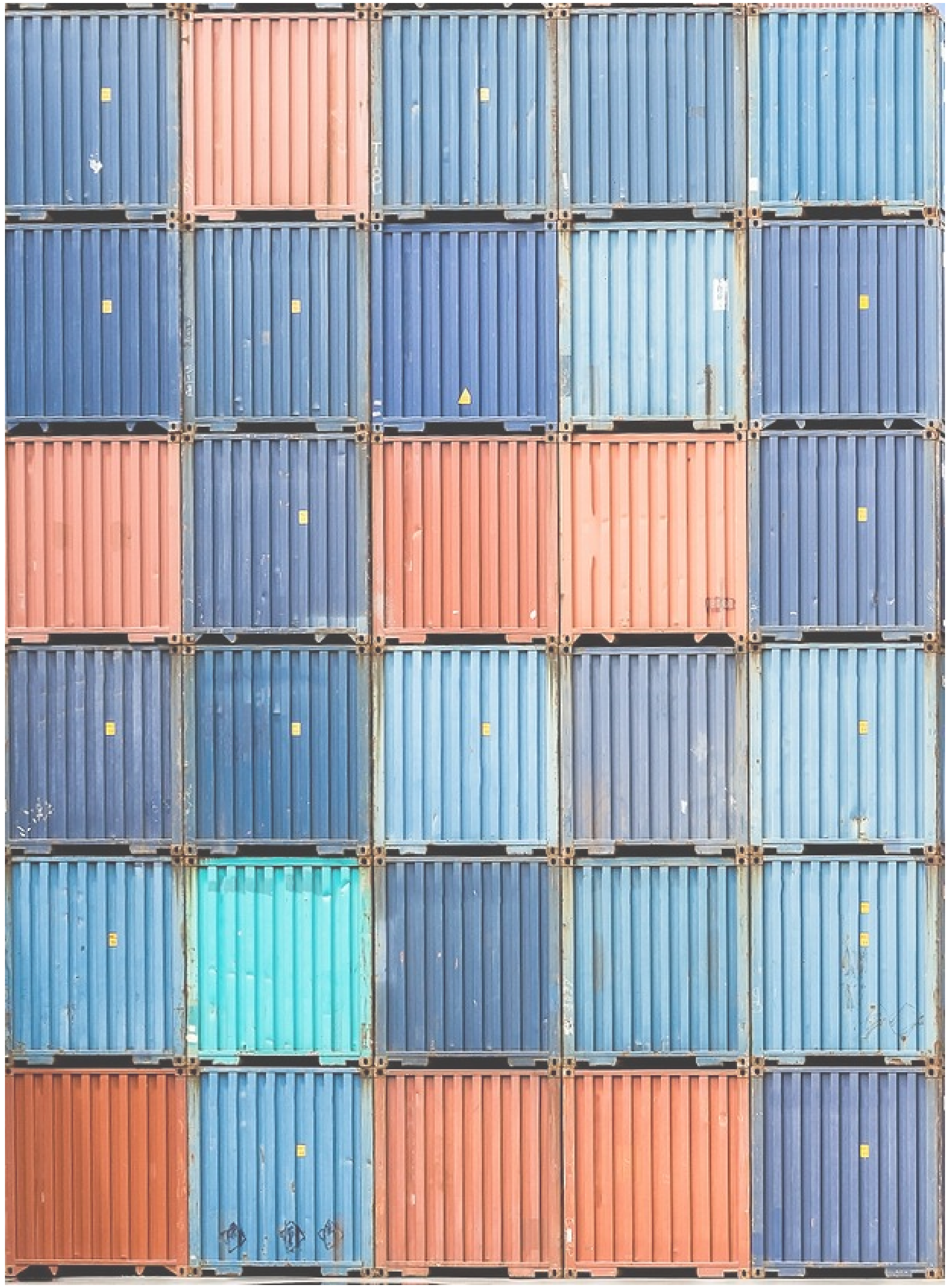
  - Namespaces, cgroups



Containers

- Lightweight virtualization mechanism
  - Package, deploy, isolate
- Based on recent developments in Linux
  - Namespaces, cgroups
- Rapidly replacing VMs
  - Smaller, faster



Motivation

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- Streamline experiments
  - Package scripts, tools, libraries
  - Consistent interface
- Expose new, cloud-native vantage points
  - Azure
  - AWS
  - GCP
  - etc.
- Less CPU and memory overheads than VMs [1]

PlanetLab since 2012 [0]

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Sure we can!

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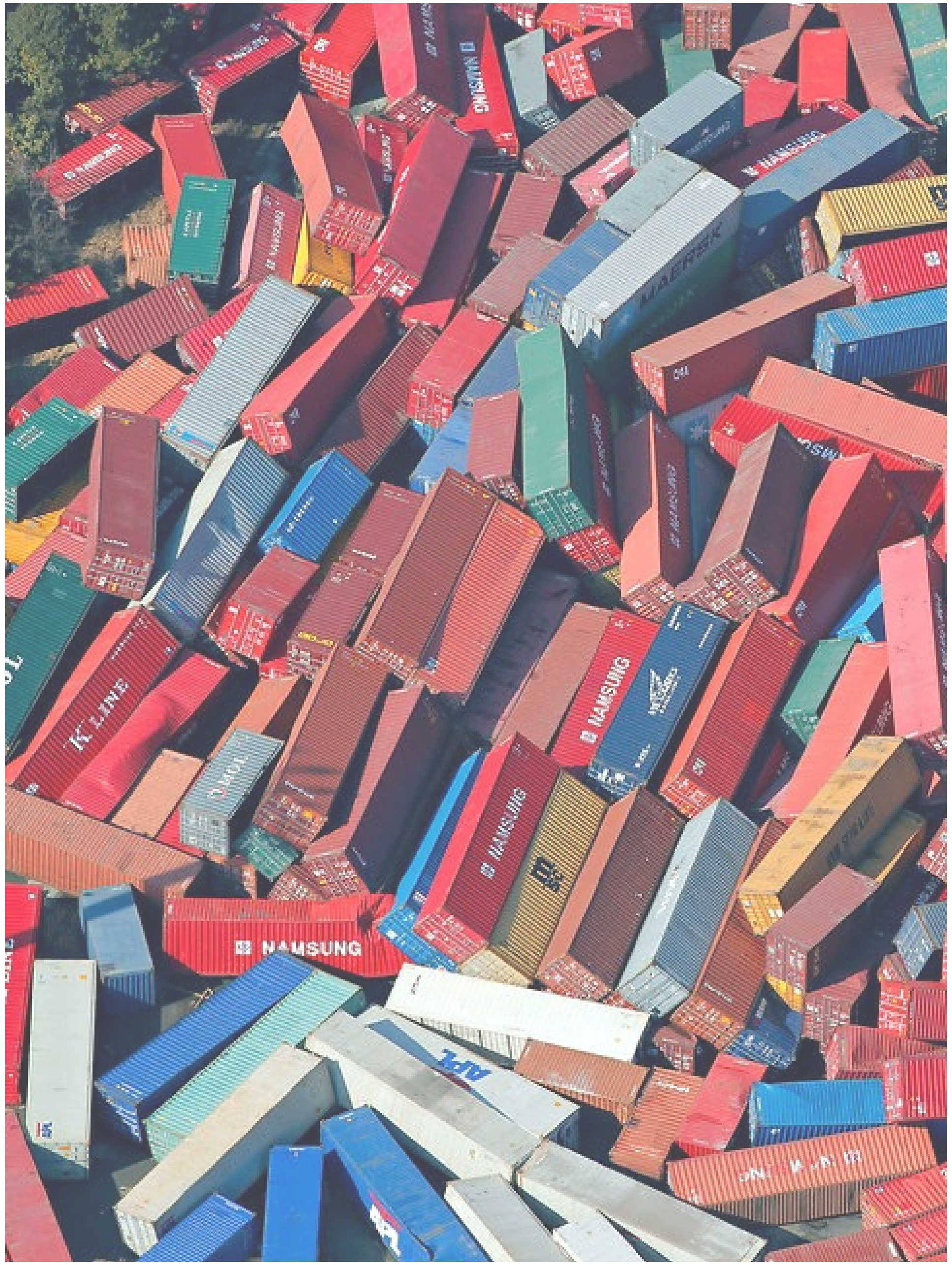
Why not?

Network Isolation

- Extra latency [2]
  - ~50µs in resting system



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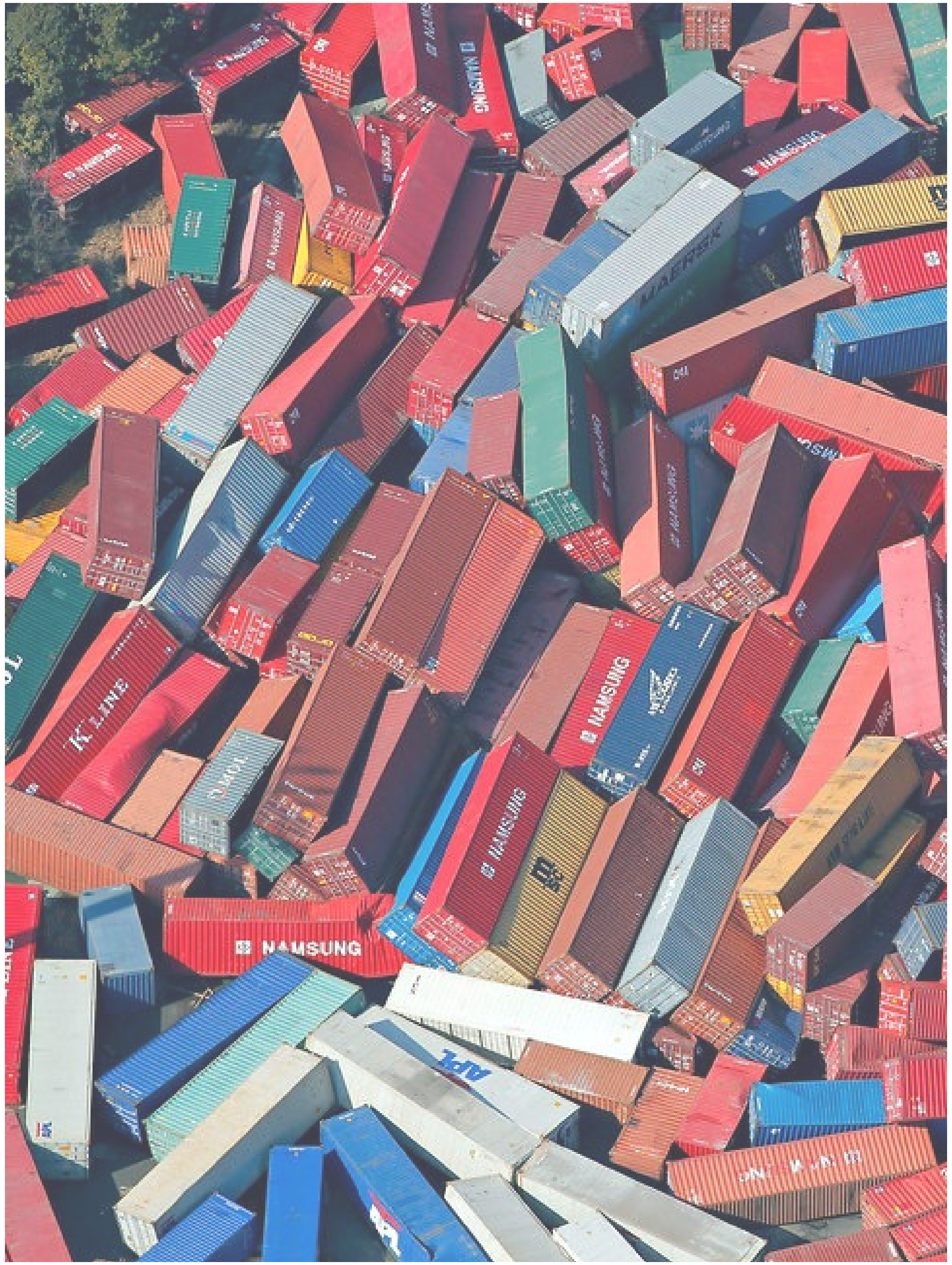
  - Up to 300µs depending on traffic



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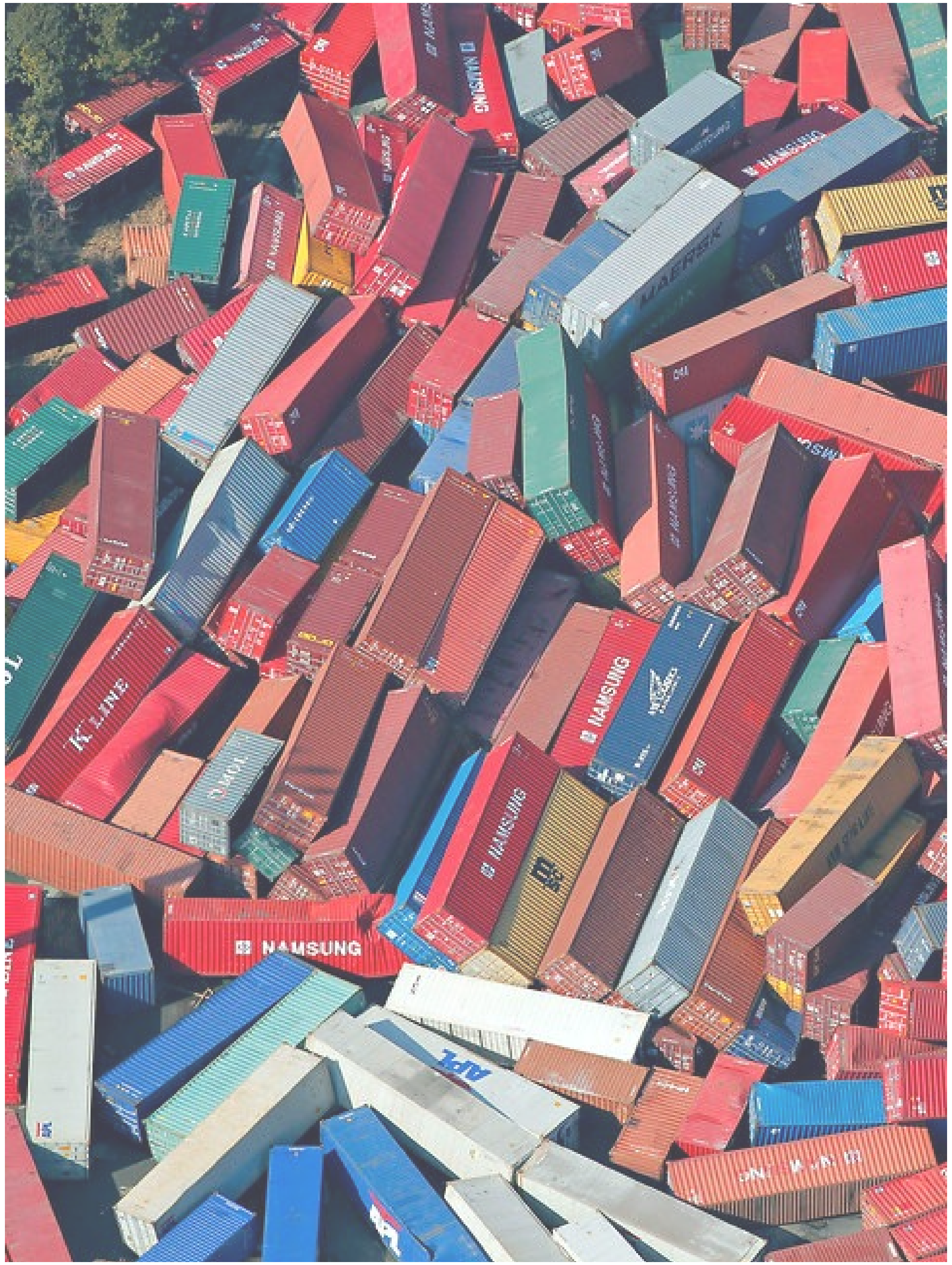
- Biased measurement results
  - Non-constant latency overheads



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Network Isolation

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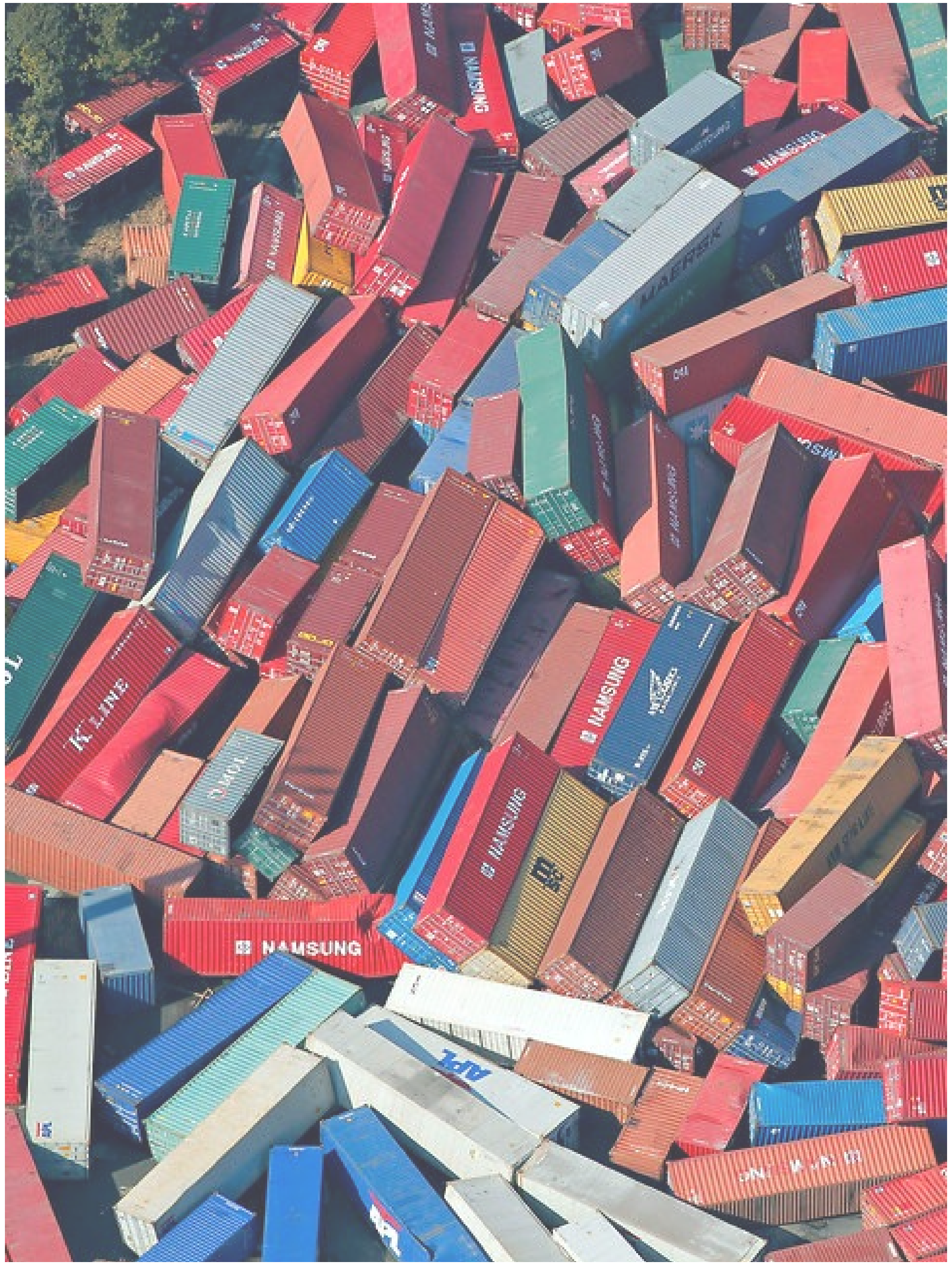
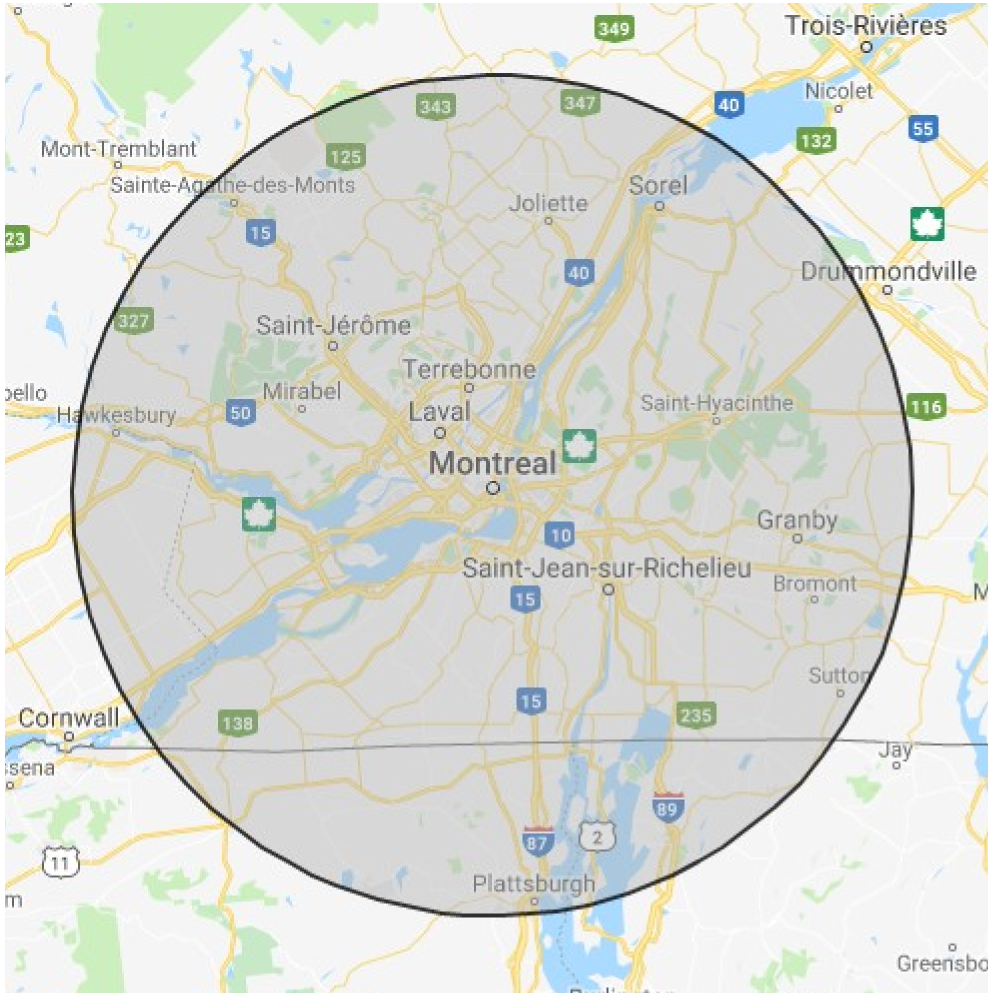
  - ~50μs in resting system
- Co-located containers
  - Up to 300μs depending on traffic
- Biased measurement results
  - Non-constant latency overheads
- Slim [3], FreeFlow [4] don't help
  - Flow-based, RDMA



Importance of Latency

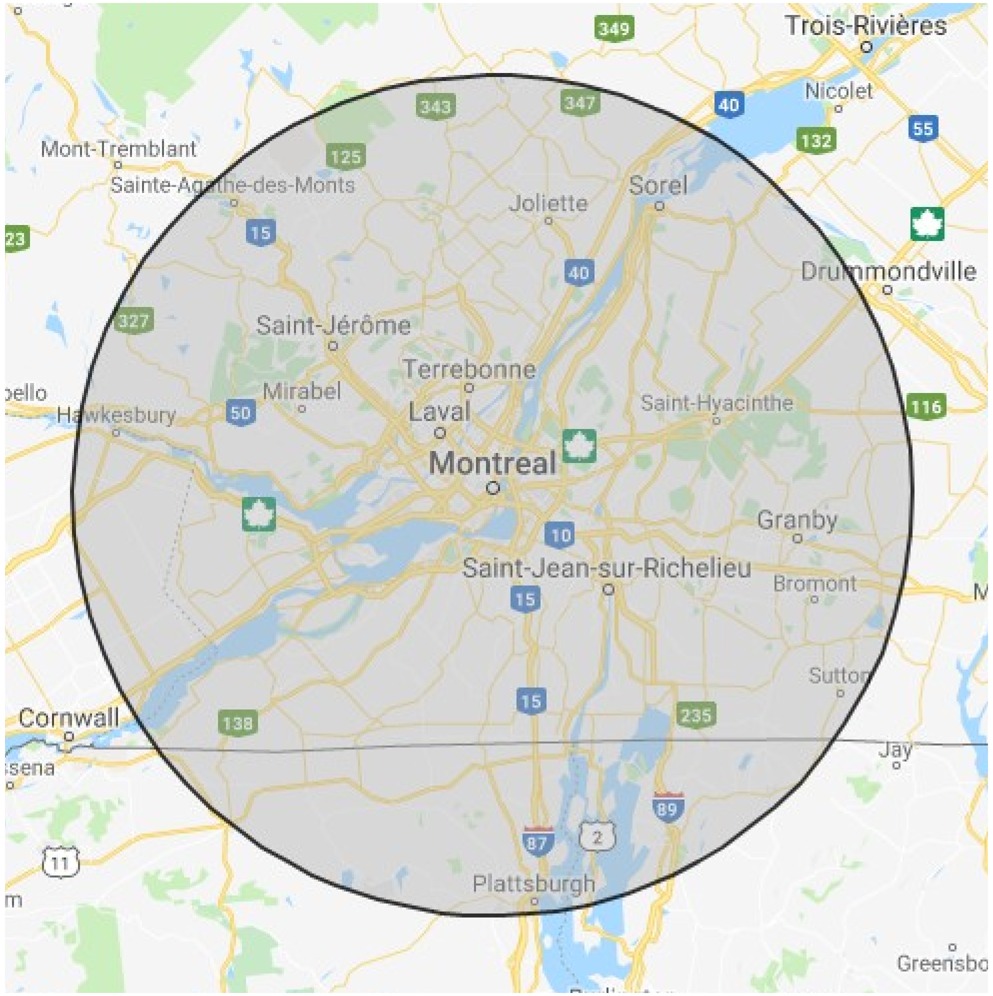
- An error of 300μs translates to
  - 90km at the speed of light [6, 7]
  - $1.2 million for online trading [5]



Source: Google

Importance of Latency

- An error of 300μs translates to
  - 90km at the speed of light [6, 7]
  - $1.2 million for online trading [5]
- Hard to isolate latencies
  - OS, virtualization, physical



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How to account for latency in a running container system?

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MACE:

Measure the Added Container Expense

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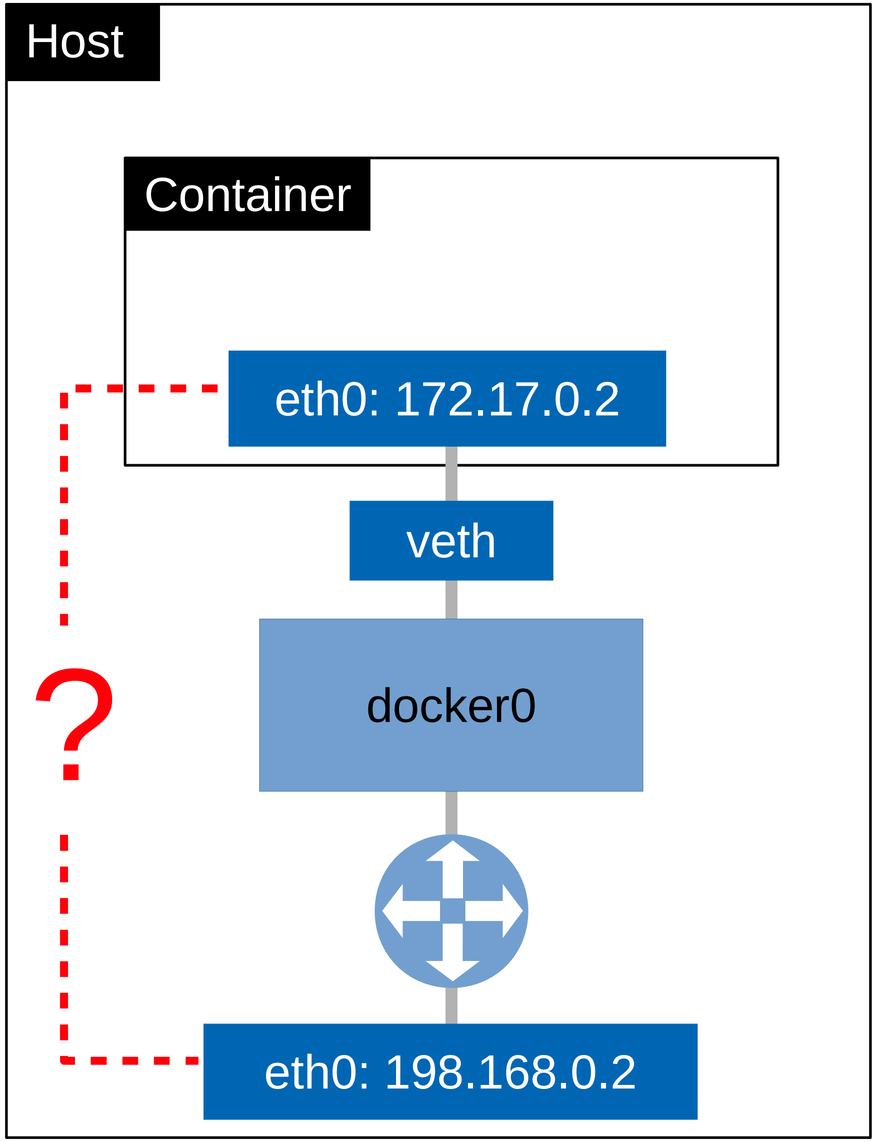
- Evaluation of MACE

MACE: Goals

- Packet-level latencies
  - Ingress and egress
  - High accuracy



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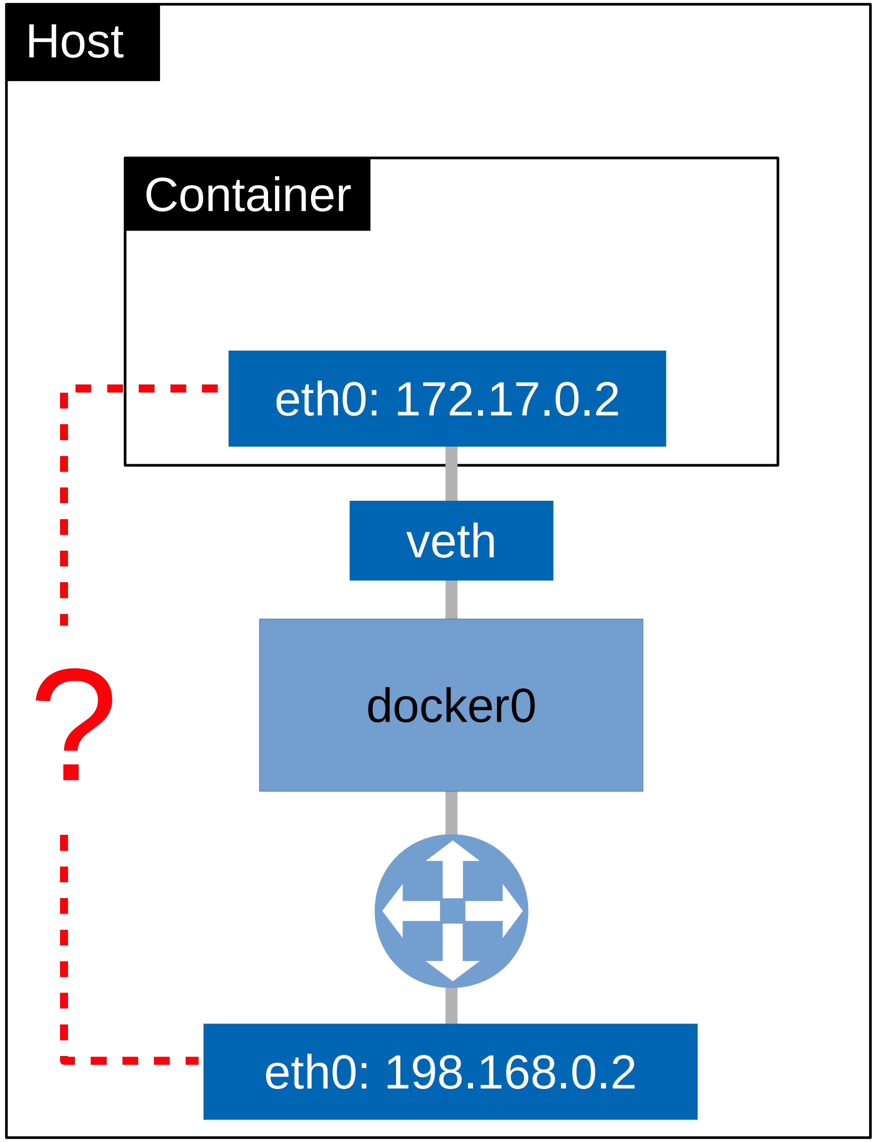

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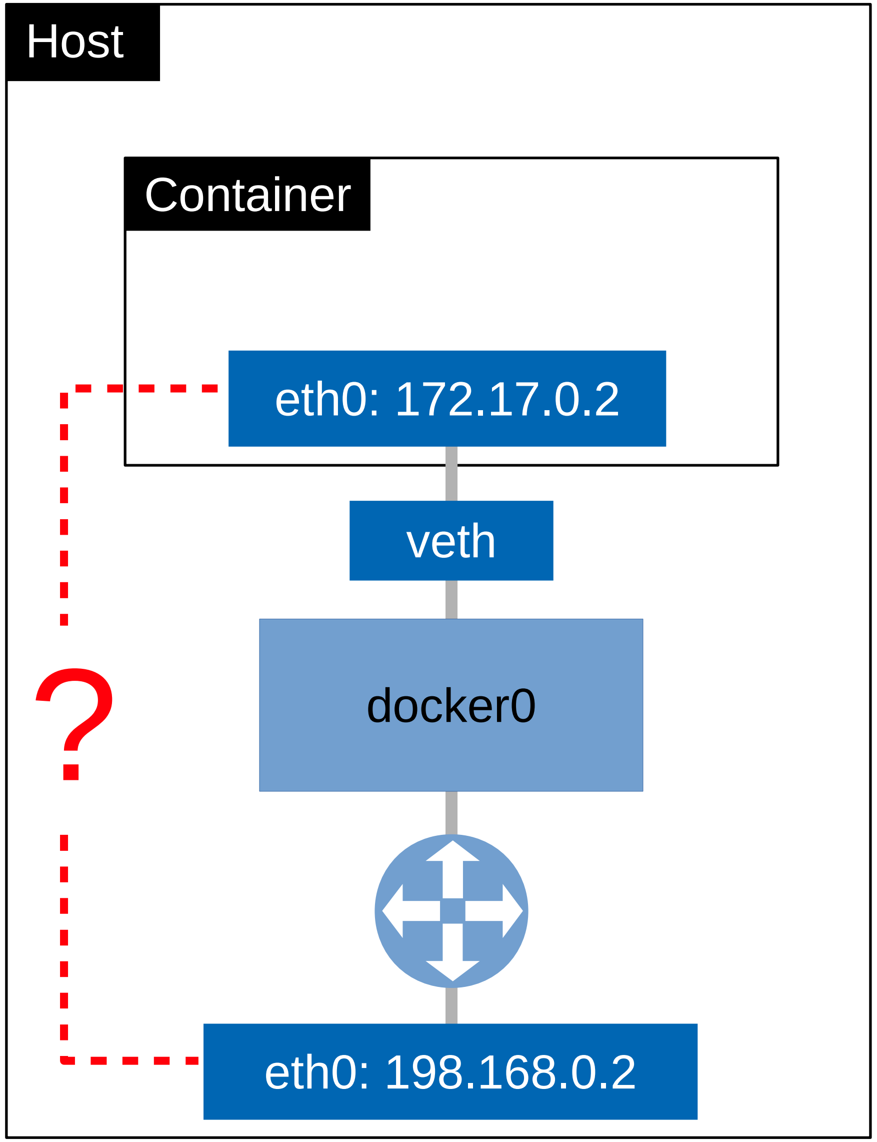
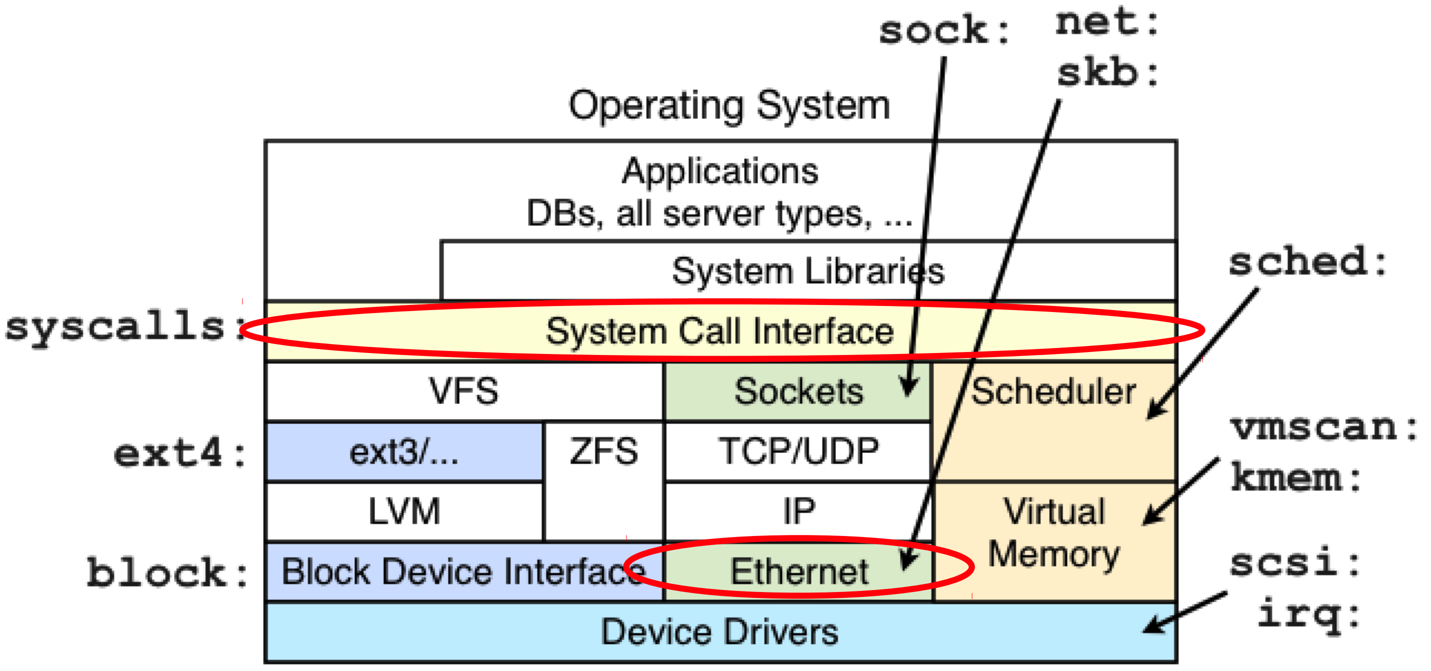
MACE: Goals

- Packet-level latencies
  - Ingress and egress
  - High accuracy
- Minimal impact on network performance
- Consistent, container-friendly interface



MACE: How?

- Linux Kernel Tracepoints [9]
  - Hooks into kernel
  - Net device and system call subsytems



Static Tracepoints

Source: http://www.brendangregg.com

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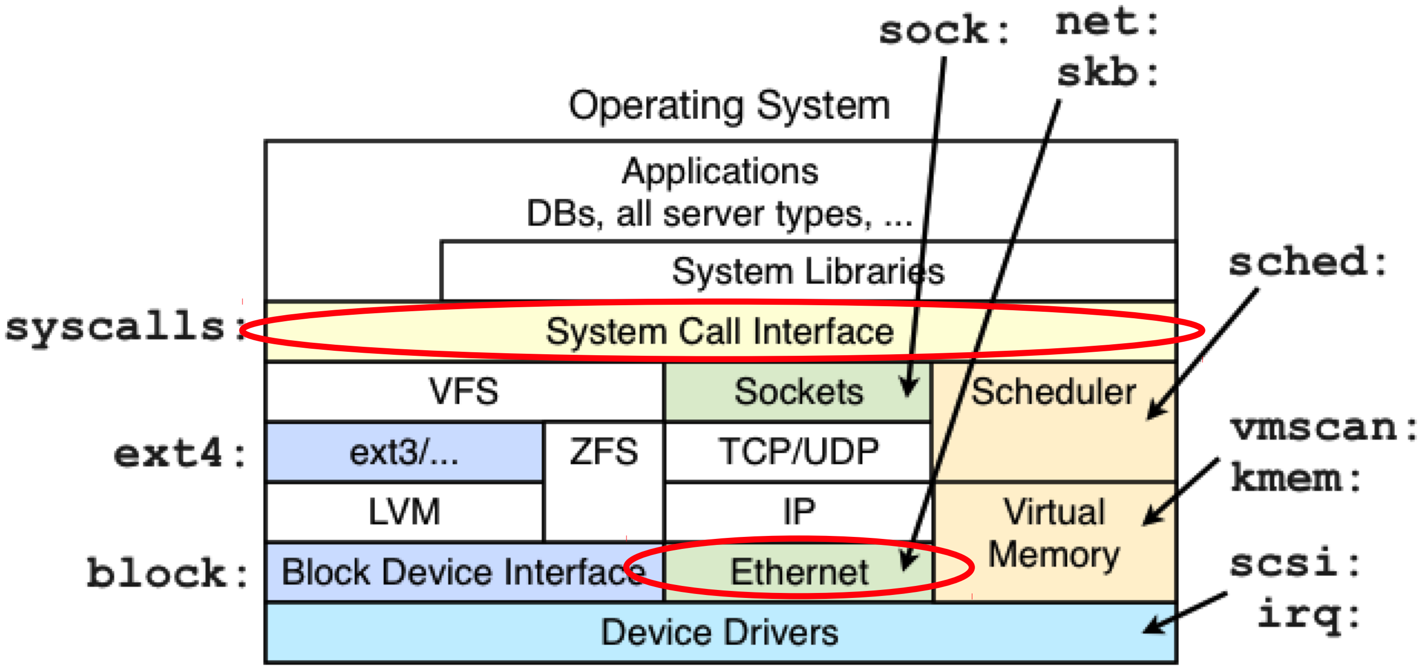
  - Large perturbation



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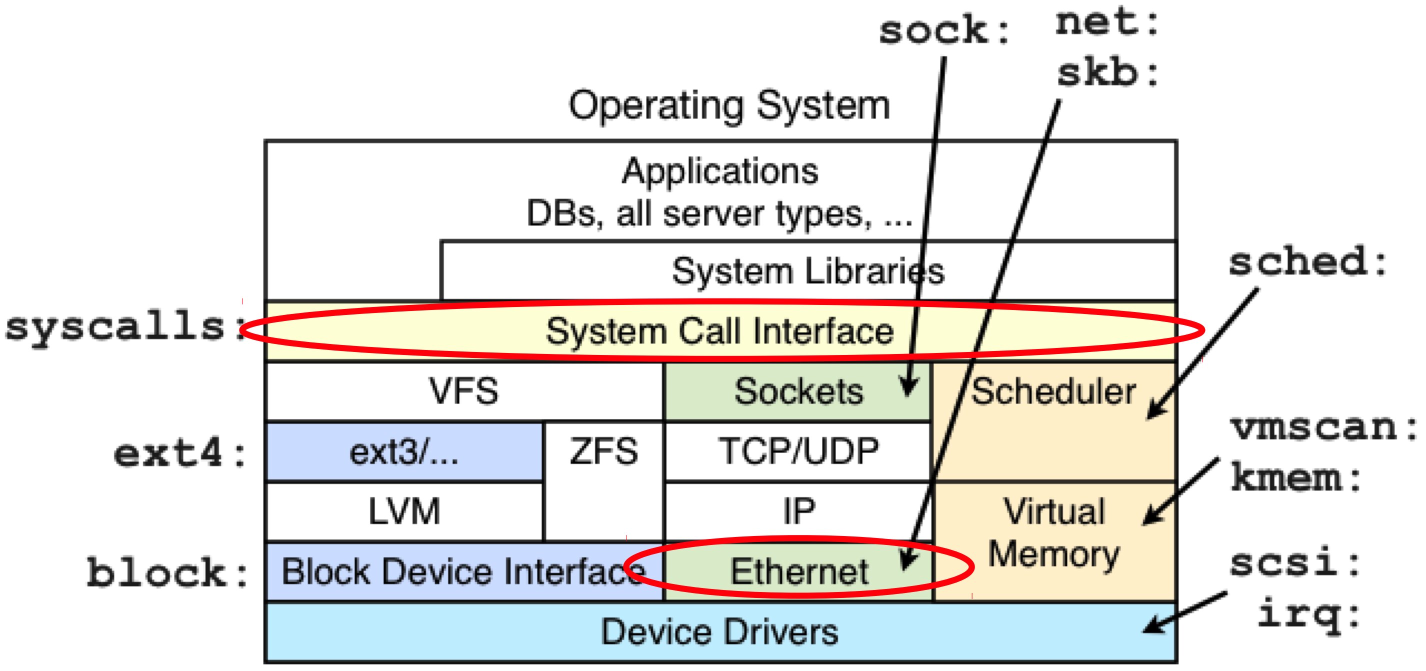
MACE: How?

- Linux Kernel Tracepoints [9]
  - Hooks into kernel
  - Net device and system call subsytems
- Existing tracers
  - Large perturbation
- Kernel module
  - For container hosts
  - Report to containers



Static Tracepoints

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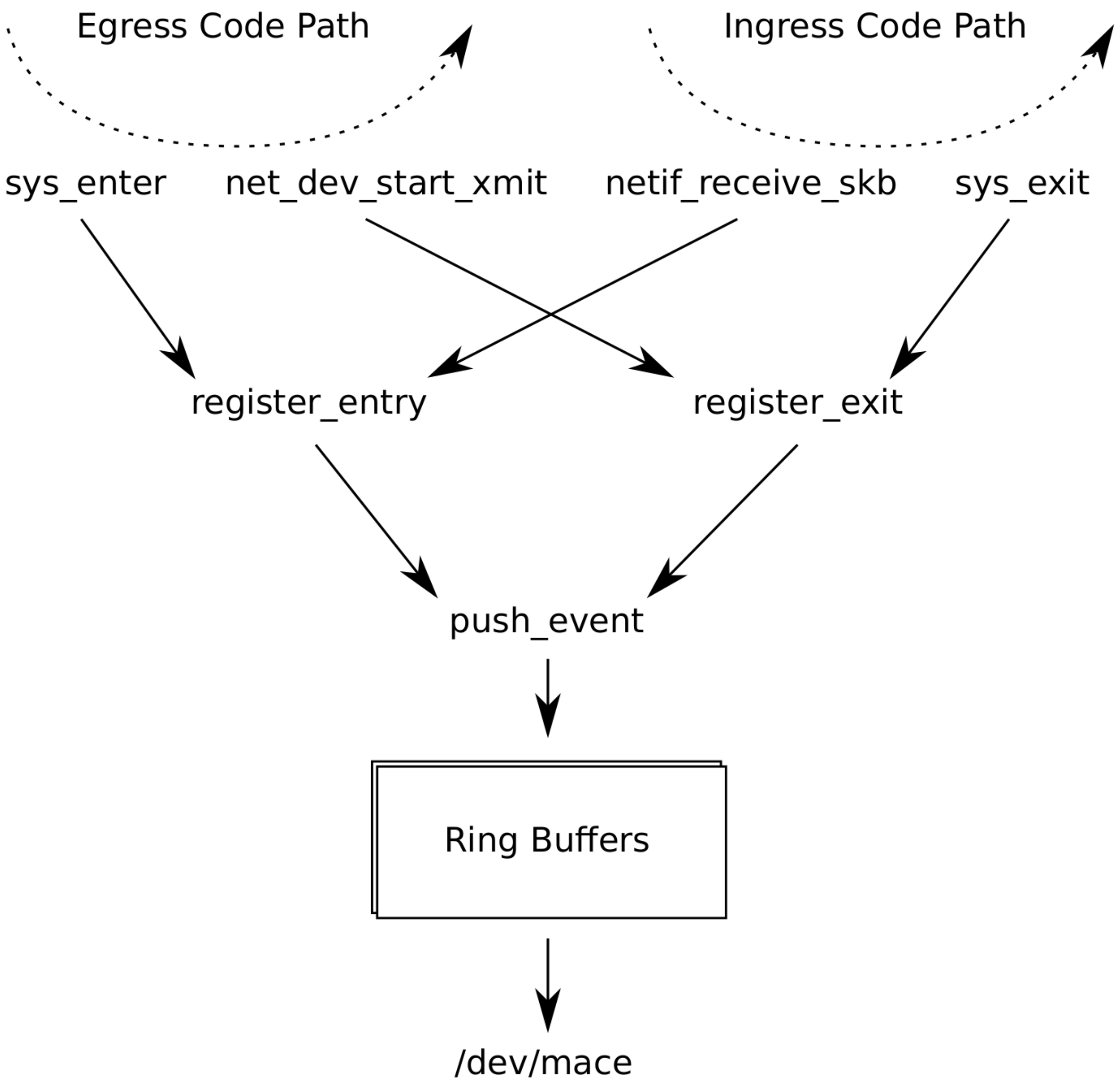
MACE: Design

- Filter trace events
  - Interface
  - Namespace



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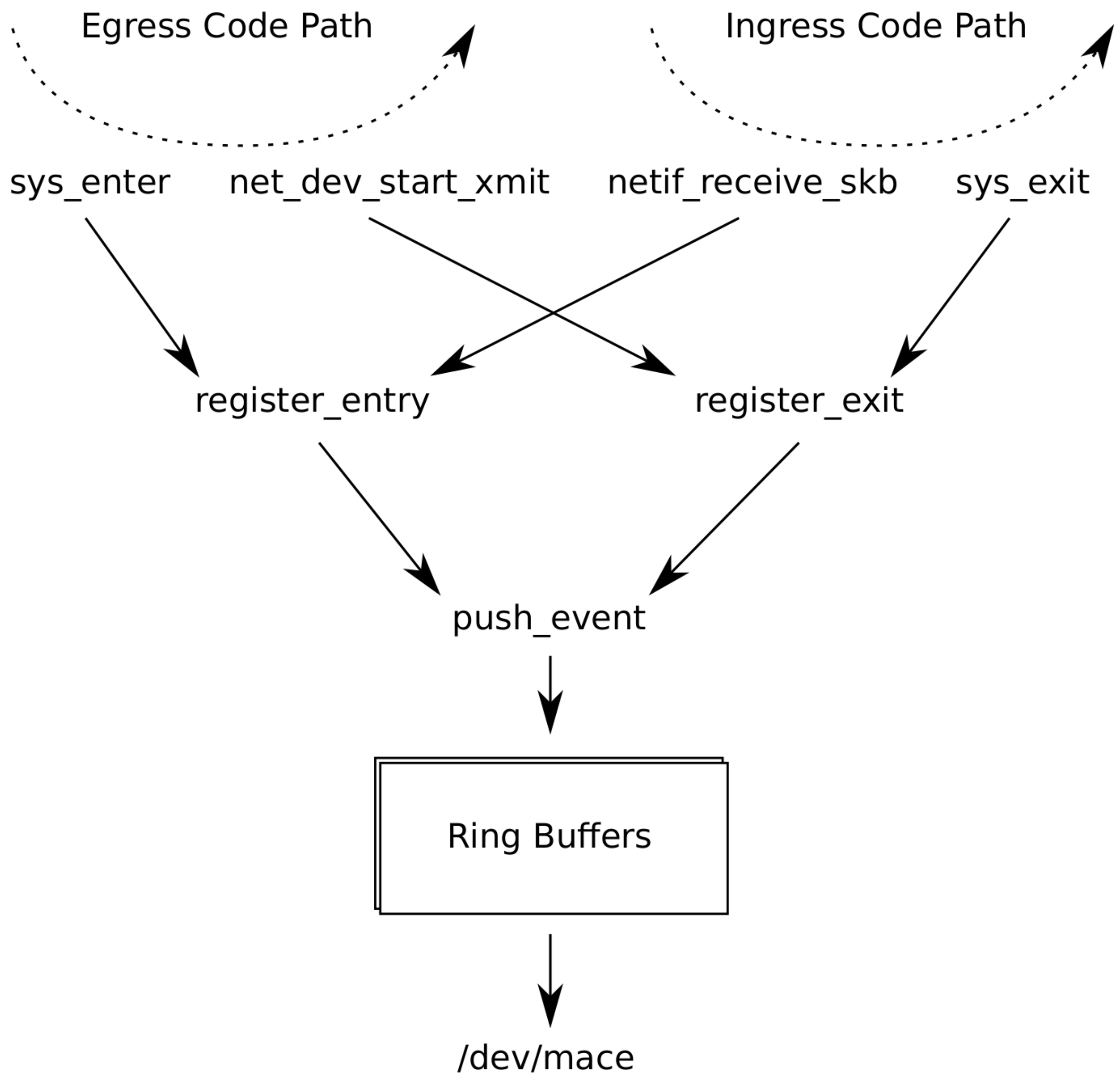
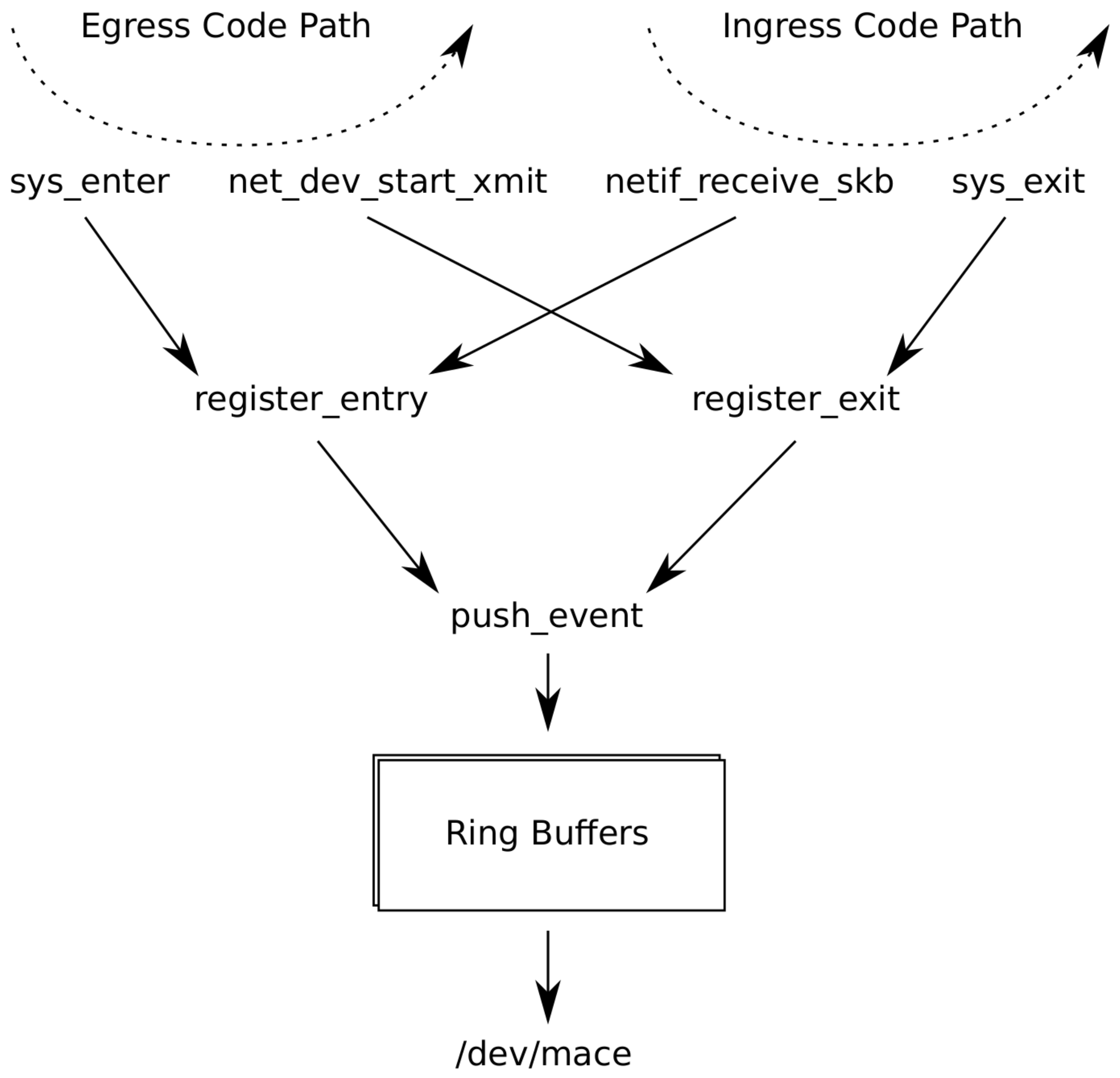
MACE: Design

- Filter trace events
  - Interface
  - Namespace
- Correlate events in hash tables
  - Ingress
  - Egress



MACE: Design

- Filter trace events
  - Interface
  - Namespace
- Correlate events in hash tables
  - Ingress
  - Egress
- Maintain list of latencies
  - Report via device file



MACE: Implementation

- High accuracy
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Open source at:
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  - Only lock hash buckets
  - Atomic types for ring buffer

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MACE: Implementation

- High accuracy
  - Read tsc for timing
- Low perturbation
  - Only lock hash buckets
  - Atomic types for ring buffer
- Consistent API
  - Interface is namespace-aware
  - Allow and enable per container

Open source at:
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MACE: Interface

- Select the container’s namespace:

```
# echo 1 > sys/class/mace/on
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- Execute measurement:

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# ping –c 10 google.com
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- Collect latencies:

```
# cat dev/mace
[1552589043.315681] (1) egress: 80932
[1552589043.315937] (1) ingress: 46208
[1552589043.316012] (2) egress: 13699
...
```

How do we know those numbers are correct?

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- **Evaluation of MACE**

Evaluation: Methodology

- No direct method

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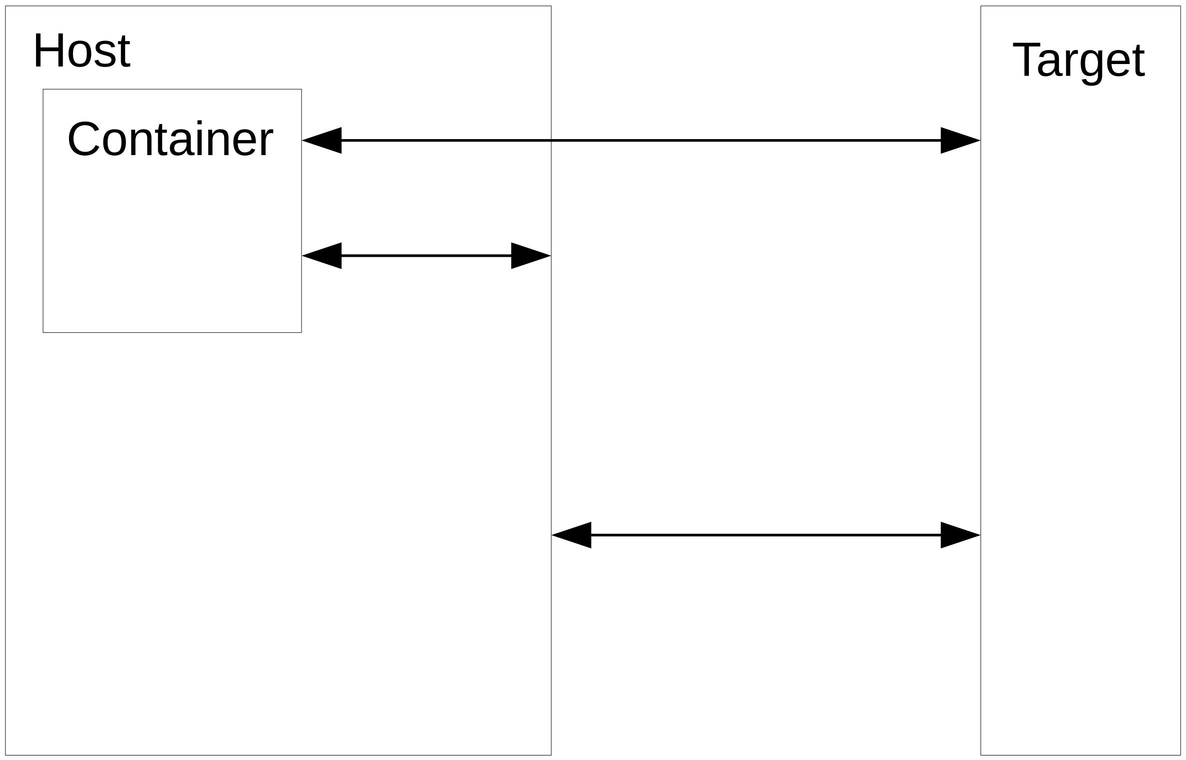
- Use difference in RTT



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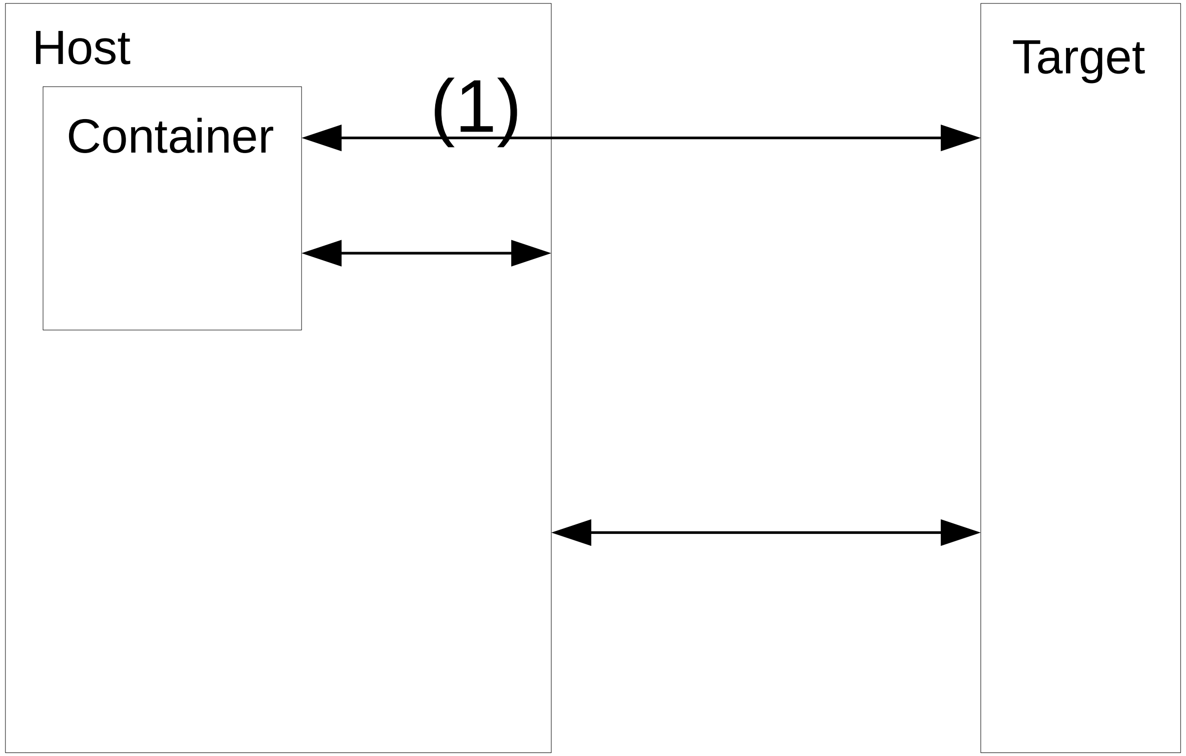
    (1) RTT from container



Evaluation: Methodology

- No direct method
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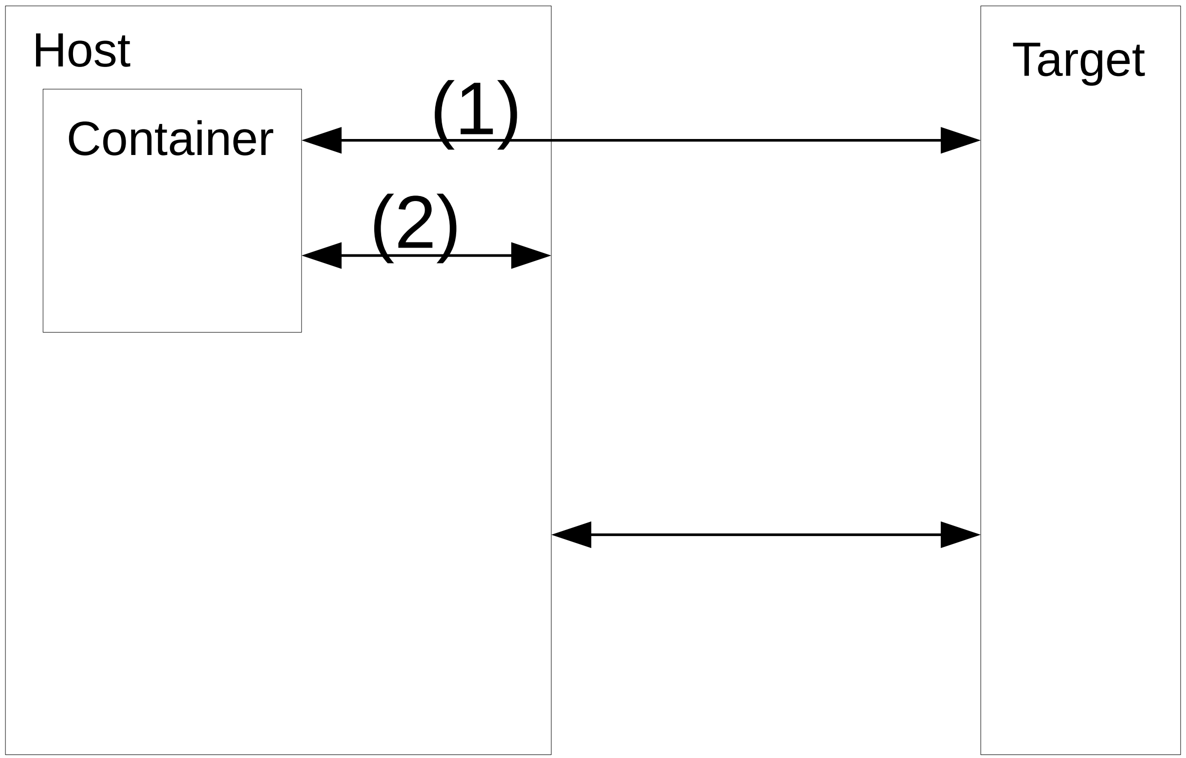
  - (1) RTT from container
  - (2) Latency overheads from MACE



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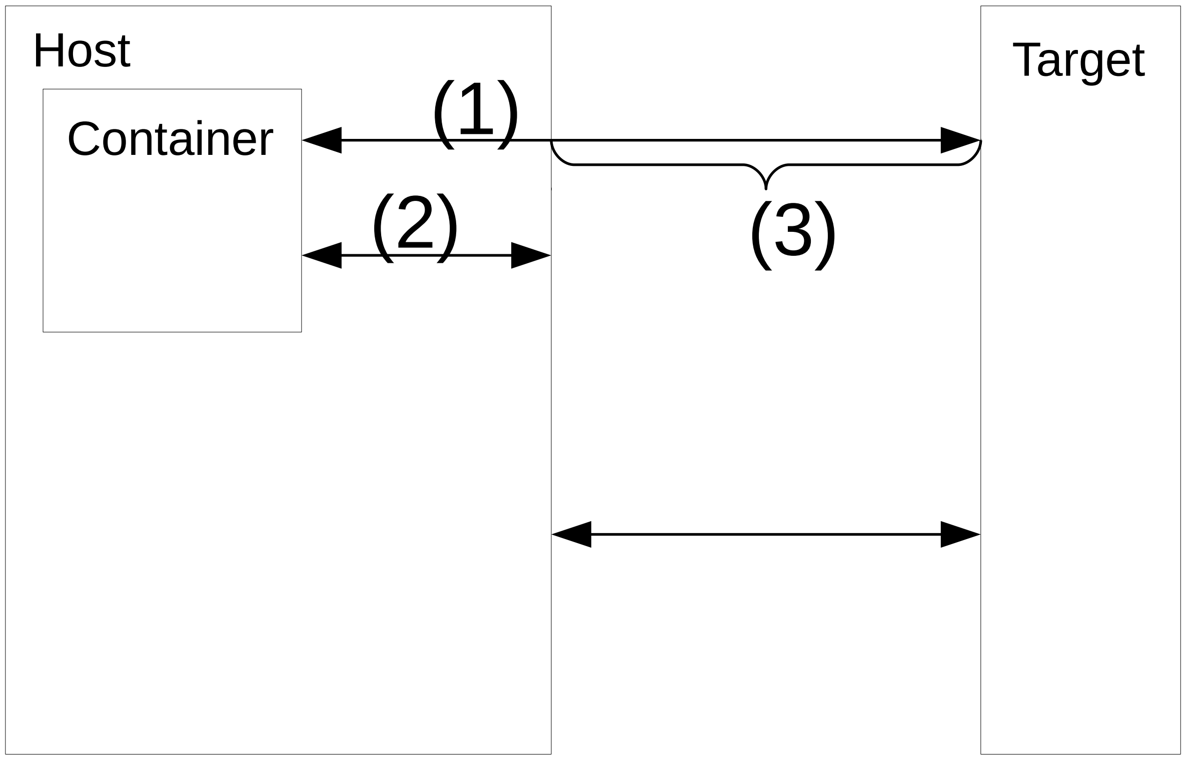
  (3) 'corrected' RTT

  = (1) minus (2)



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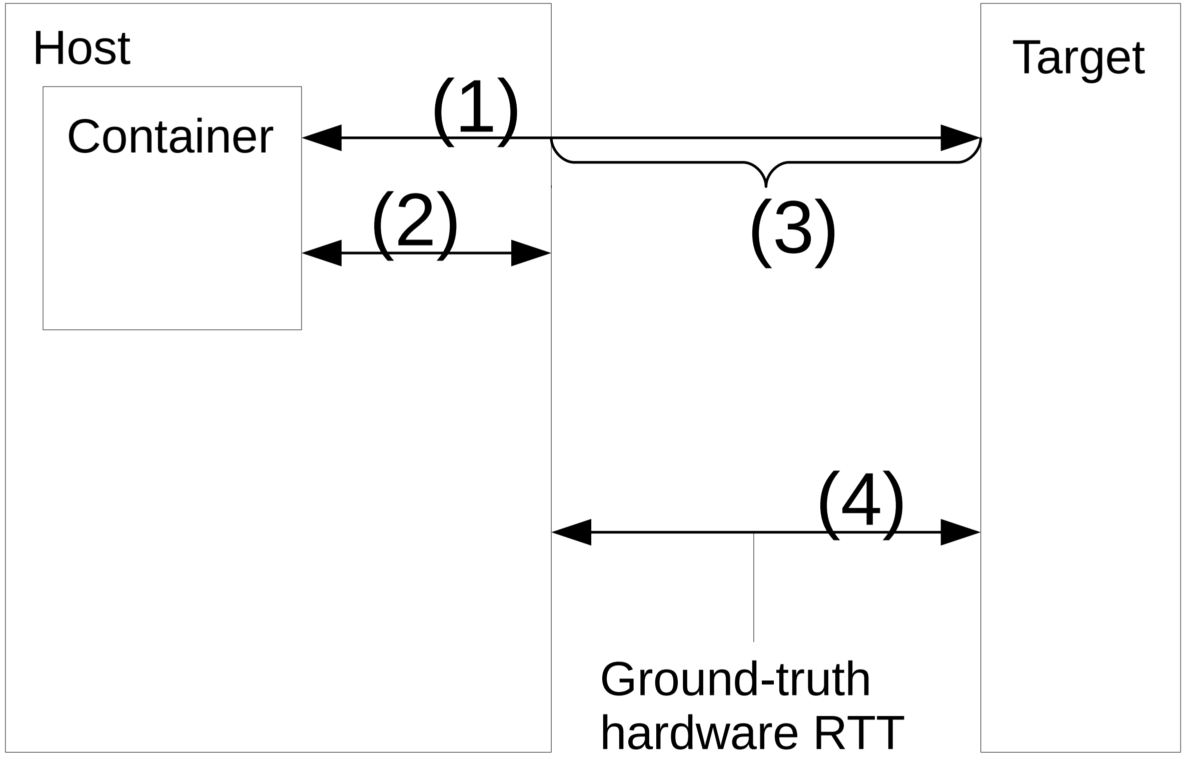
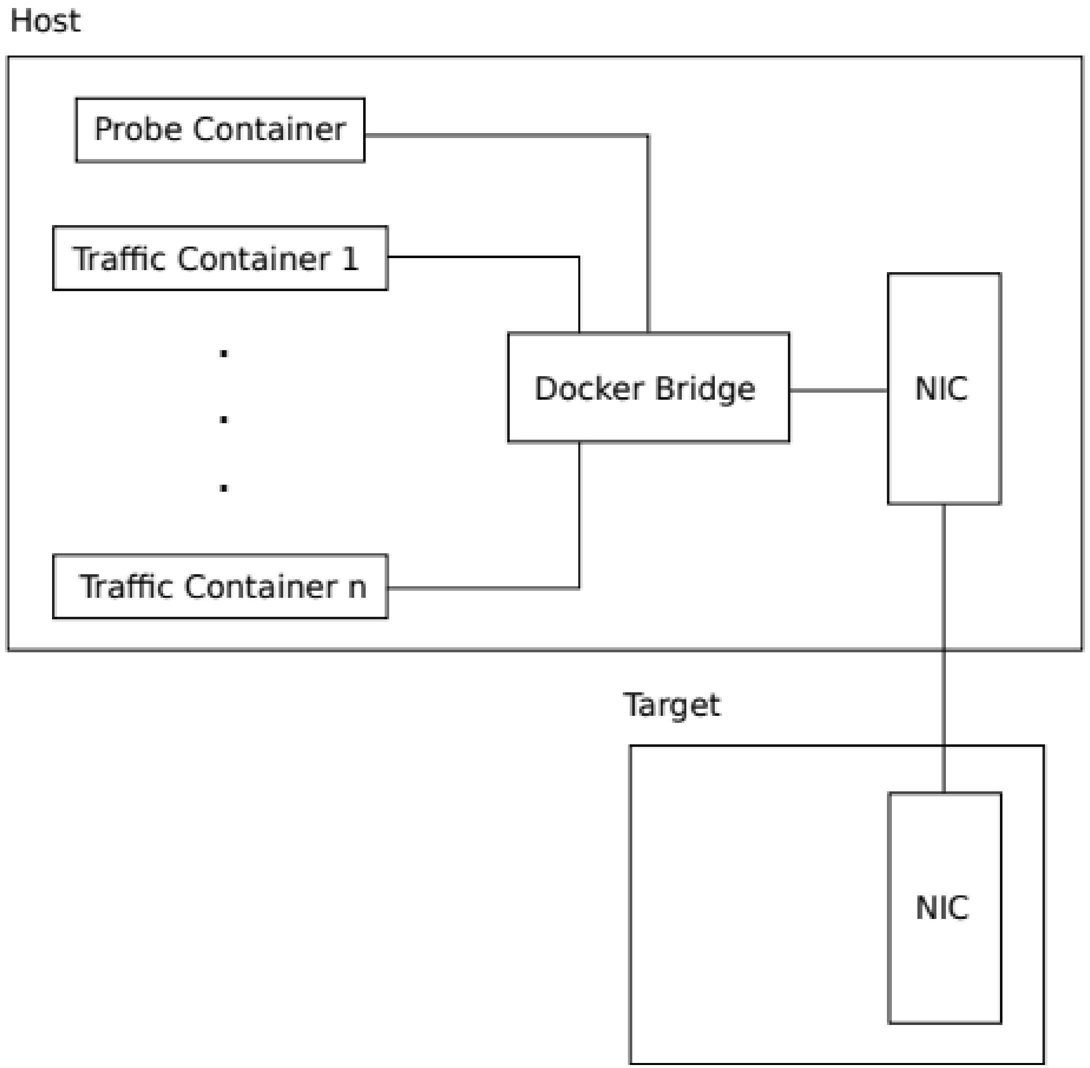
  = (1) minus (2)

  (4) Compare with RTT measured from hardware

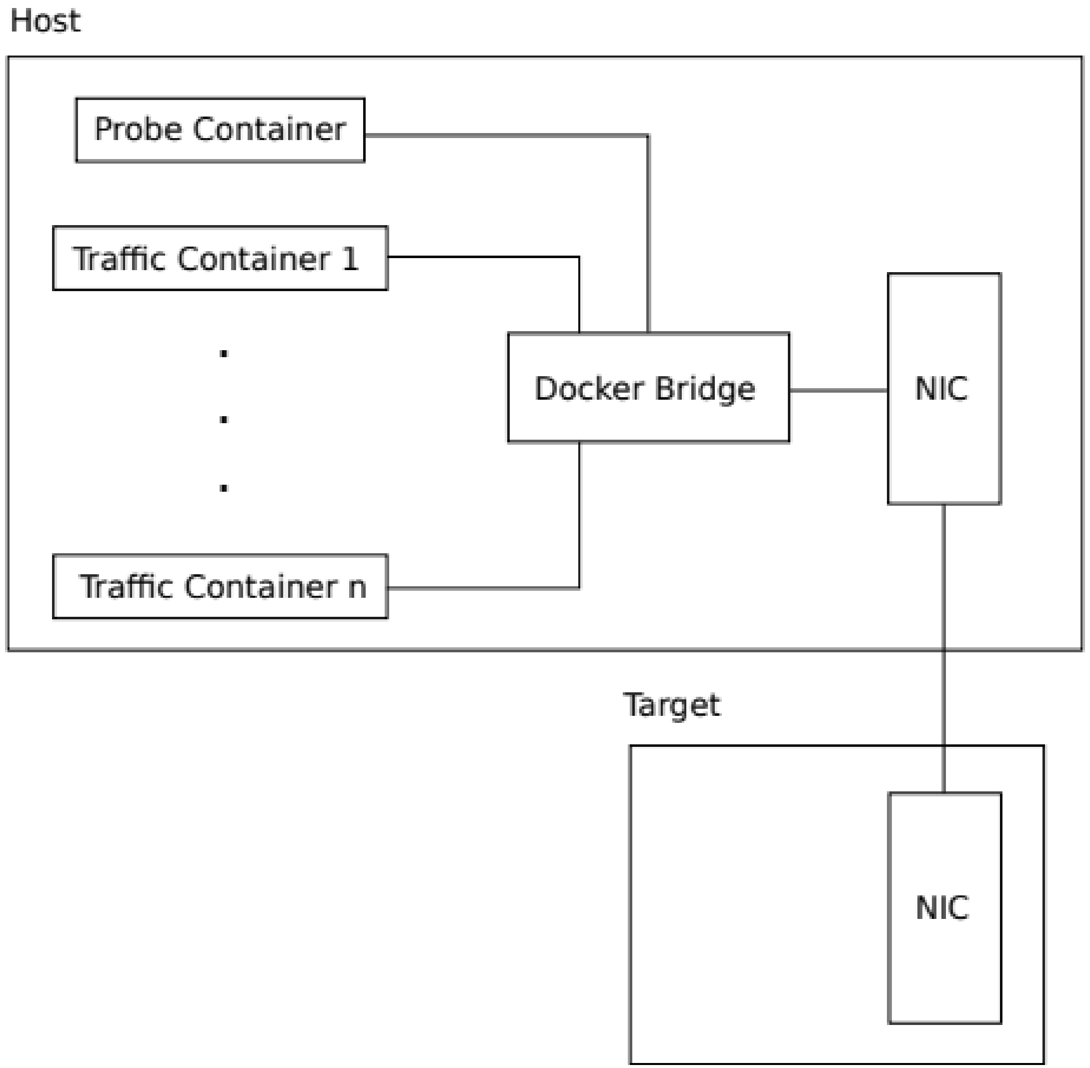


Evaluation: Setting



- Ping across single physical link
  - Minimize network latency

Evaluation: Setting



- Ping across single physical link
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- Add co-located containers
  - Flood ping
  - Worst-case traffic setting

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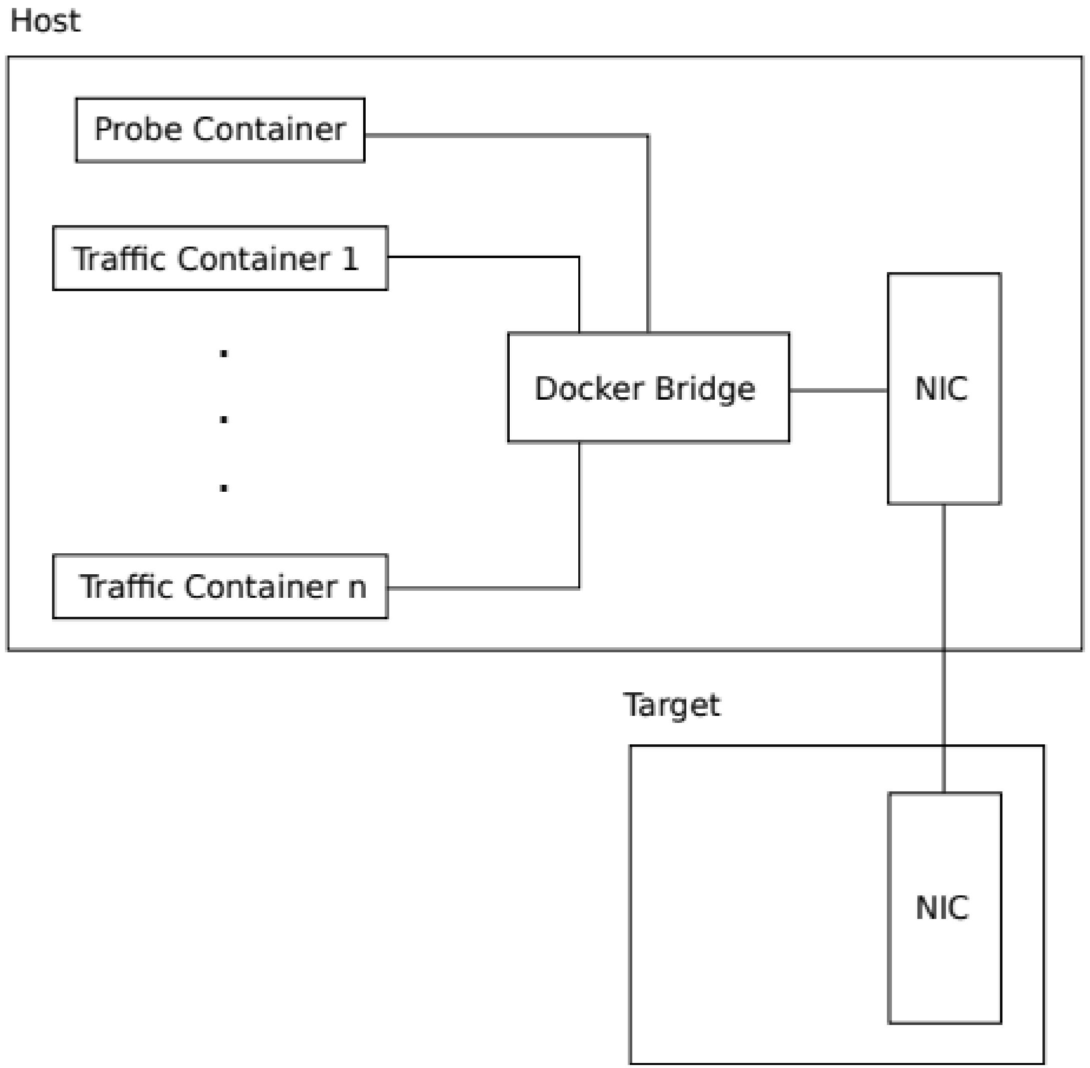
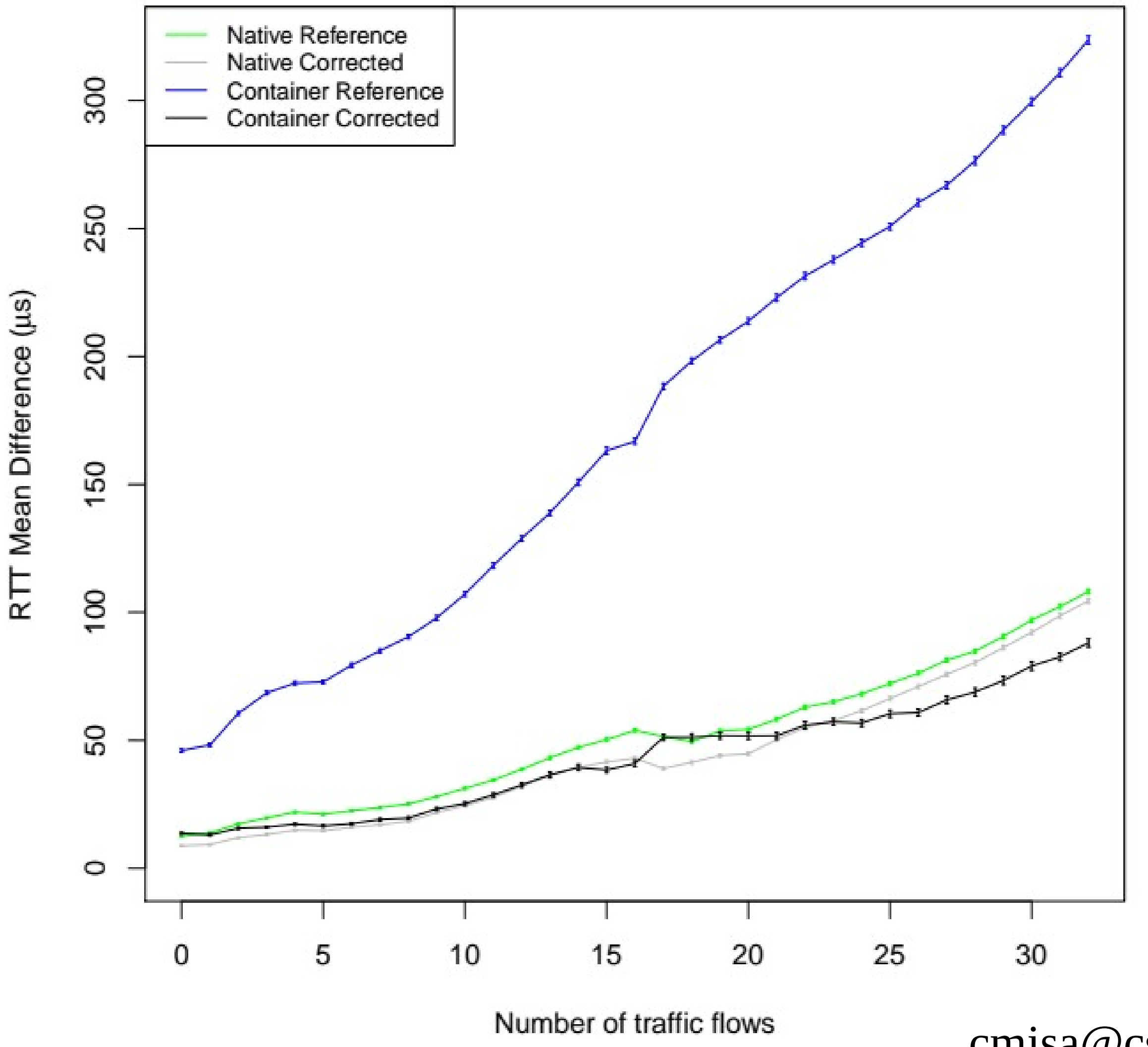


- Ping across single physical link
  - Minimize network latency
- Add co-located containers
  - Flood ping
  - Worst-case traffic setting
- Run on Cloudlab [10]
  - Some RTT noise from experiment network

Results: RTT Bias



- Reported RTT - actual RTT
  - ‘raw’ container (blue)
  - ‘corrected’ container (black)

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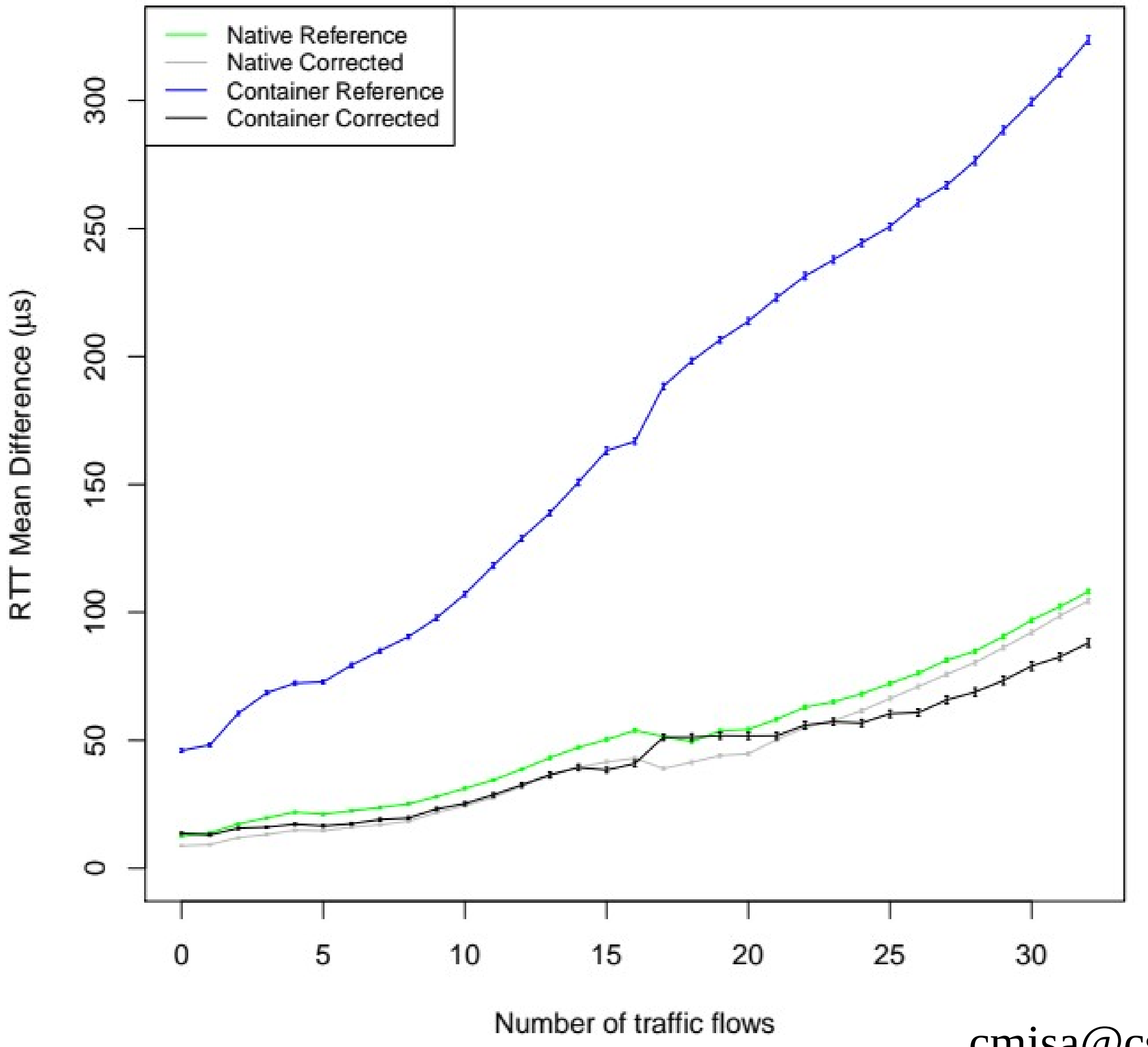

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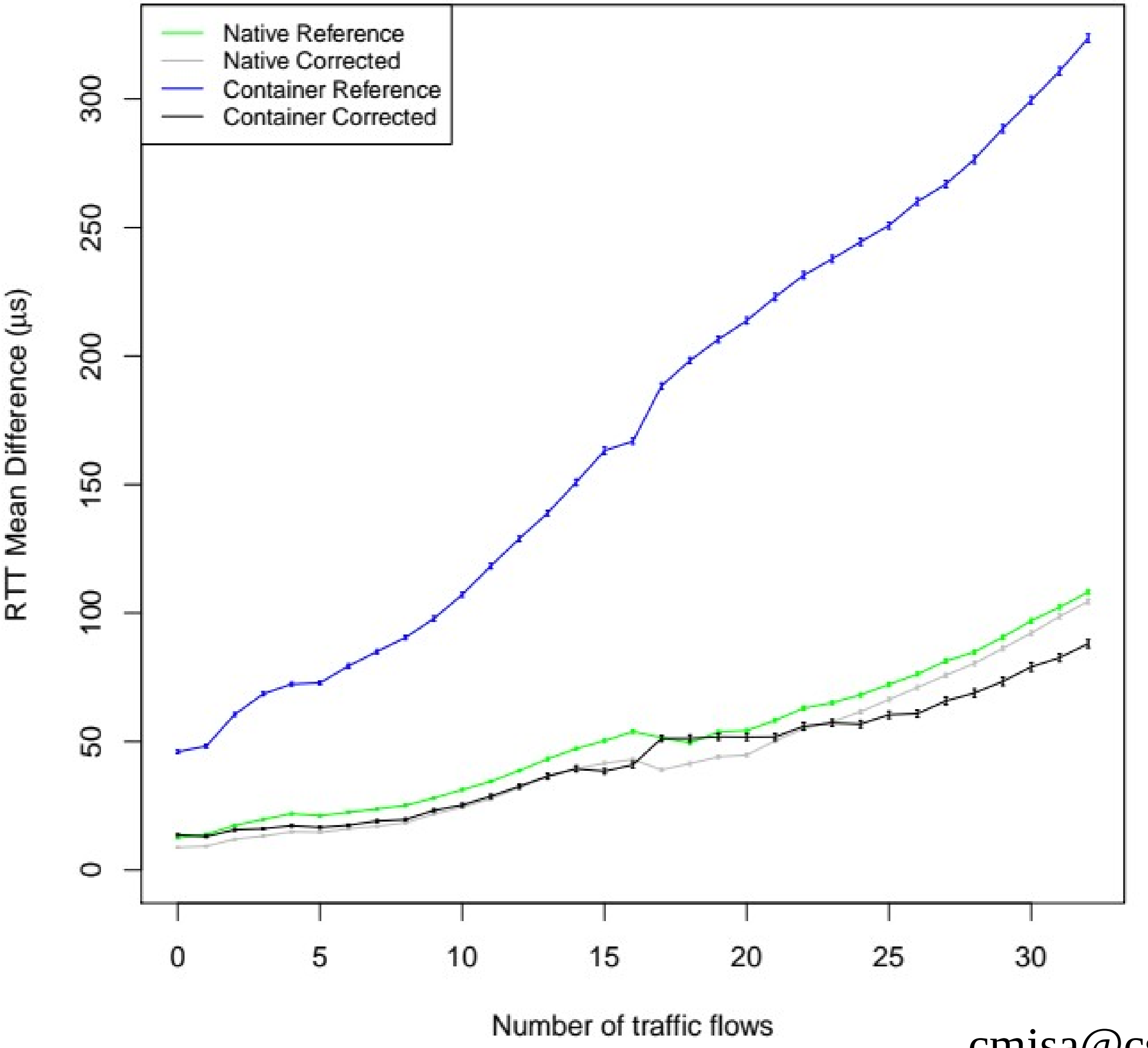

- Reported RTT - actual RTT
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- MACE-corrected RTT is **within 20µs** in worst case
- Traffic impacts all software RTTs
  - Up to **100 µs**

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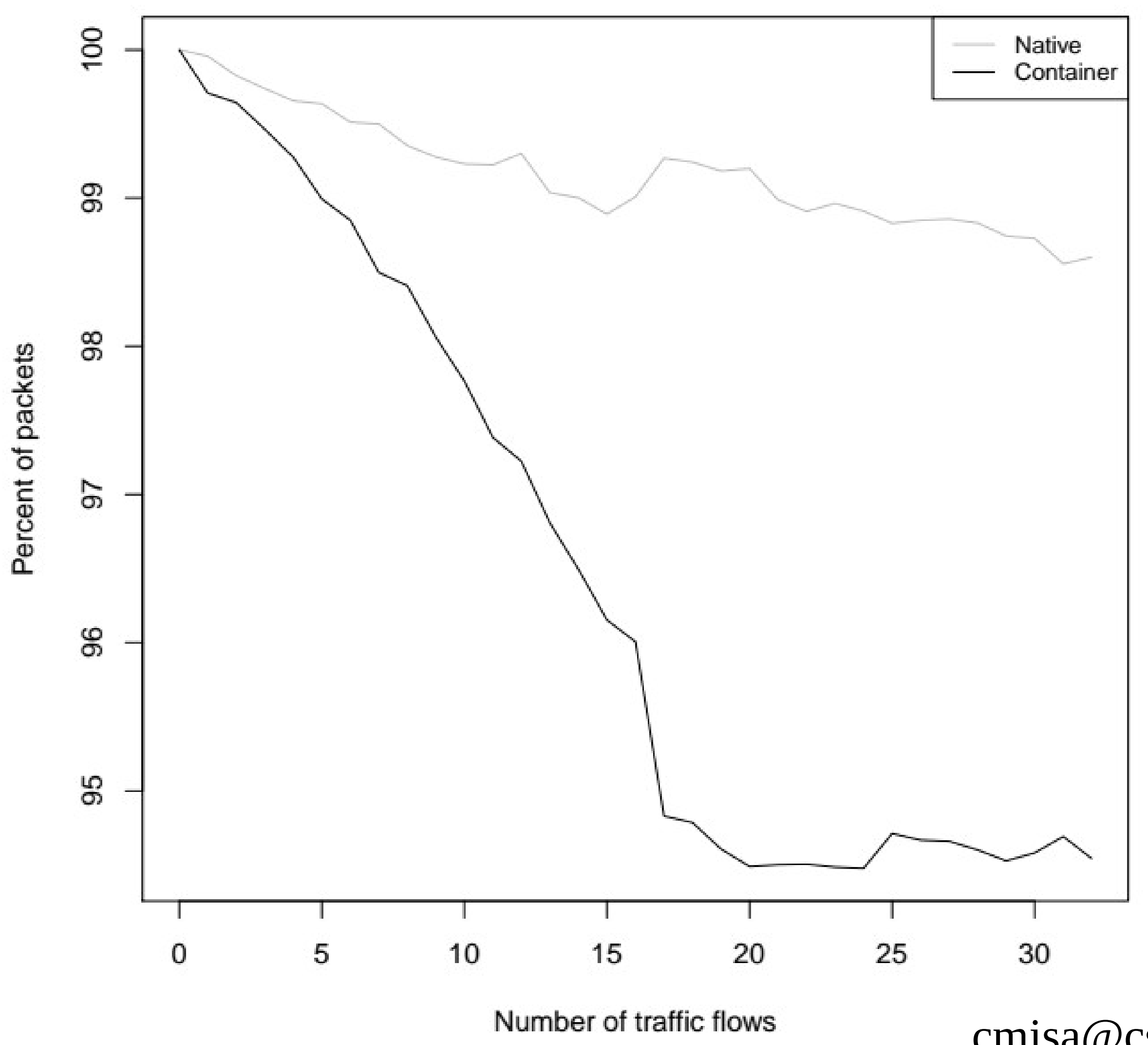
Results: Coverage



- Latency reports / packets (%)

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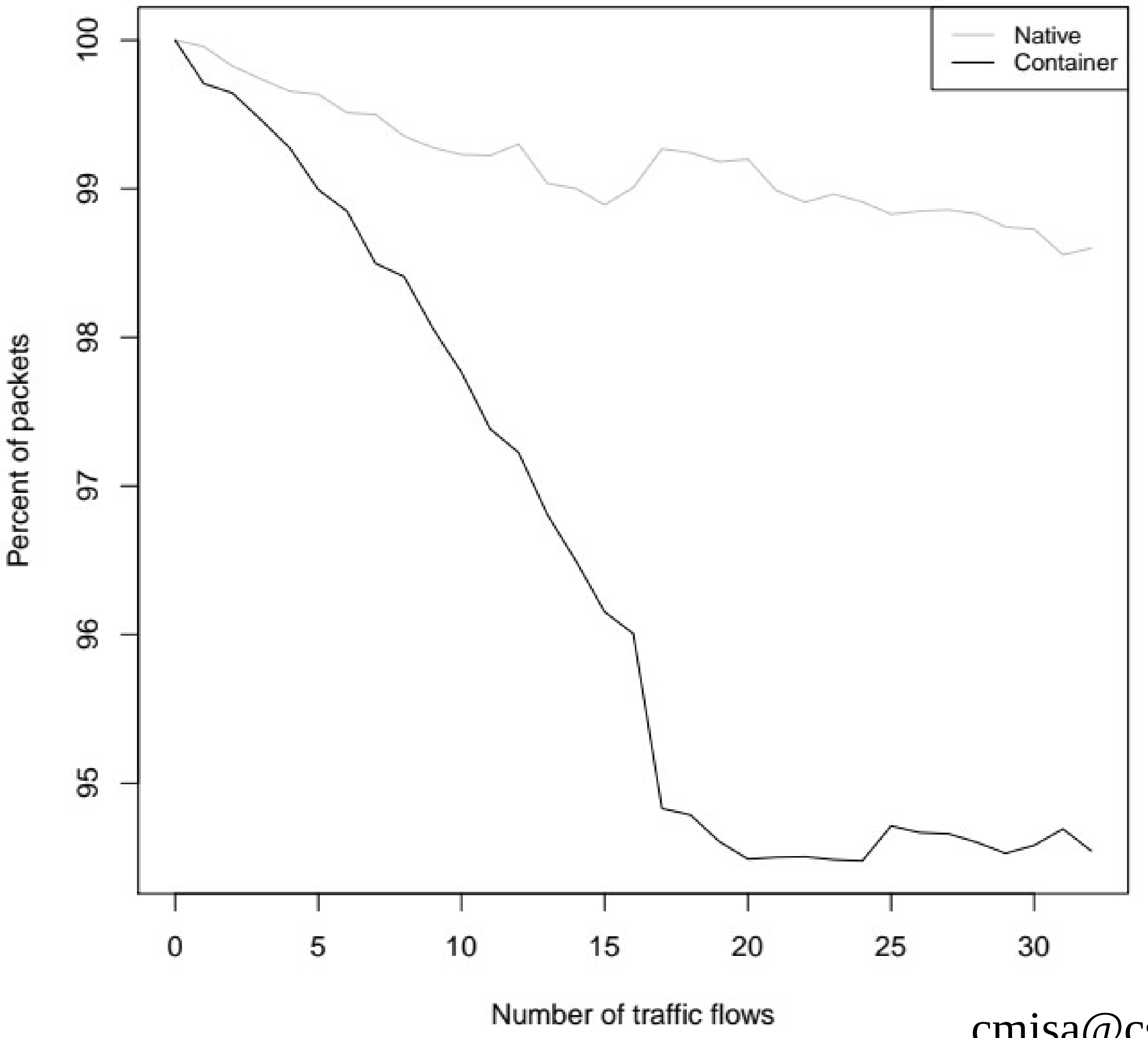
Results: Coverage



- Latency reports / packets (%)
- Decrease due to collisions in hash tables

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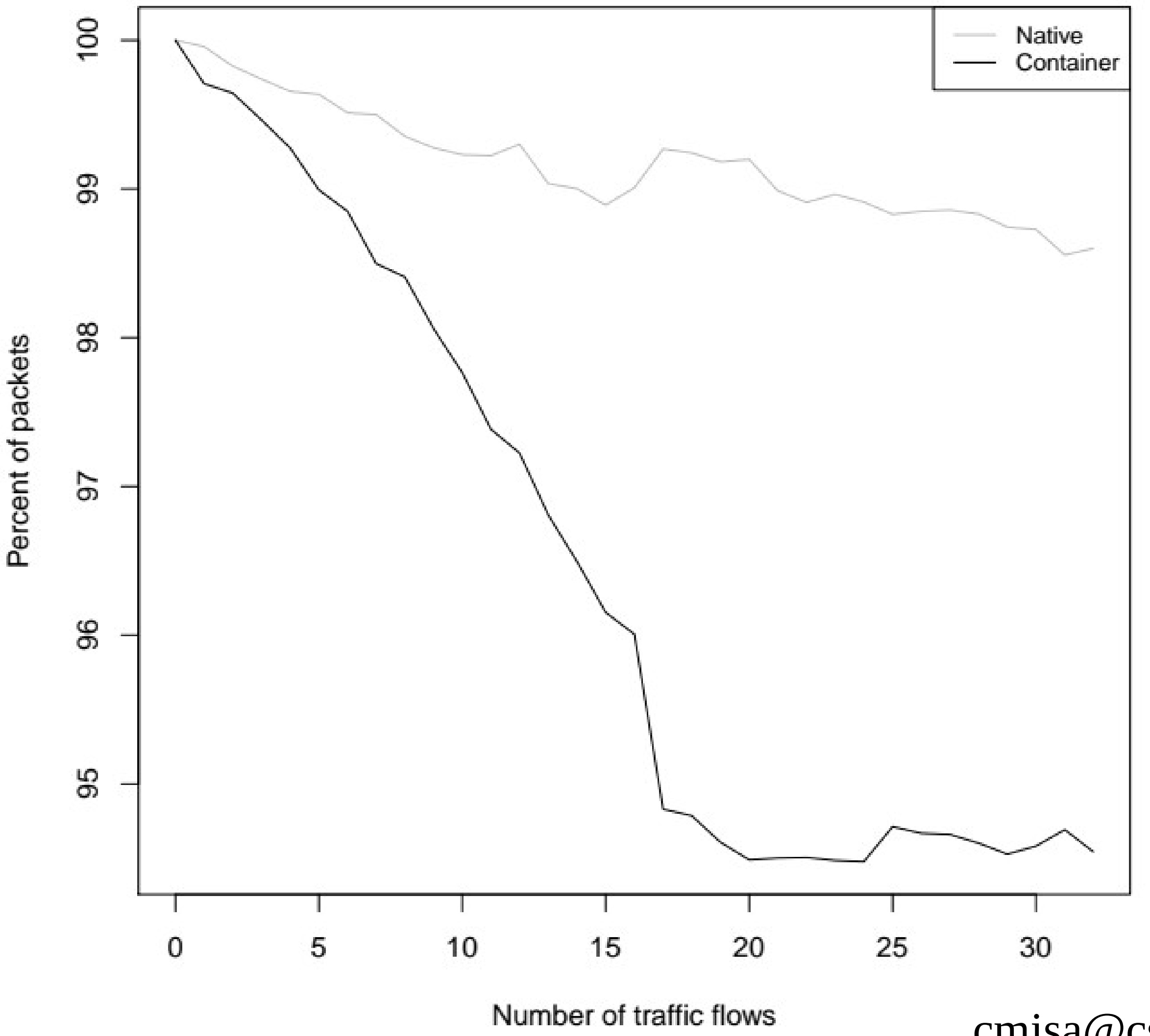

- Latency reports / packets (%)
- Decrease due to collisions in hash tables
- Increased table size can improve coverage to 100%

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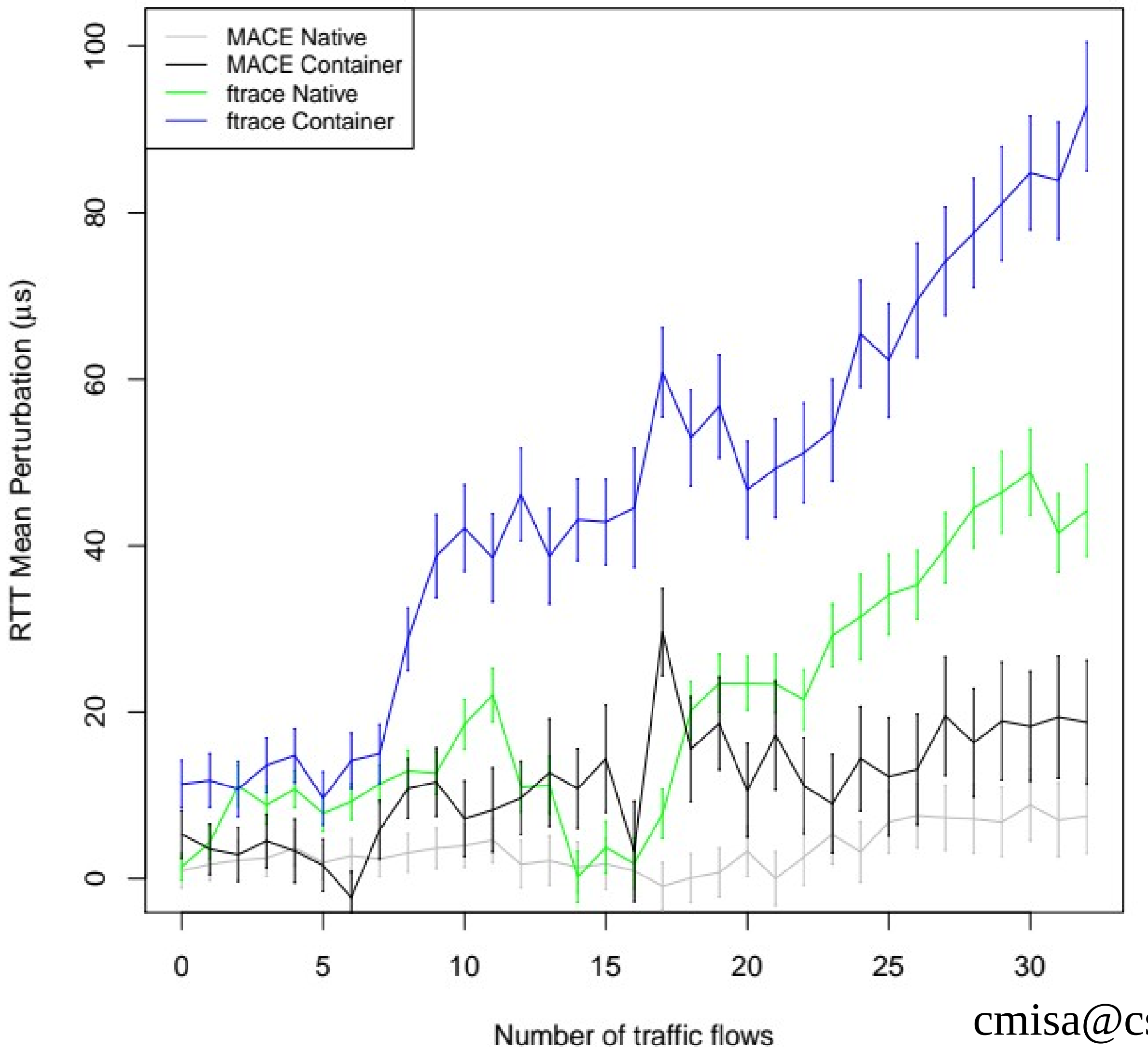
Results: Perturbation



- Instrumented RTT

  minus non-instrumented RTT

  – MACE (black)
  – Ftrace (blue)

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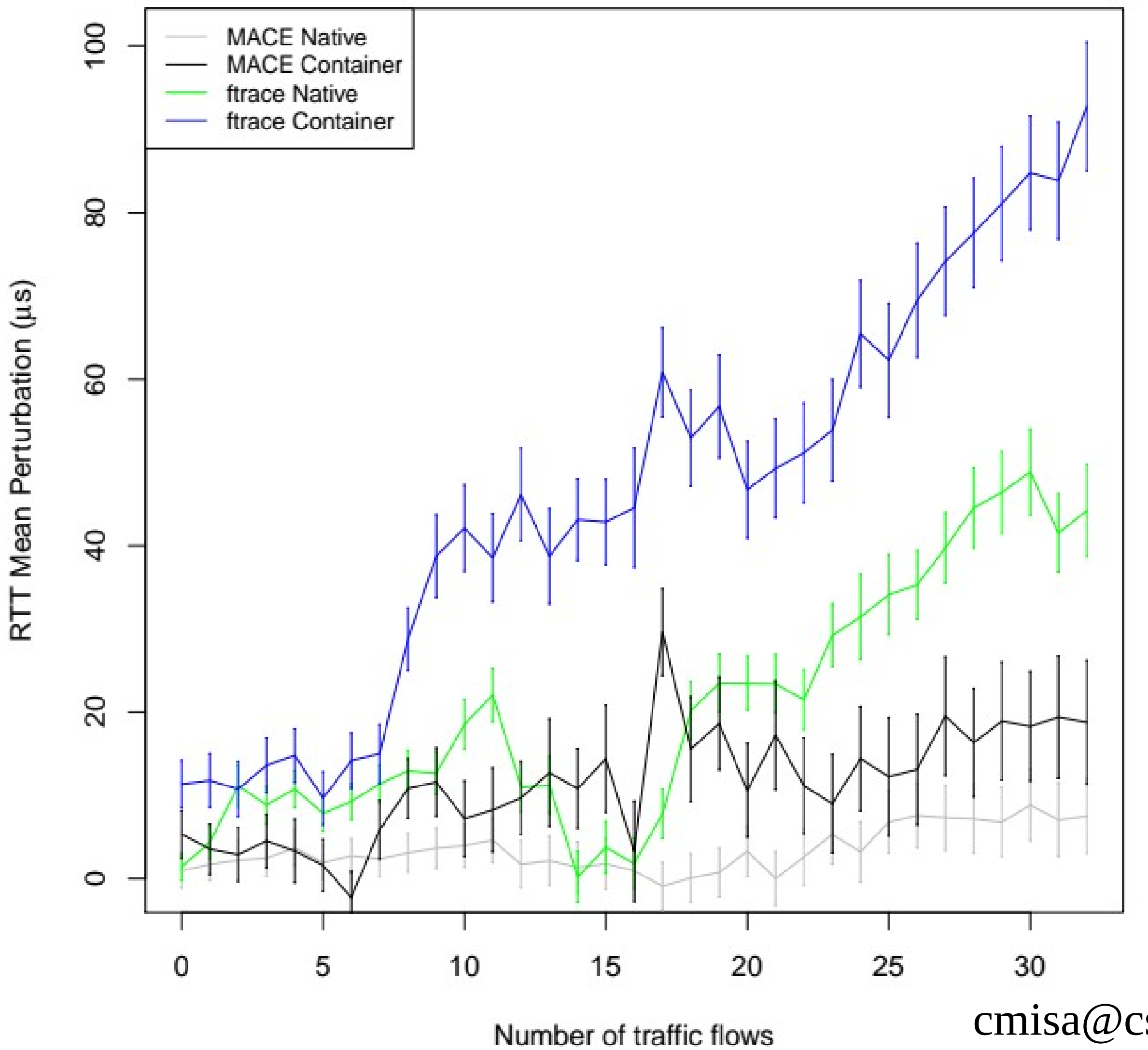
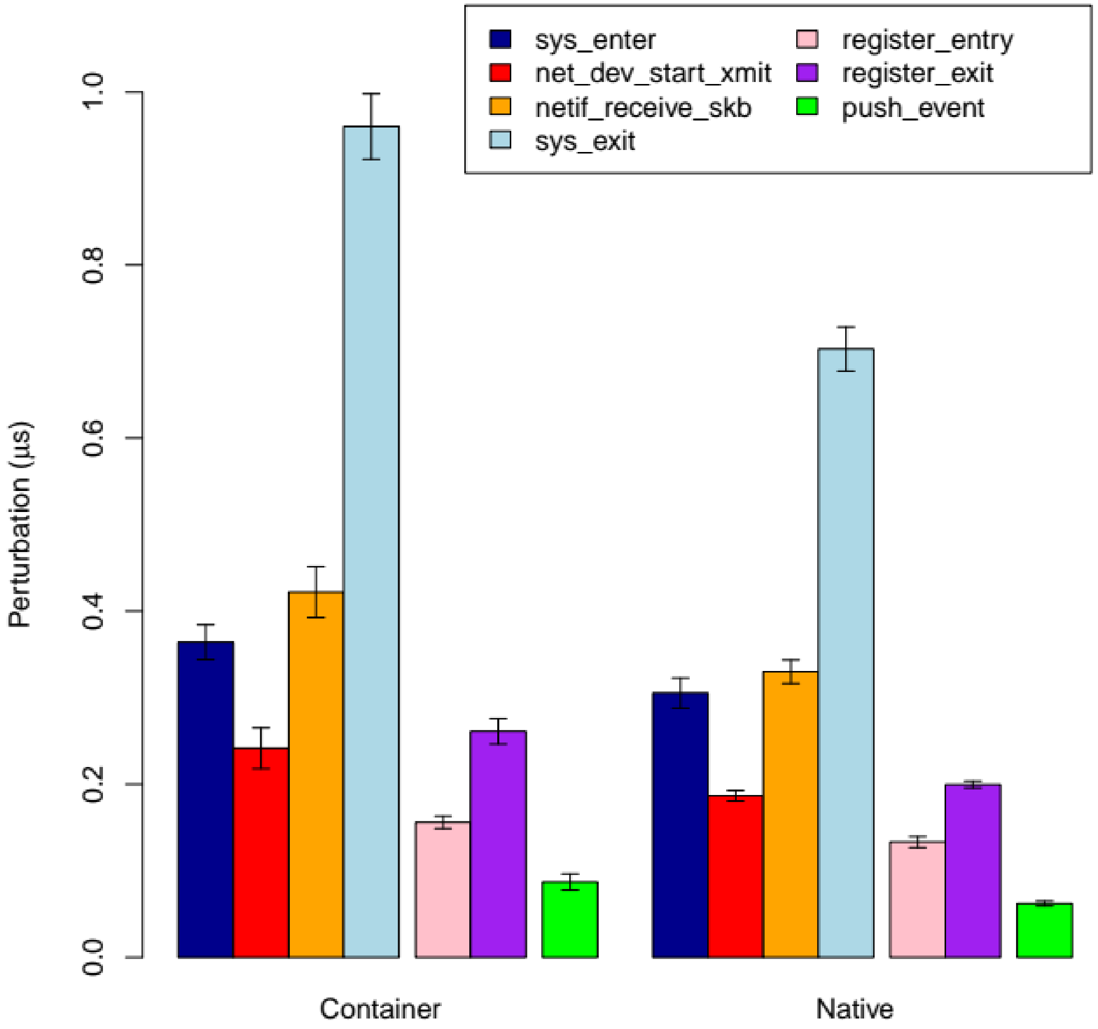


- Instrumented RTT

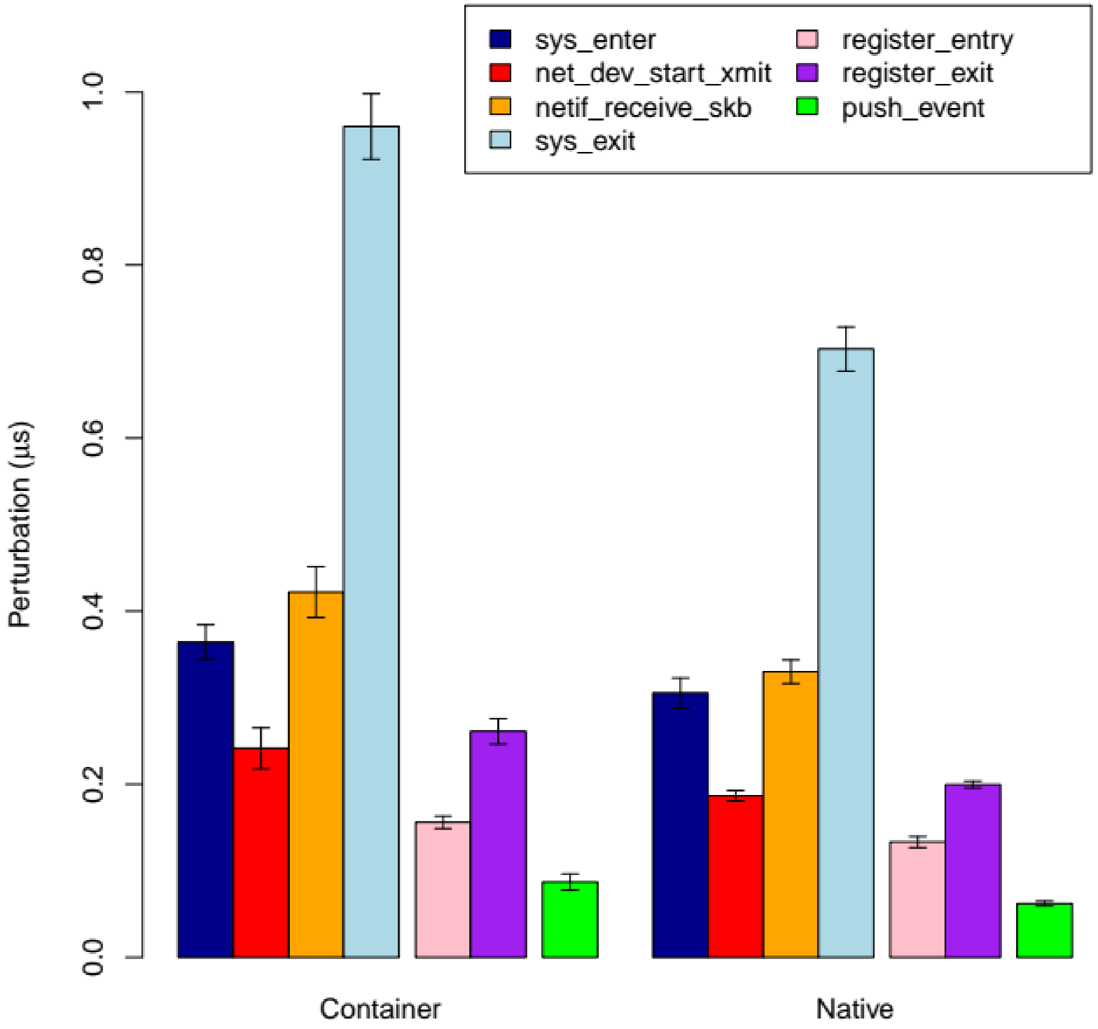
  minus non-instrumented RTT
  - MACE (black)
  - Ftrace (blue)
- MACE **scales well** as traffic increases

Results: MACE Functions



- Execution time of MACE functions
  - Tracepoint probes
  - Hash table management
  - Latency list management

Results: MACE Functions



- Execution time of MACE functions
  - Tracepoint probes
  - Hash table management
  - Latency list management
- System call tracepoints are slow
  - Accessing data in userspace
  - Needed for correlation

Future Goals

- Improving MACE
  - Add TCP, UDP support
  - Hardware timestamps
  - Better in-flight correlation
  - Ease of application-level correlation

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- Improving MACE
  - Add TCP, UDP support
  - Hardware timestamps
  - Better in-flight correlation
  - Ease of application-level correlation
- Applying MACE
  - Improving measurement accuracy (e.g. geolocation)
  - Virtual network telemetry

Summary

- Containerized measurement issues
- Proposed solution: MACE
- Evaluation of MACE

Thank You!

- UO VPRI* and NSF
- Anonymous reviewers
- CloudLab team

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Questions?

Citations

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