Parallelizing Packet Processing in Container Overlay Networks

(EuroSys '21)

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Containers are taking over the cloud

- Lightweight
- OS level virtualization
- **Higher** application density
- **Better** resource utilization

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Based on report, Google launches over **7k+** containers **per sec** for its searching service.

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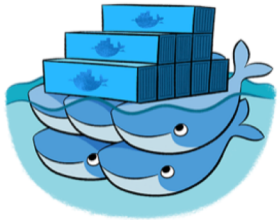
- **Overlay networks** provide connectivity
- Typical solutions: Docker Overlay, Flannel, Calico, Weave…
- Generally build upon tunneling approach like **VxLAN** protocol



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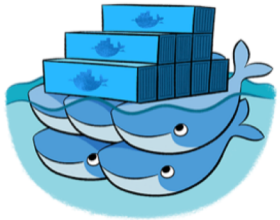

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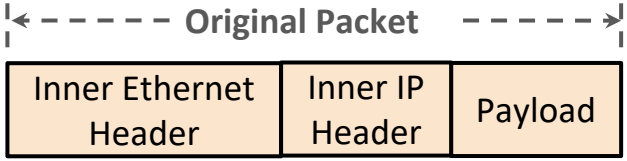

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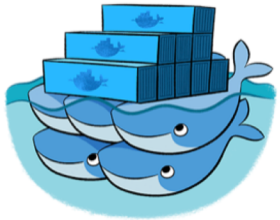

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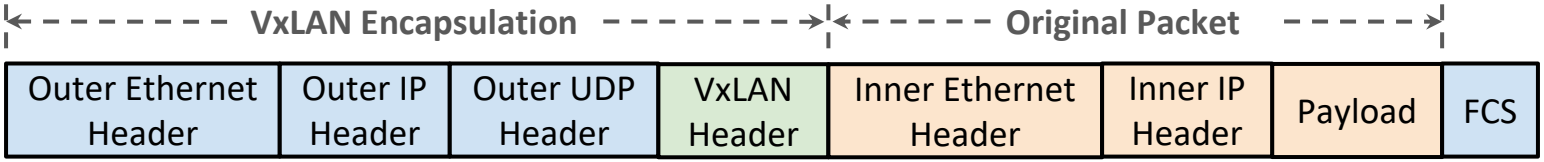

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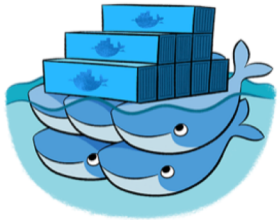

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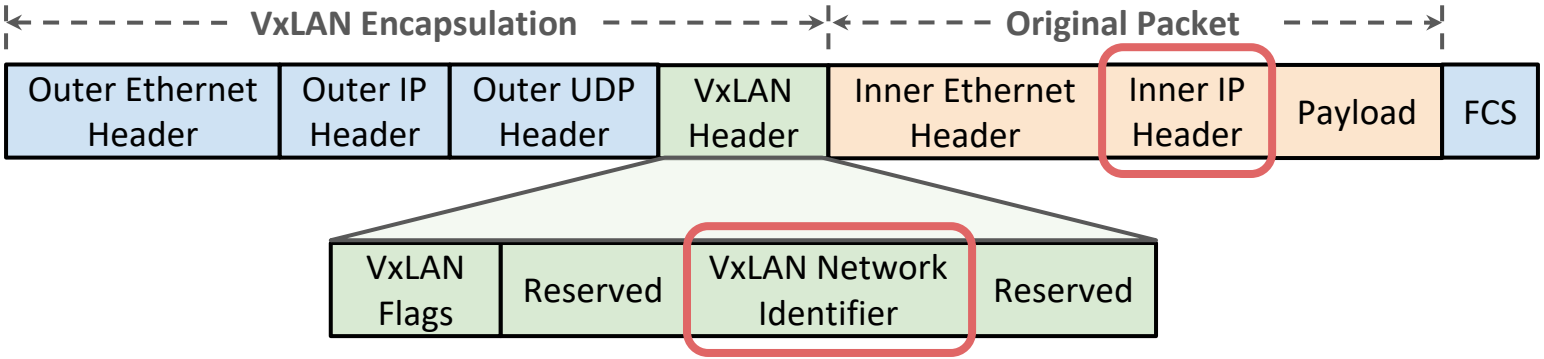

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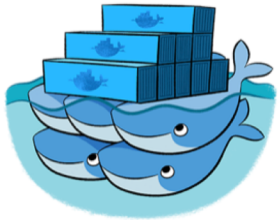

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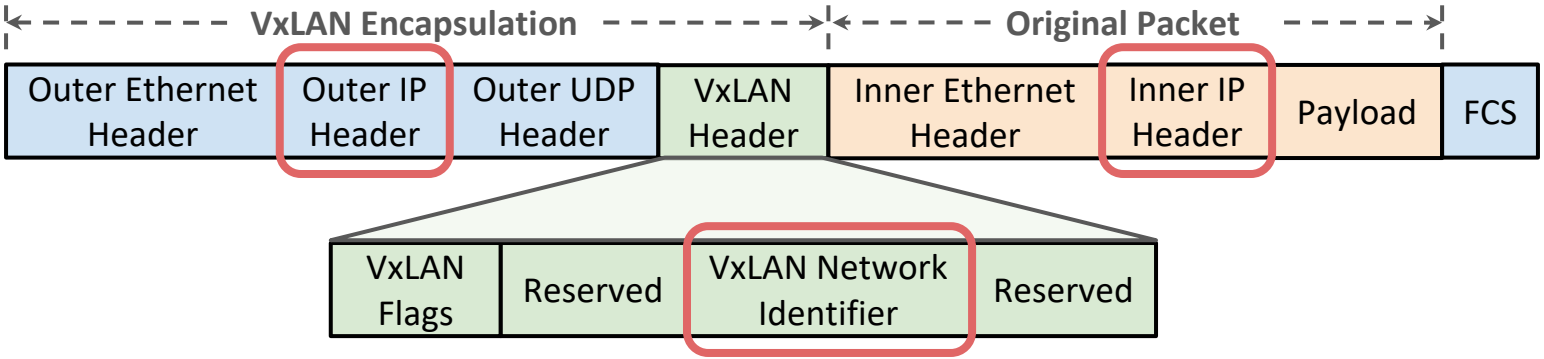
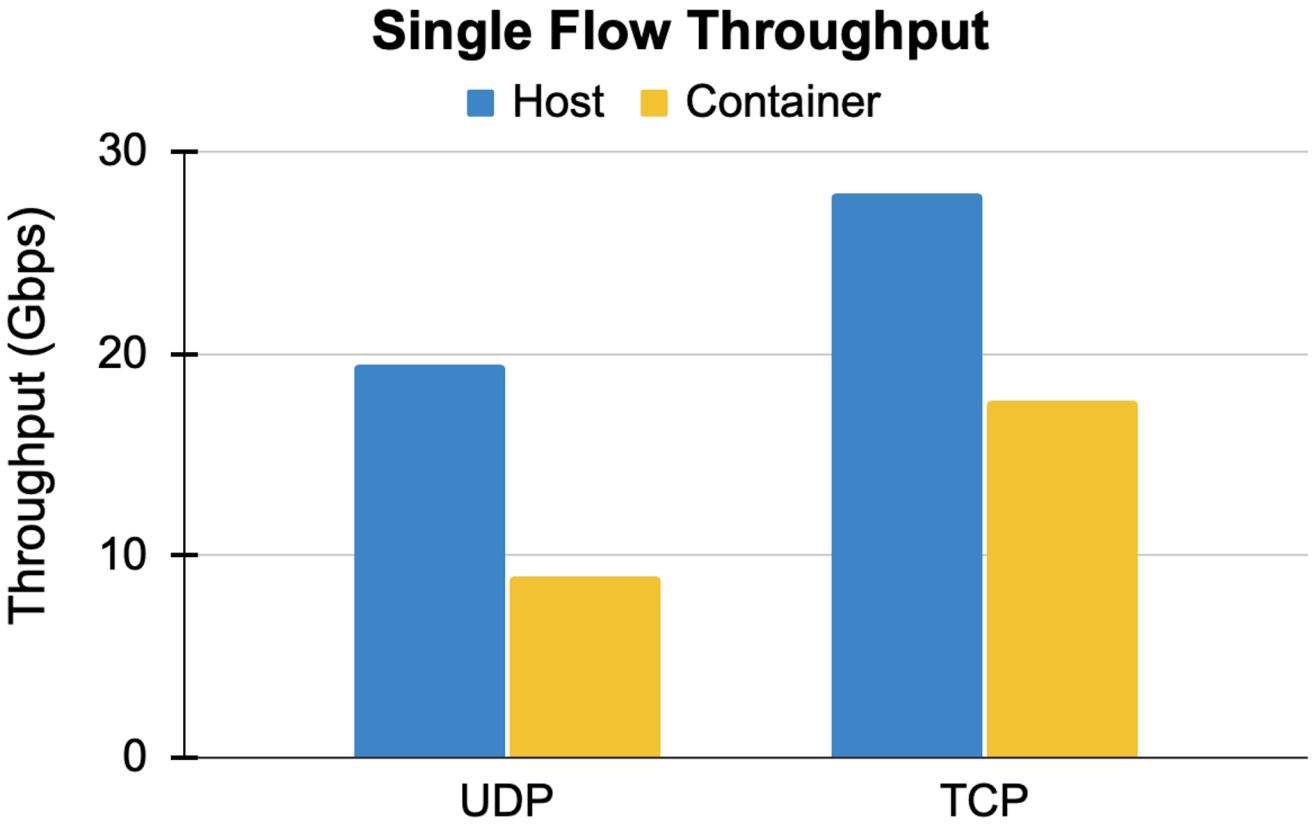


Performance overhead of overlay networks

- Machines are connected via 100 GbE NIC.



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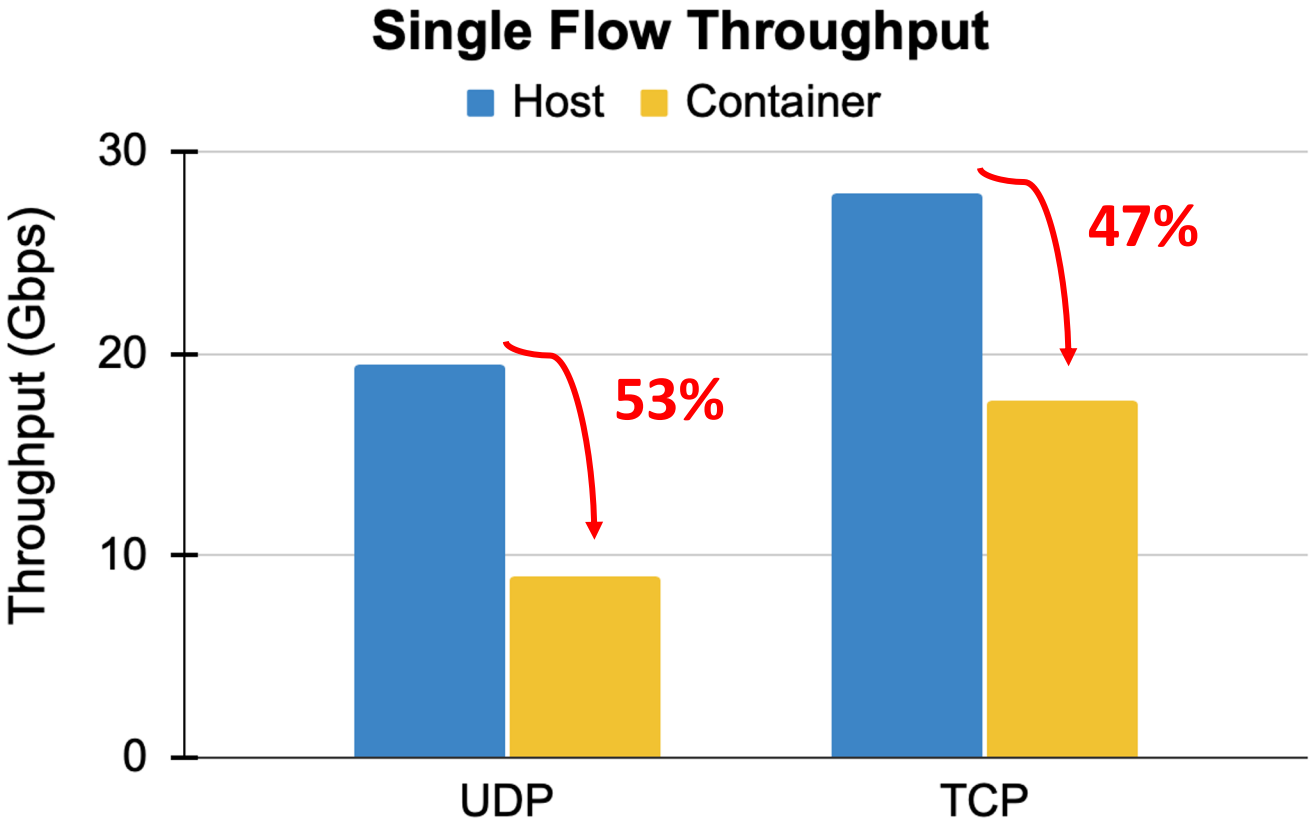

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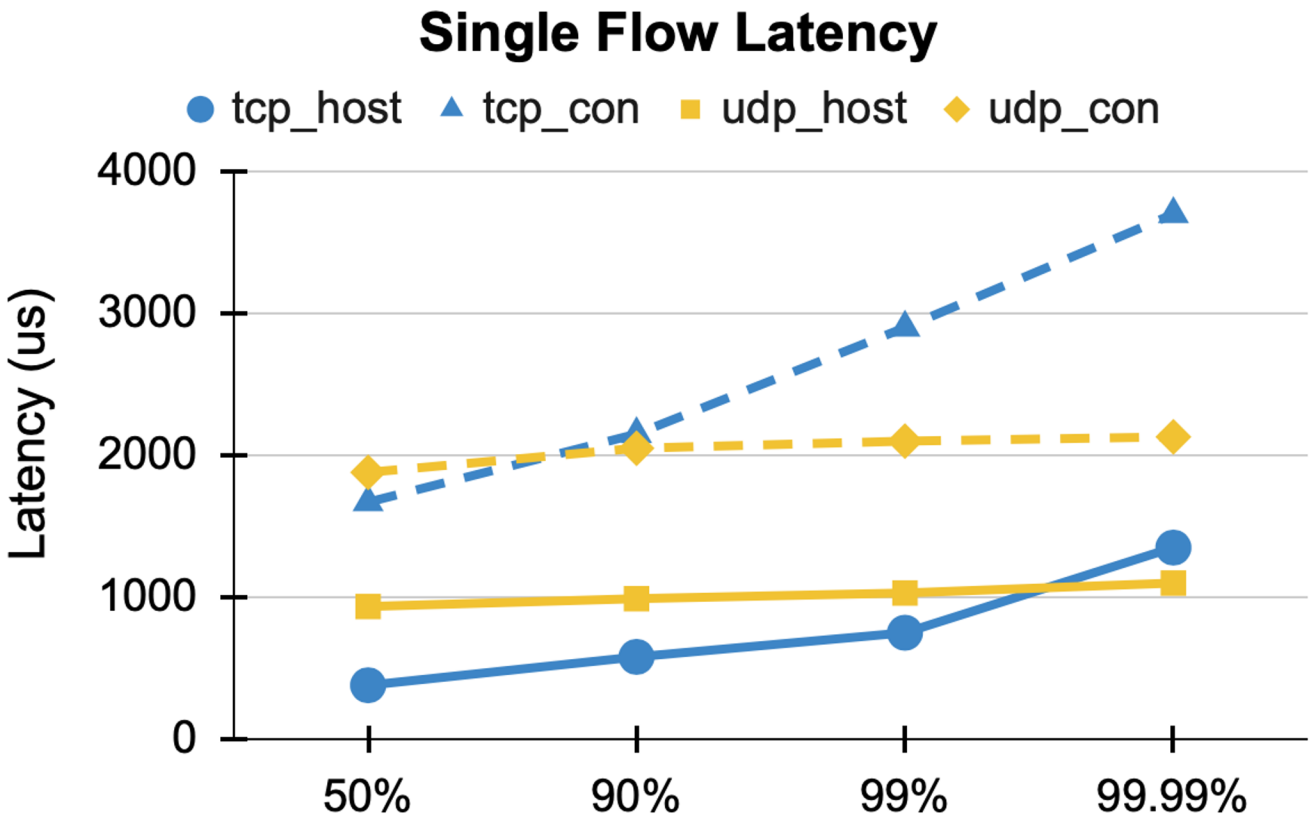

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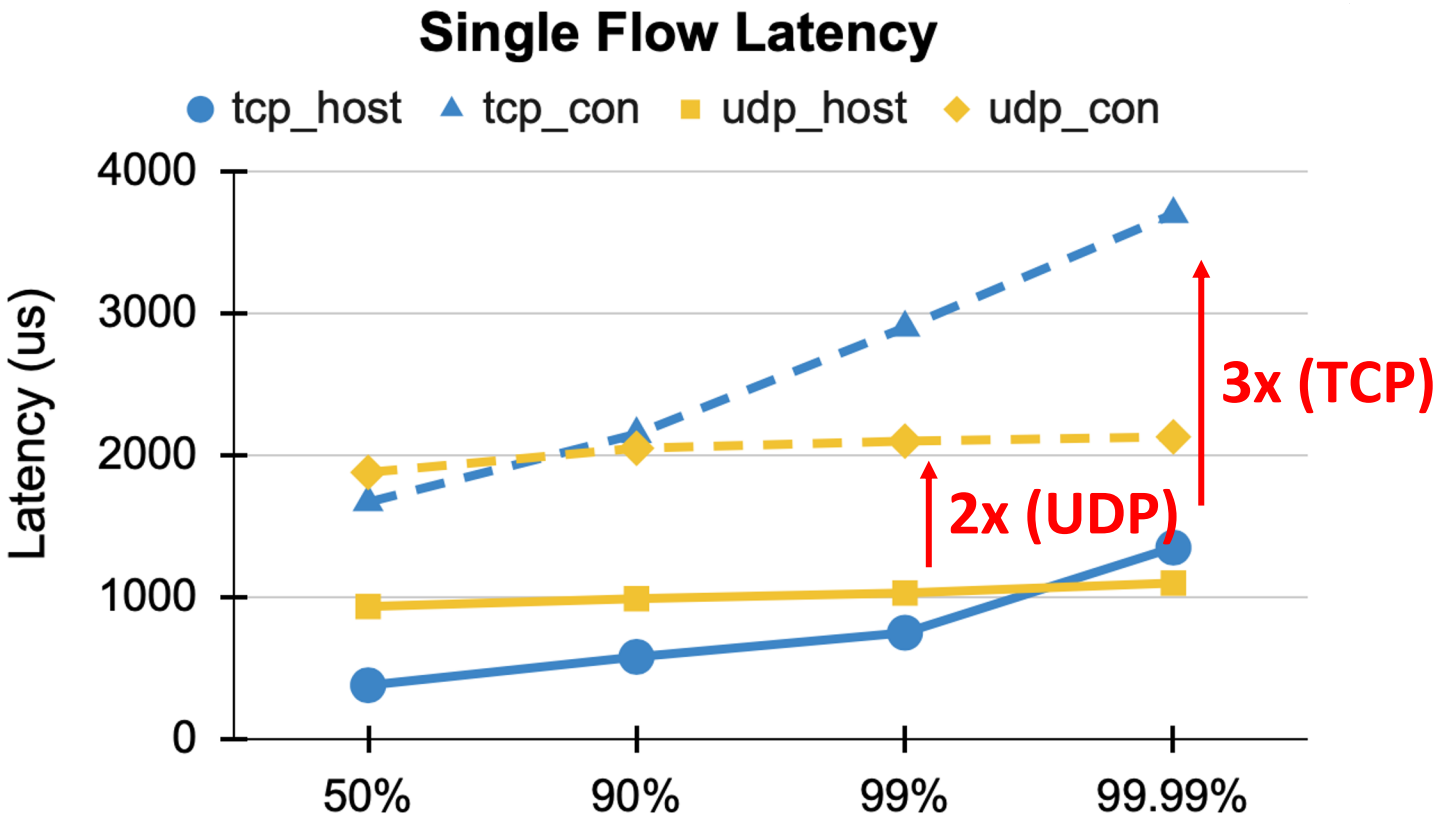

Why is overlay network slow?

L 7

L 3&4

L 2

Hardware

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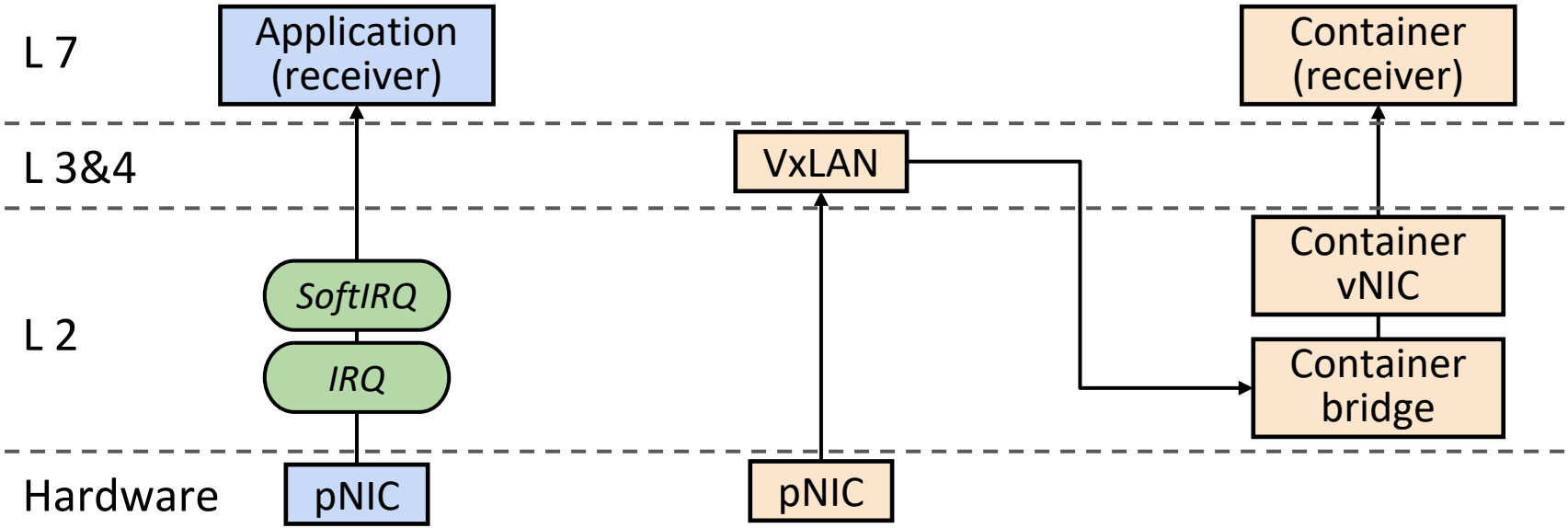

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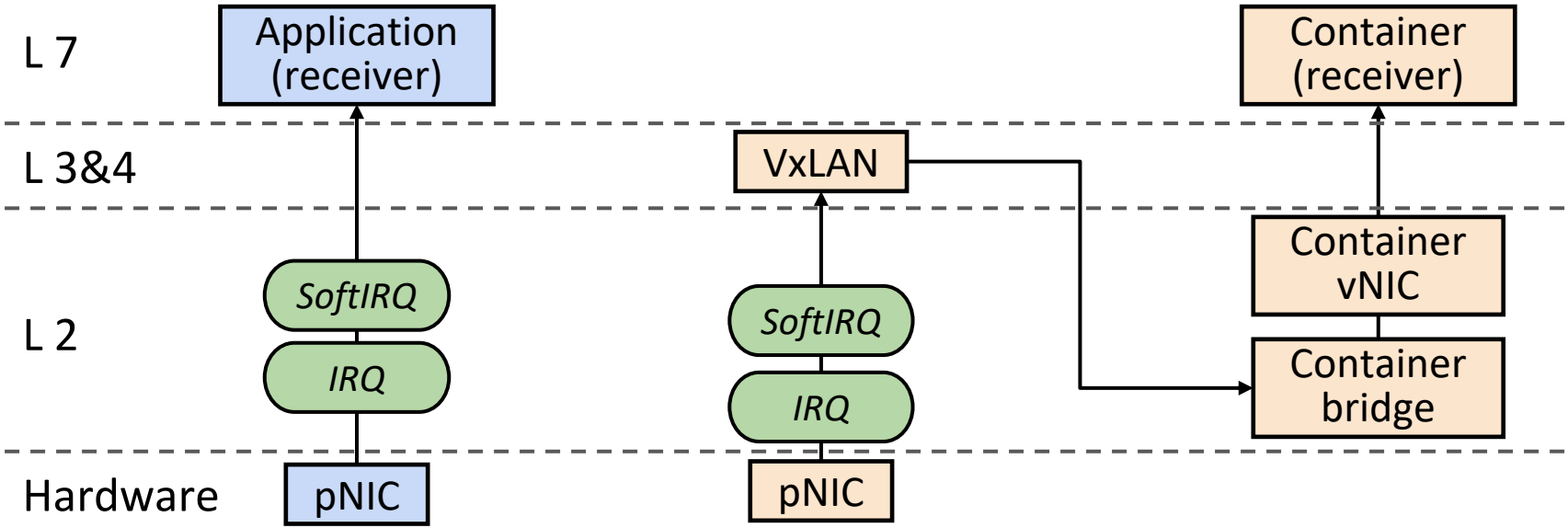

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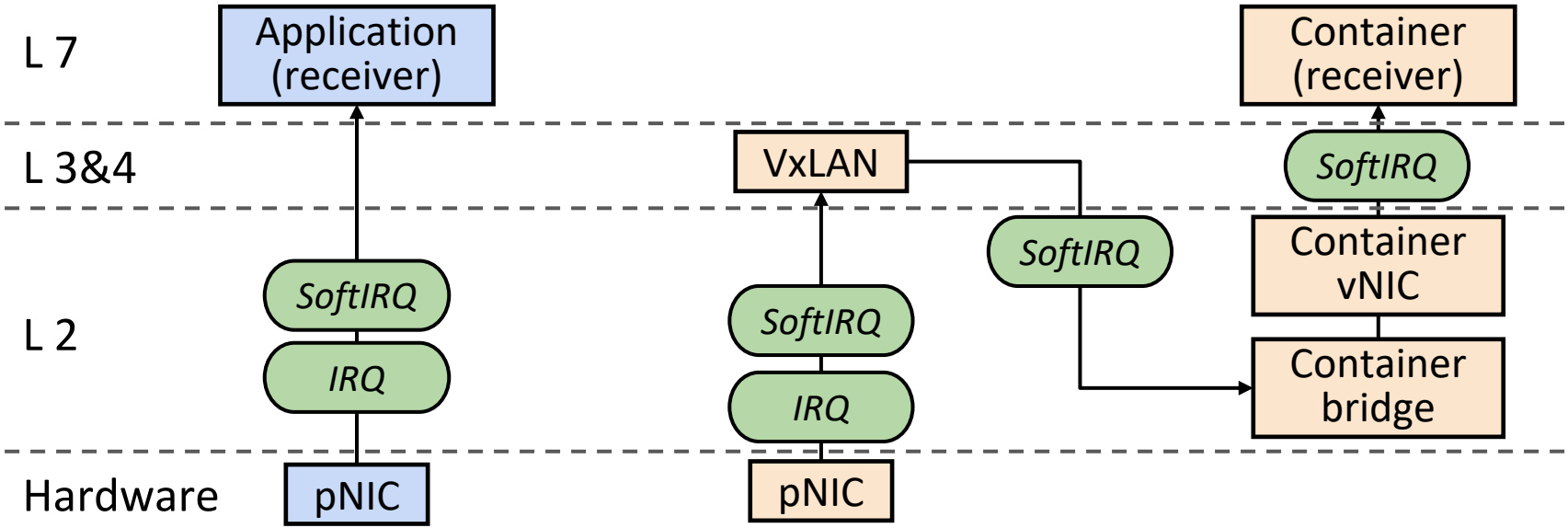

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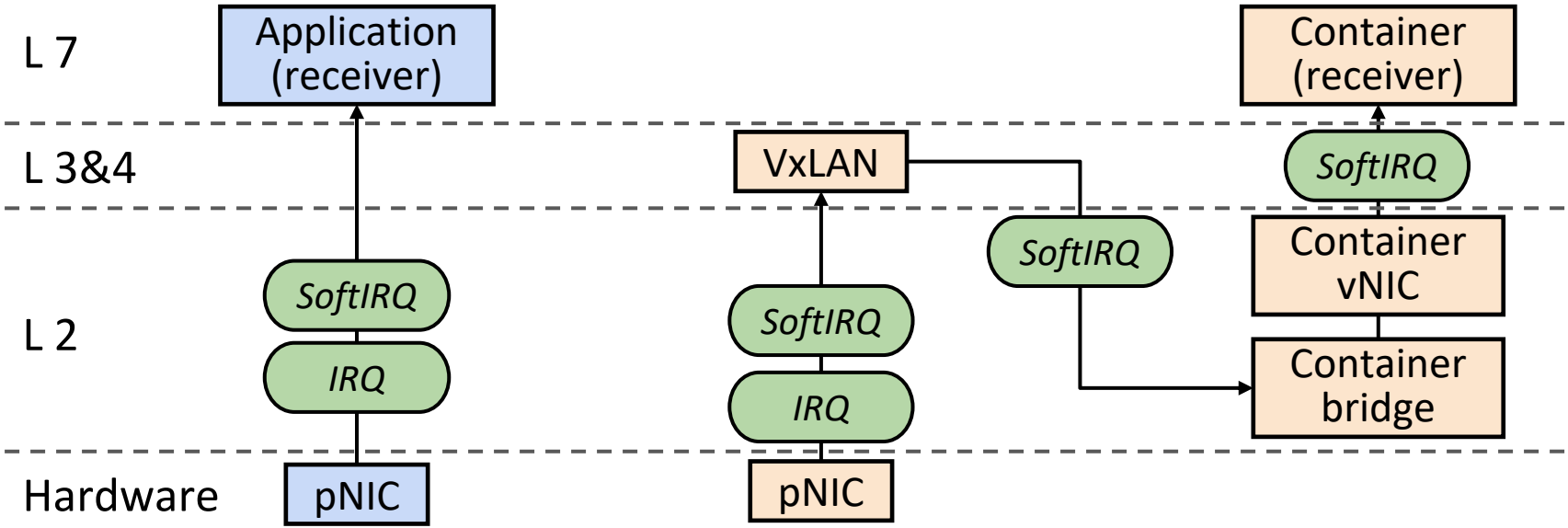

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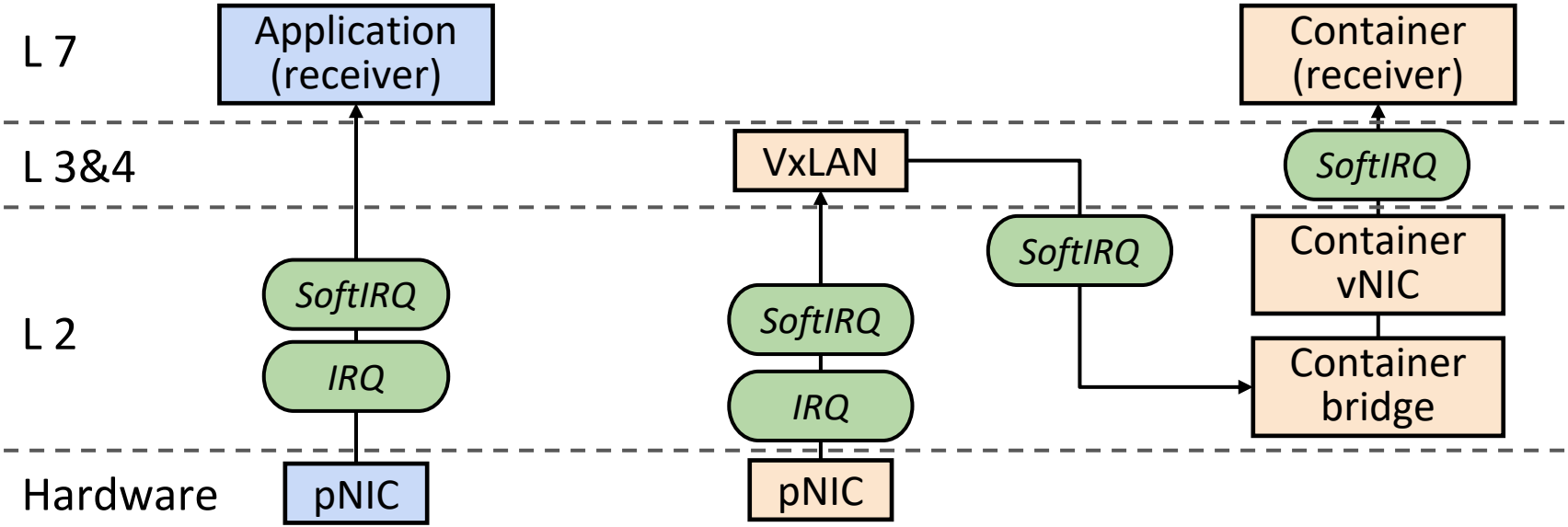
- **Overhead**
  - **Additional** devices
  - **Prolonged** path
  - **Excessive and serialized** softIRQs



Existing solutions to accelerate overlay networks

- Kernel bypass (DPDK+mTCP)
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  - ✗ Limited scalability; only for TCP; doesn't support data-plane policies
- Hardware offload (Mellanox ASAP², AccelNet)
  - ✓ Fastest, completely avoids CPU overheads
  - ✗ Requires new/expensive hardware; SR-IOV limitations; limited isolation/flexibility/scalability

Our solution - FALCON

FALCON = **F**ast and B**al**anced **Co**ntainer **N**etworking

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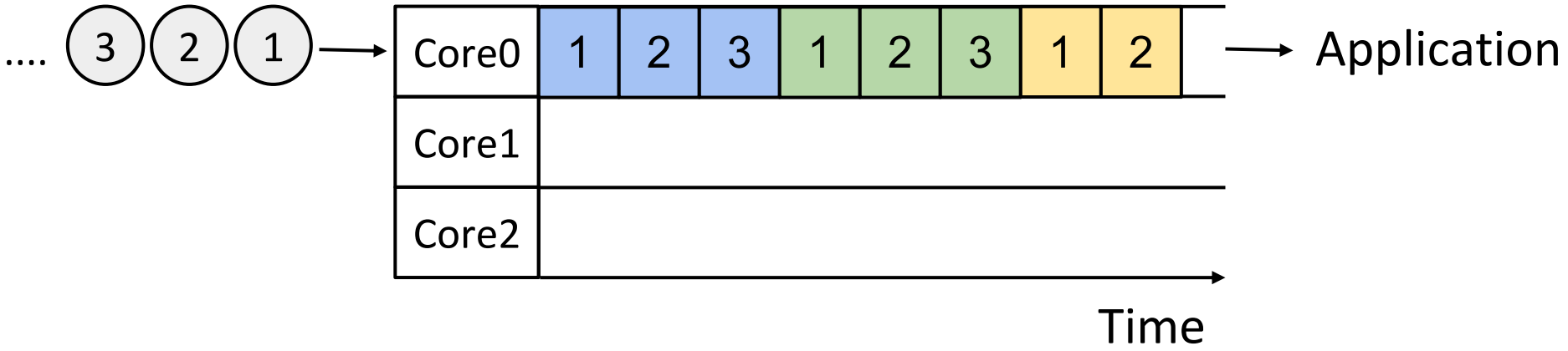
Key idea: Utilize idle CPU resources to accelerate packet processing

- ✅ Software-based solution
- ✅ Full network isolation / flexibility
- ✅ Completely backward compatible
  Immediately deployable in real systems
- ✅ Better performance

FALCON - SoftIRQs Pipelining

- **Blue** - 1st SoftIRQ ; **Green** - 2nd SoftIRQ; **Yellow** - 3rd SoftIRQ



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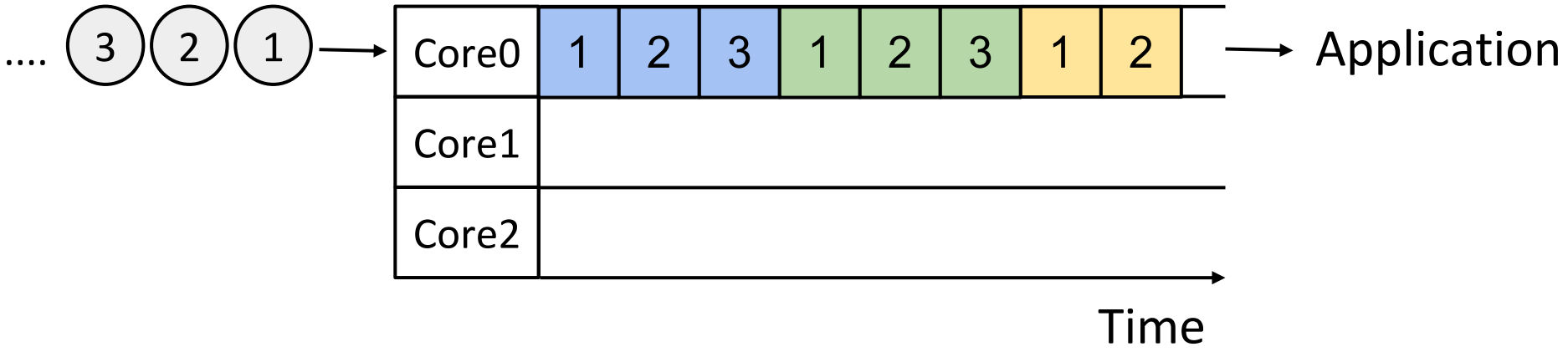

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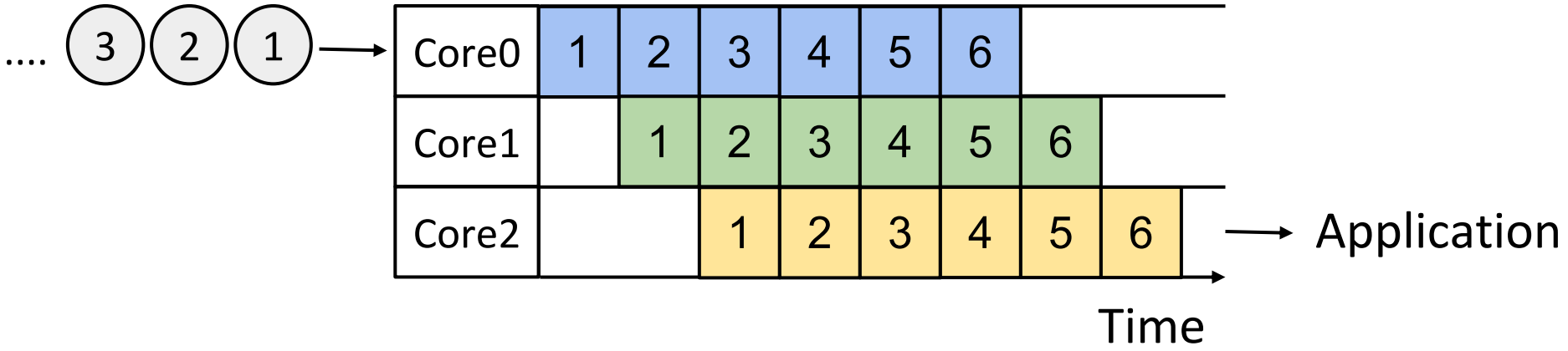

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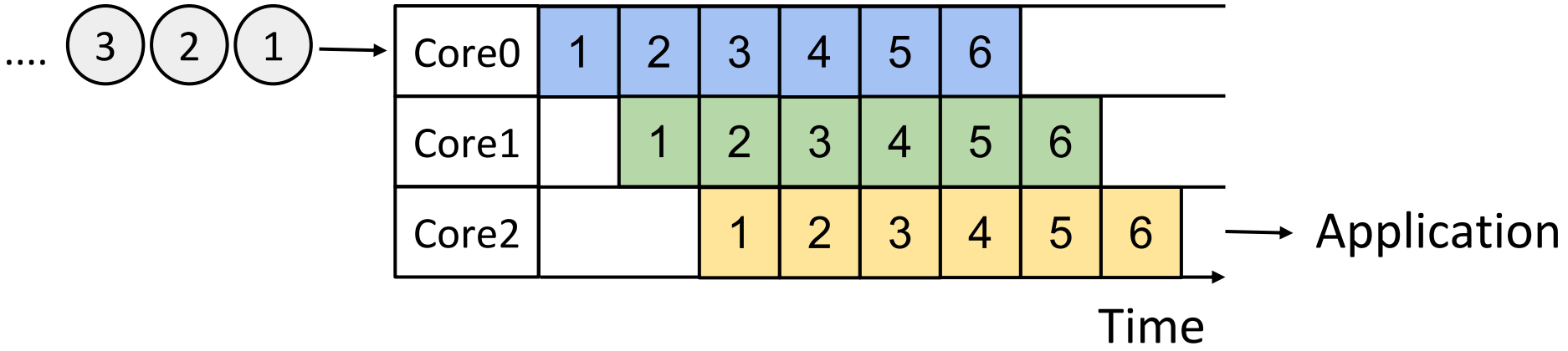

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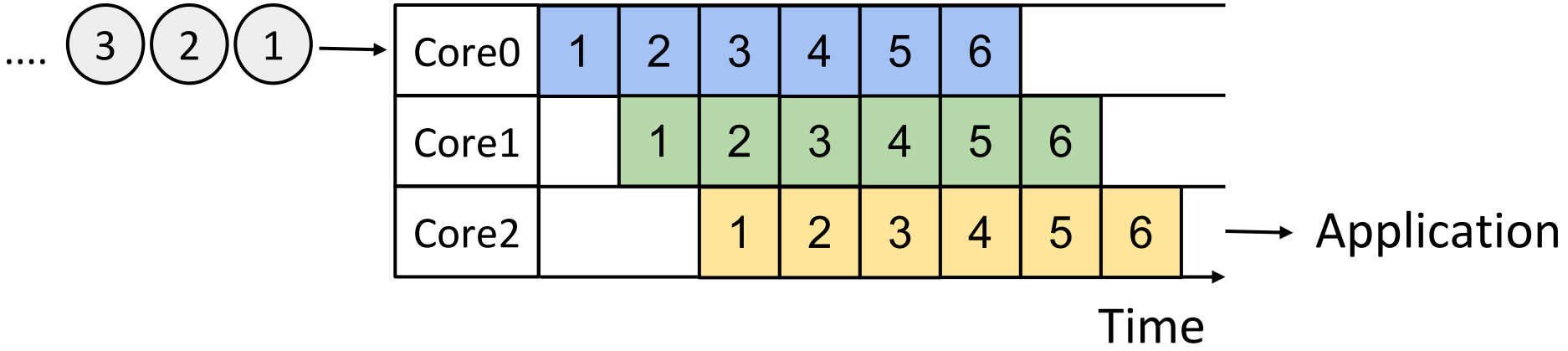
- Maintain In-order



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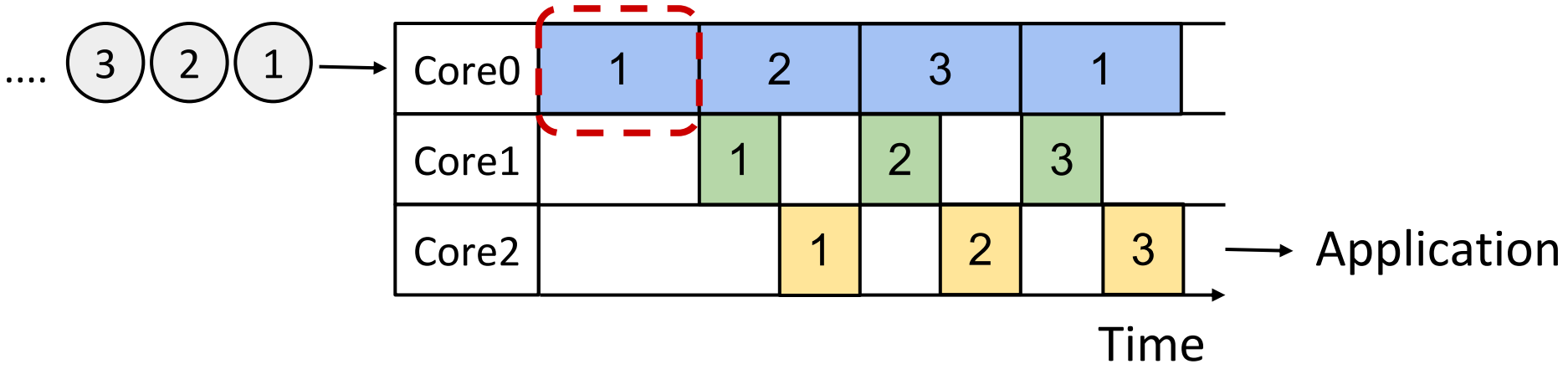

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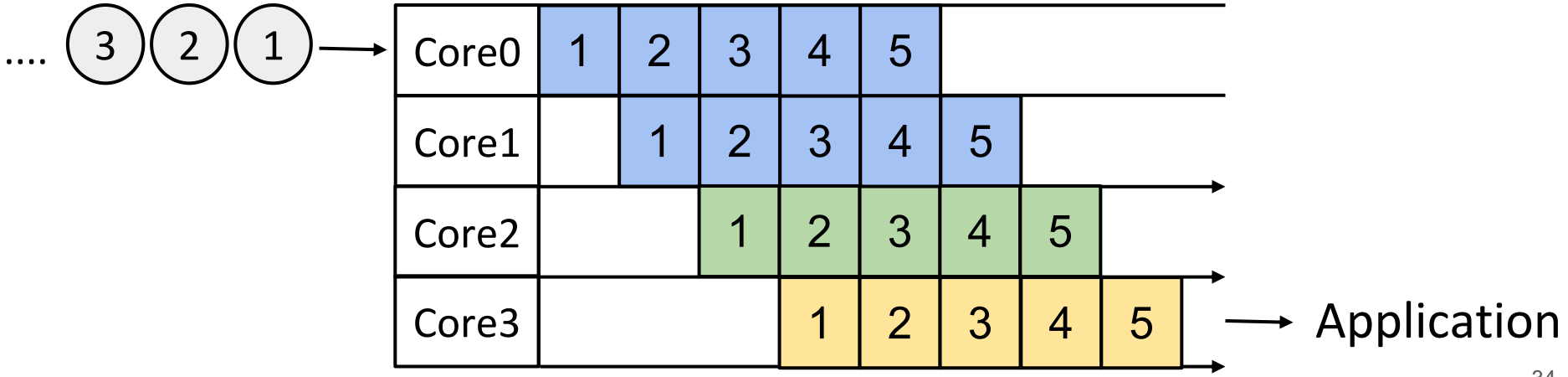

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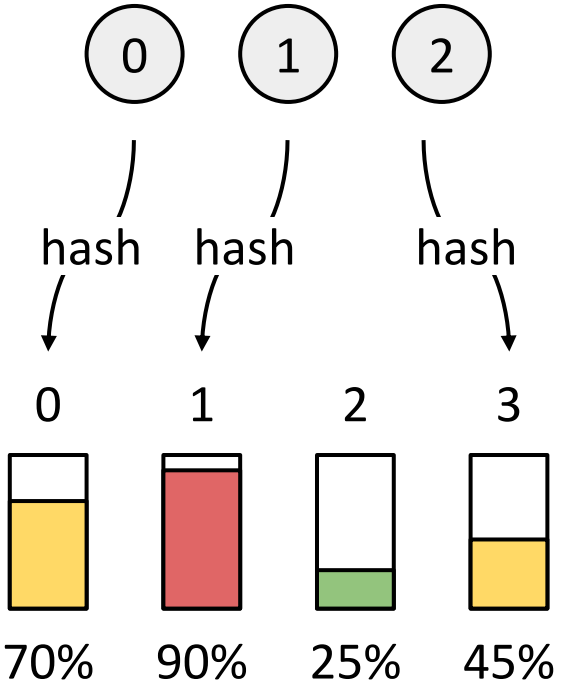

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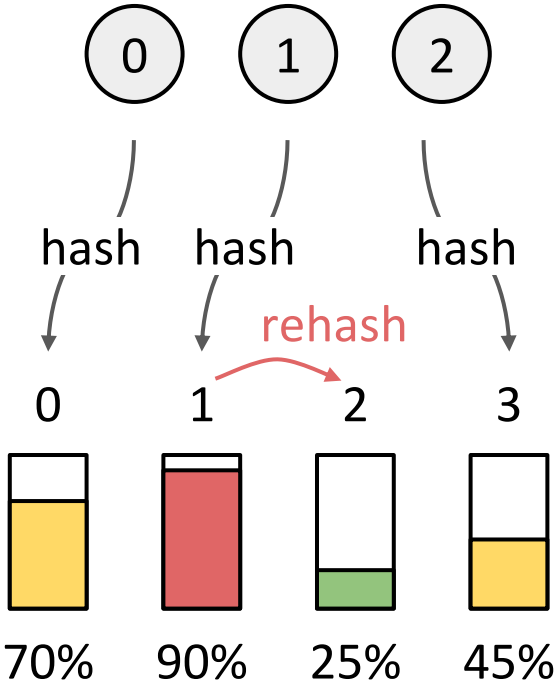

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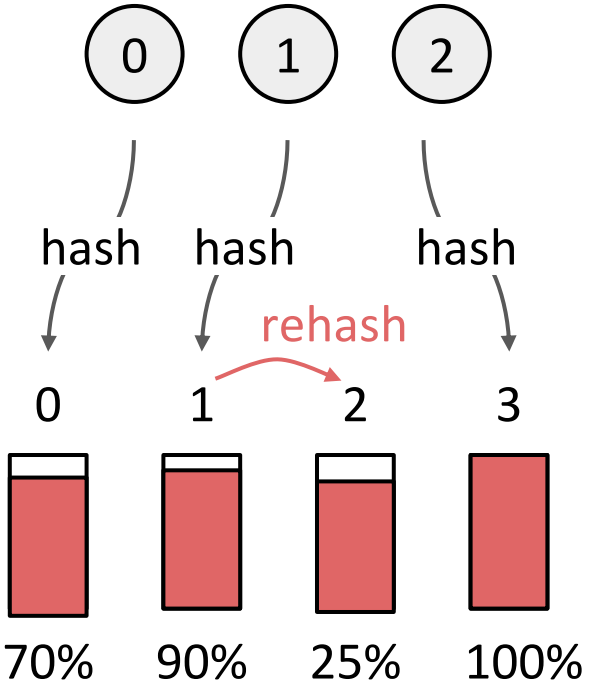

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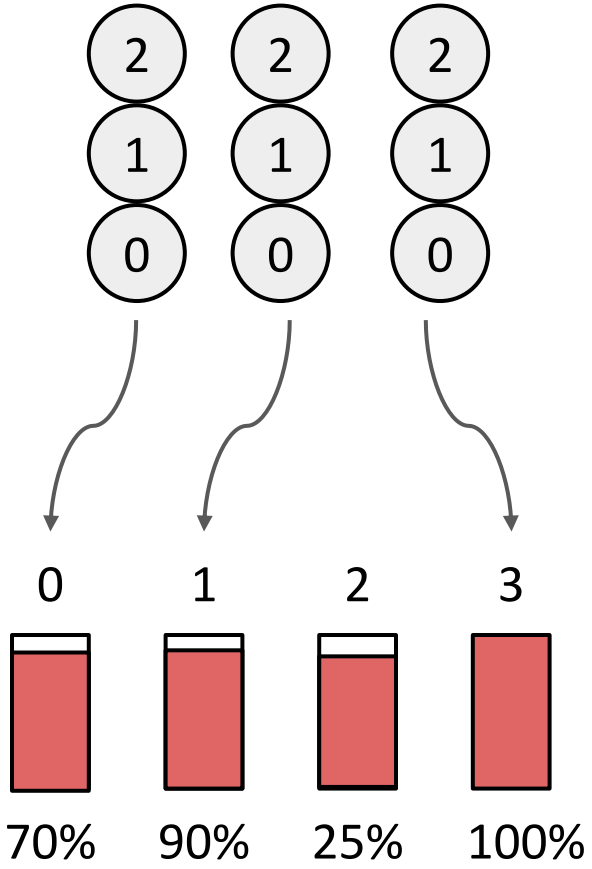
- When whole system is overloaded, FALCON can be dynamically disabled.



Evaluation - Setup

Hardware: Intel 40 logical cores @ 2.2GHz, 128 GB RAM
NIC: Mellanox ConnectX-5 EN (100 Gbps)
Software: Ubuntu 18.04 with Linux kernel v5.4

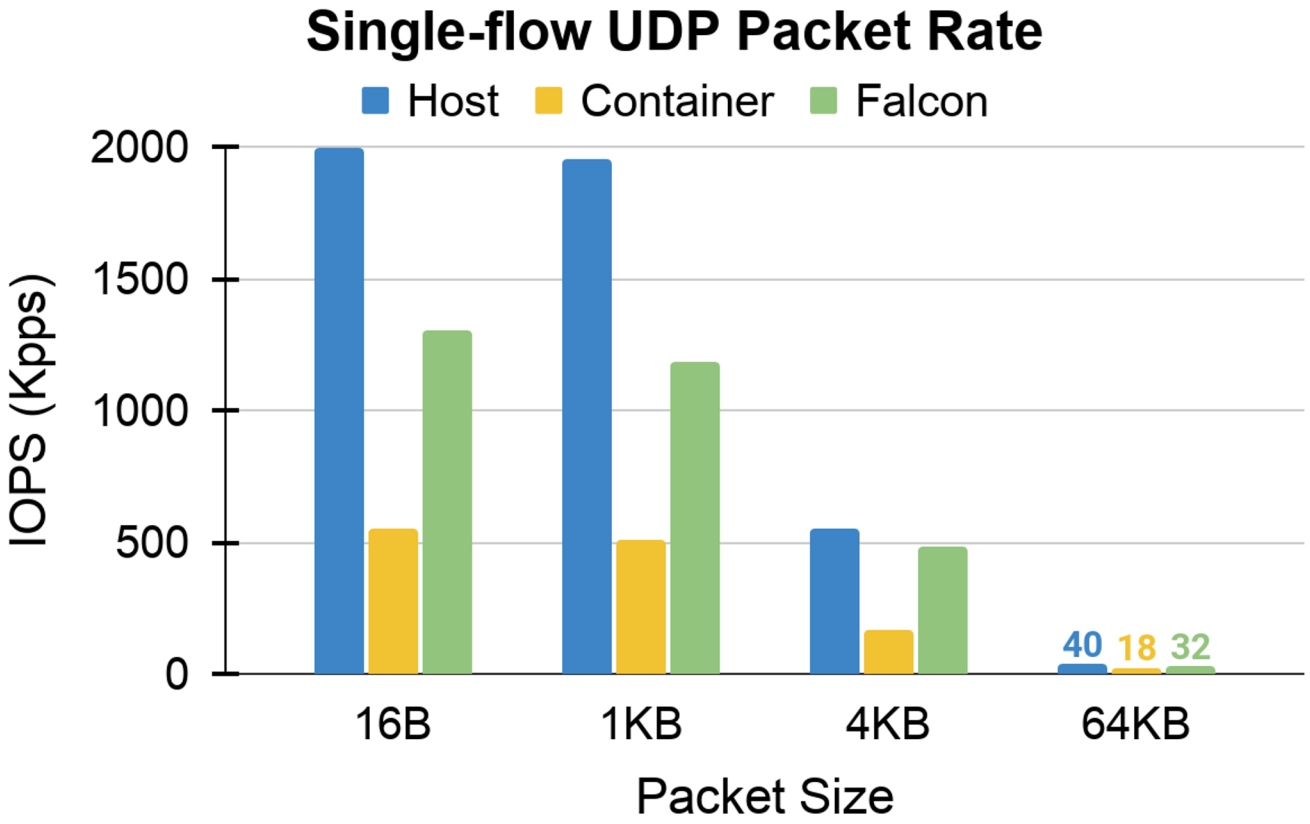
Performance comparisons: Host vs. Container vs. FALCON

Experiments:

- Single-flow and multi-flow microbenchmarks
- Load balancing
- Cloudsuite benchmark (memcached)

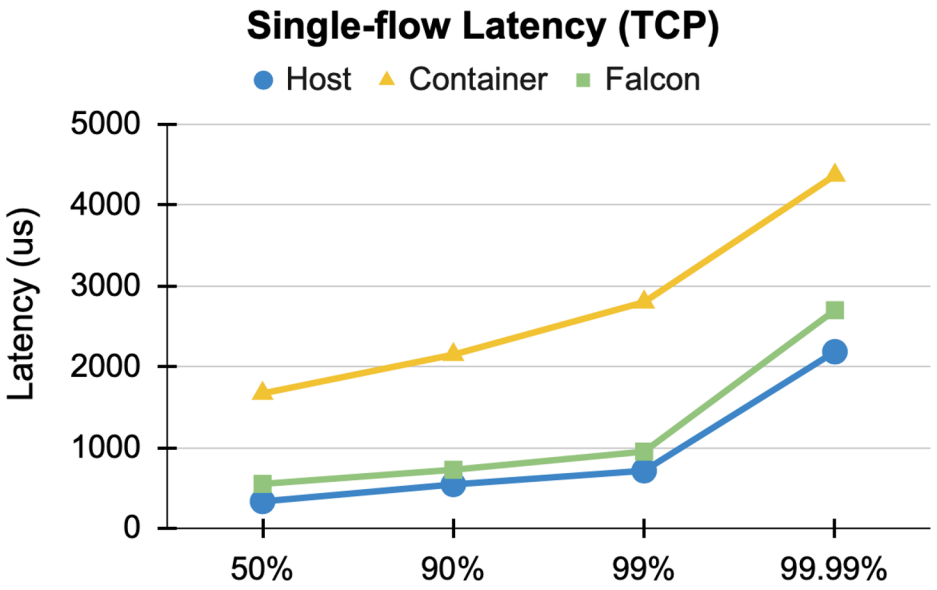
Single-flow Performance

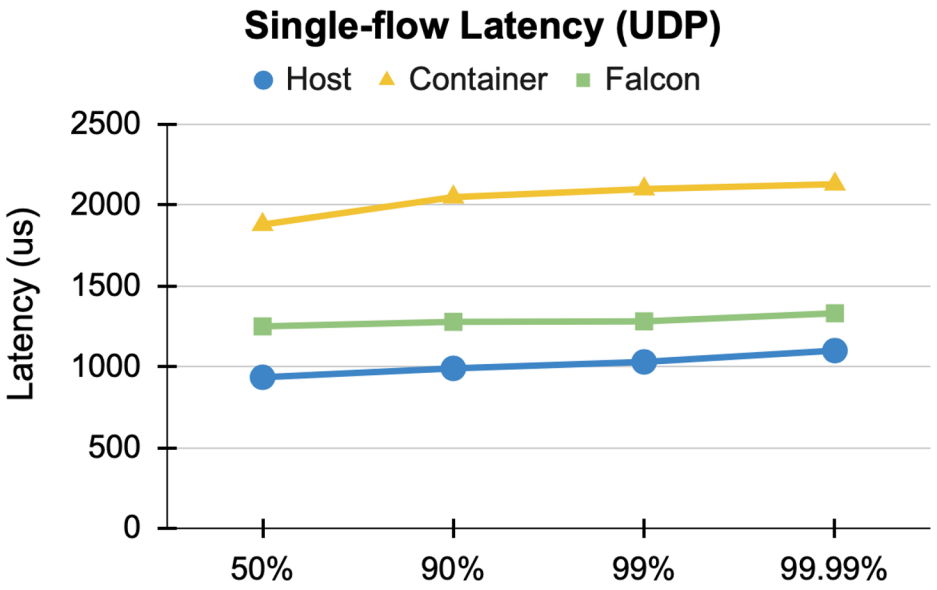
- More than **2x** improvement than vanilla container



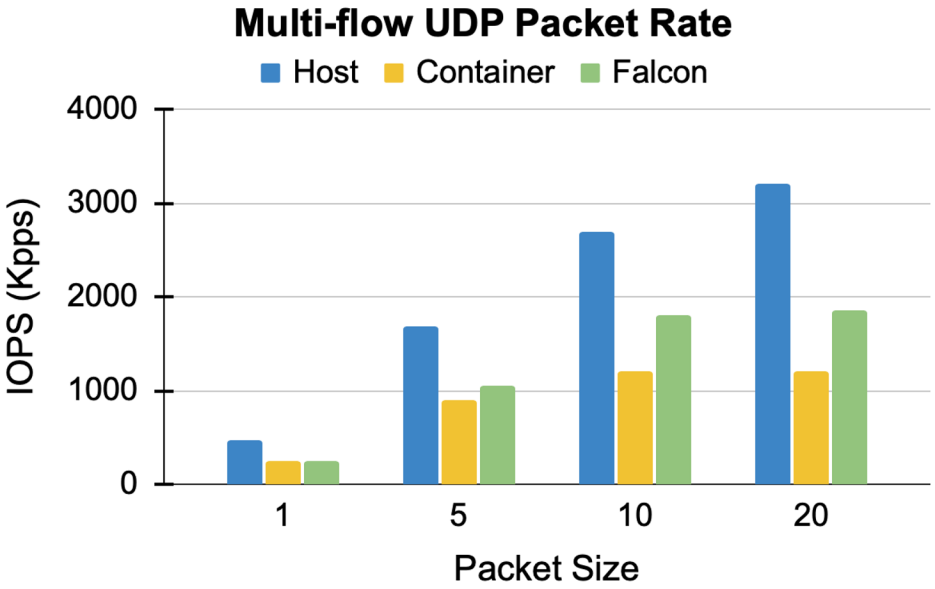
Single-flow Performance

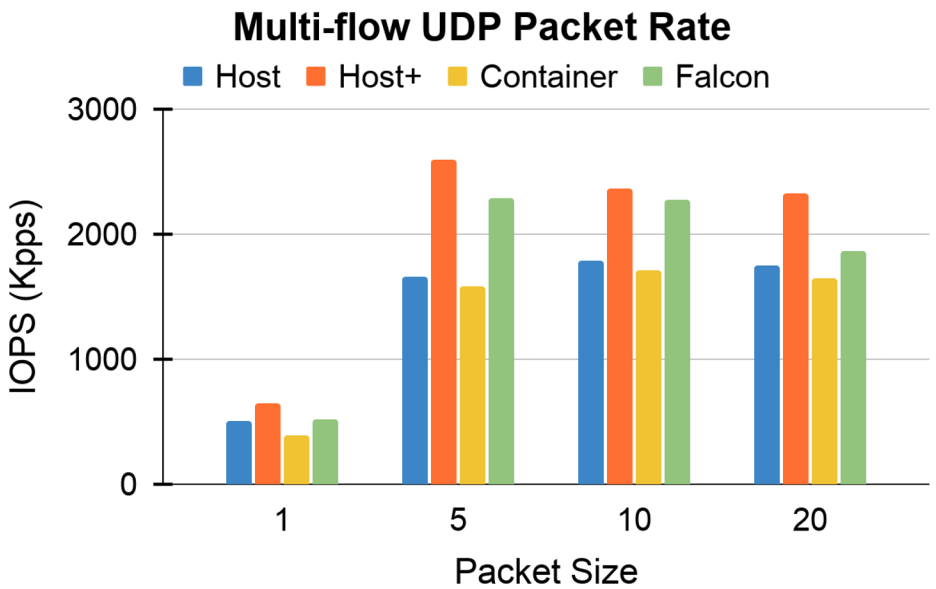
- Both median and tail latency get close to host networks



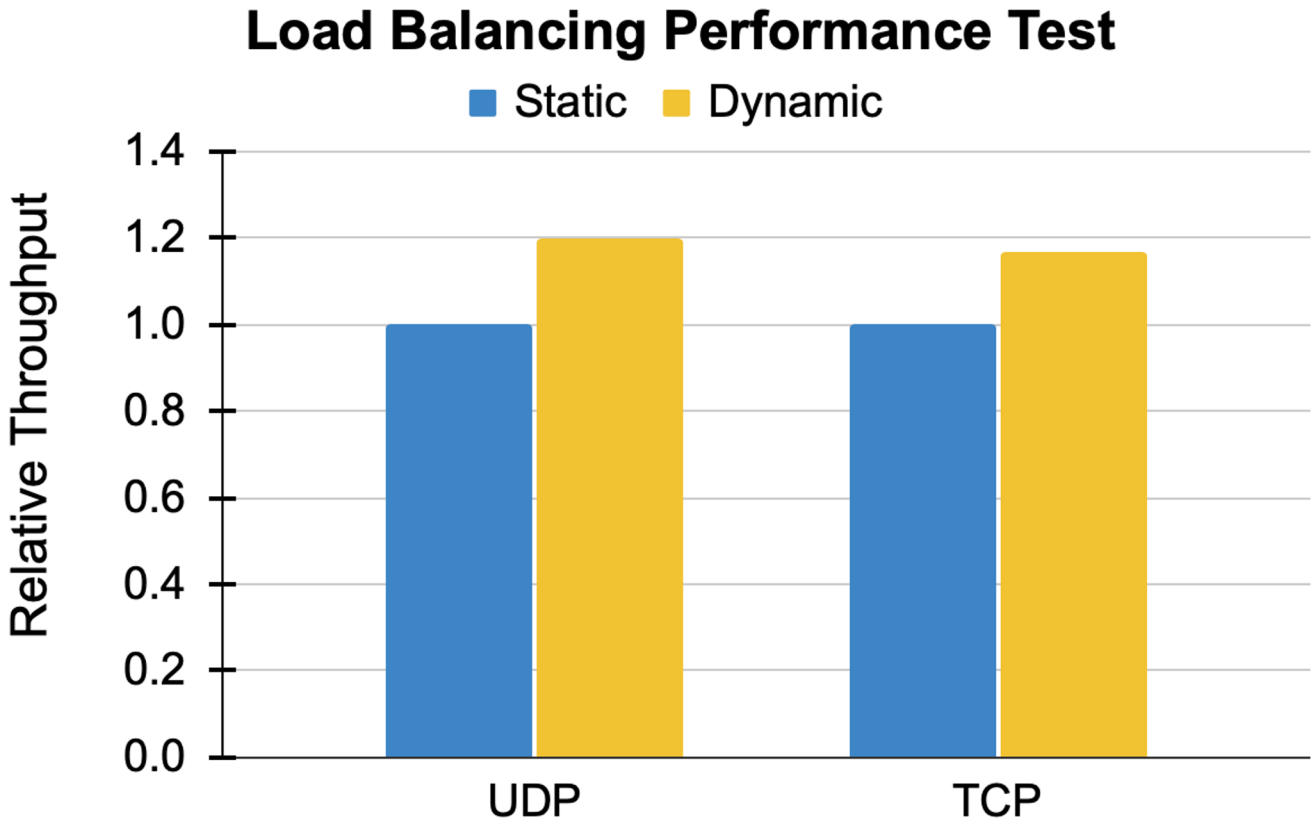


Multi-flow Performance

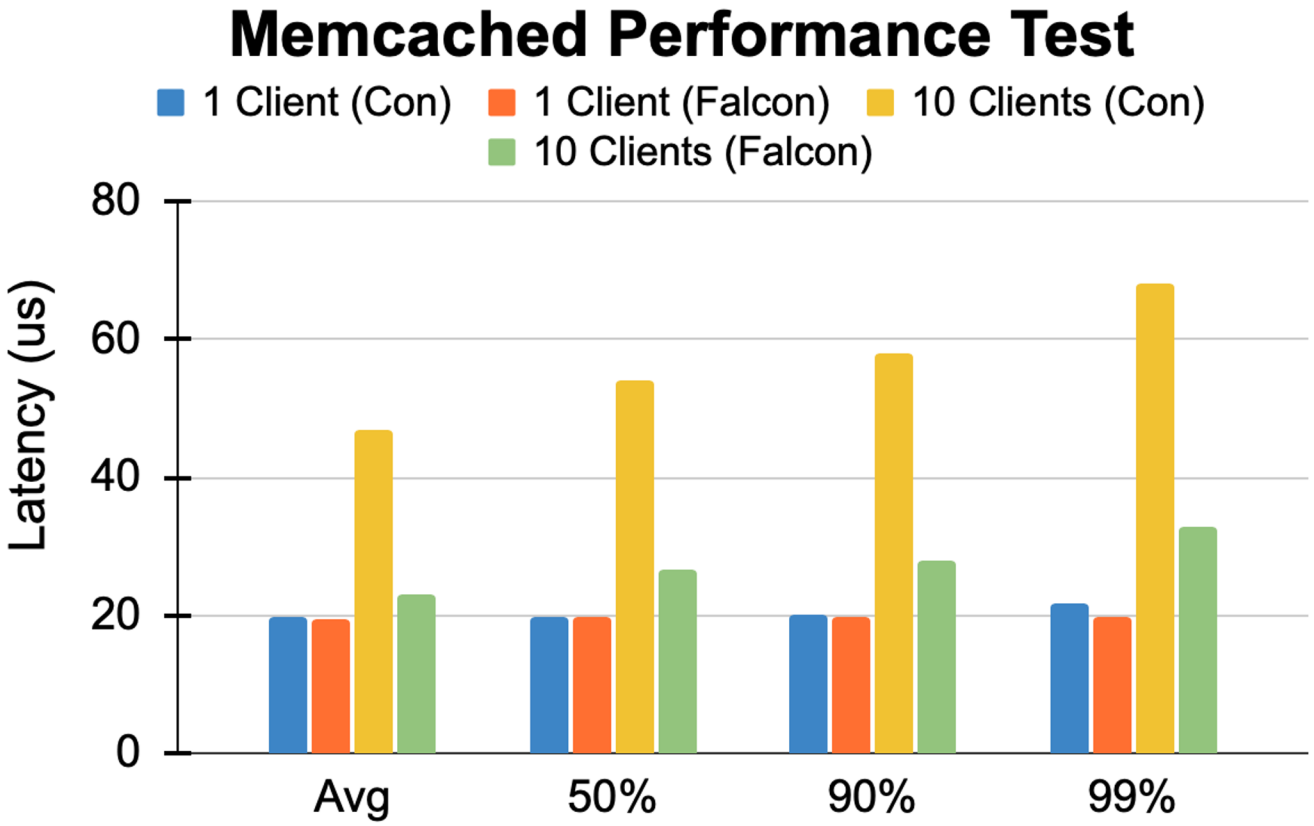




Load Balancing



Memcached Performance



Conclusion

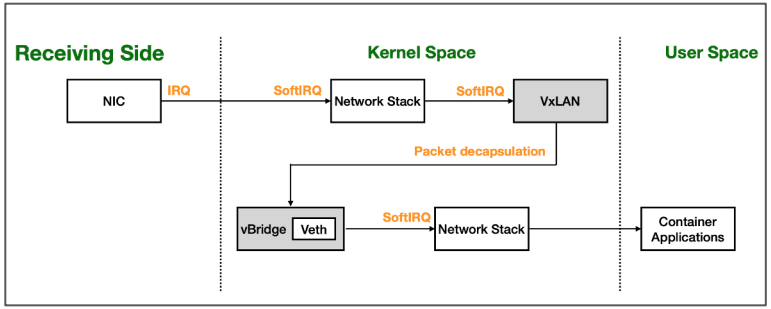
- Overlay packet processing in OS is not optimized to utilize multicore system.
- FALCON accelerates the performance of overlay networks...
  - Without losing any security, generality, or compatibility.
- Purely software-based solution that is immediately deployable.
- Our implementation is open-sourced at: github.com/munikarmanish/falcon

Thank you!

Backup Slides

Why is overlay network slow?

- Additional virtual devices
  - Prolonged packet processing path
- Serialization of single-flow processing
  - Quick saturation
  - Longer queueing delays
  - Load imbalance



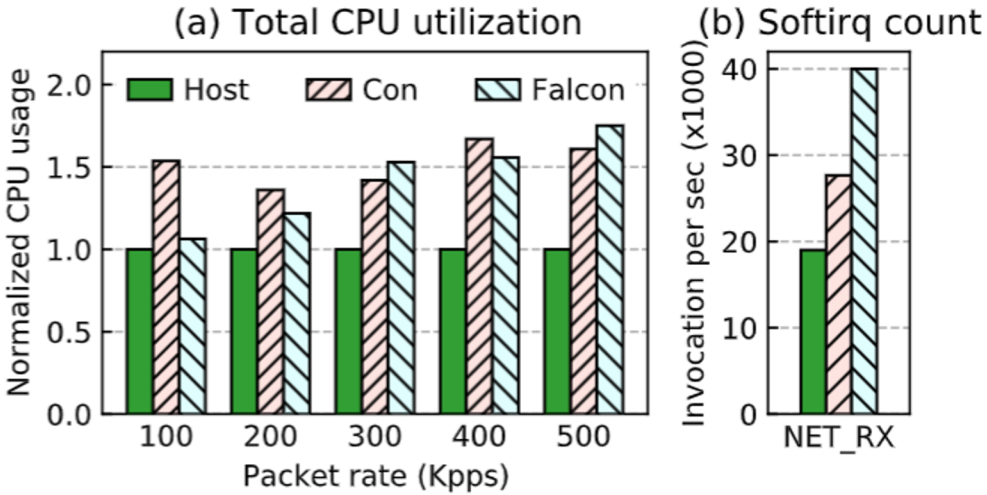
<show the packet path from NIC to Application>

How do containers communicate?

- Host mode (containers use host network namespace)
  - ✓ Simple and fast
  - ✗ No network isolation/flexibility
- Macvlan mode (assign multiple MAC to same physical NIC)
  - ✓ Fast and some isolation/flexibility
  - ✗ Complex host network routing management
- Overlay mode (packet encapsulation)
  - ✓ Full network isolation and flexibility
  - ✗ High overheads / slow

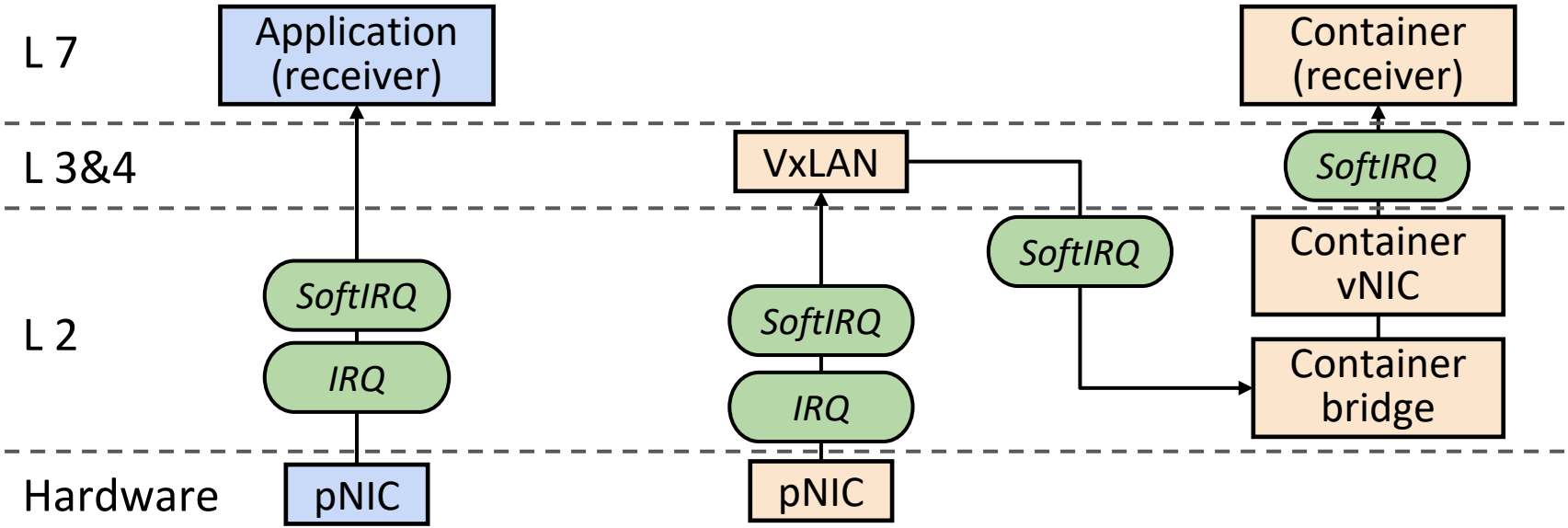
Overheads and Limitations

- Higher overall CPU utilization
  - More softirq invocations
- Loss of data locality



Existing optimizations in Linux

- IRQ coalescing
- GRO/GSO
- RSS/RPS



Evaluation - Setup

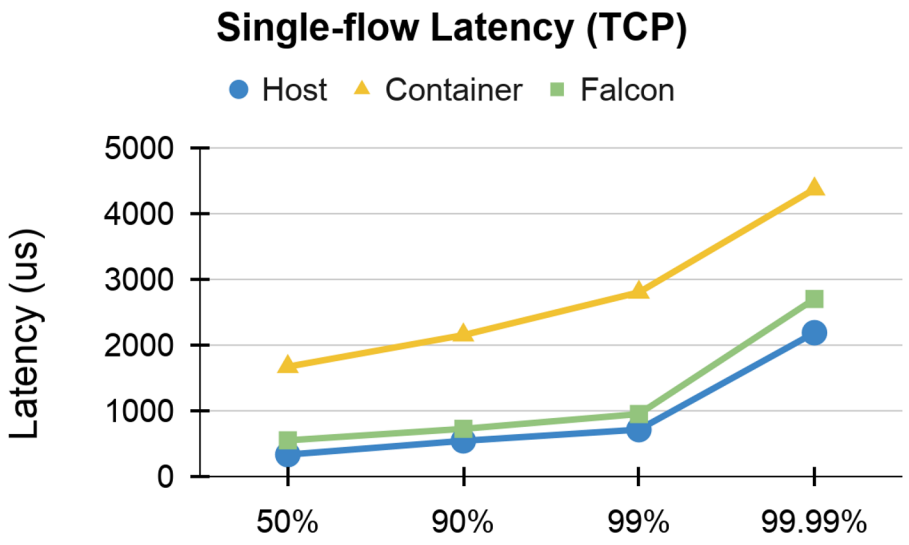
Hardware: Intel Xeon Silver 4114 with 40 logical cores @ 2.2GHz, 128 GB RAM
NIC: Mellanox ConnectX-5 EN (100 Gbps)
Software: Ubuntu 18.04 with Linux kernel v5.4

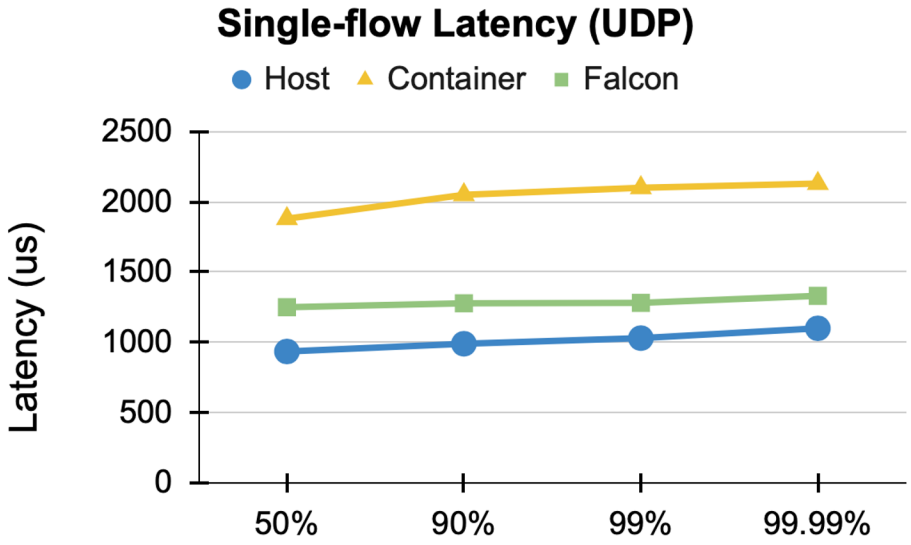
Performance comparisons: Host vs. Container vs. FALCON

Experiments:

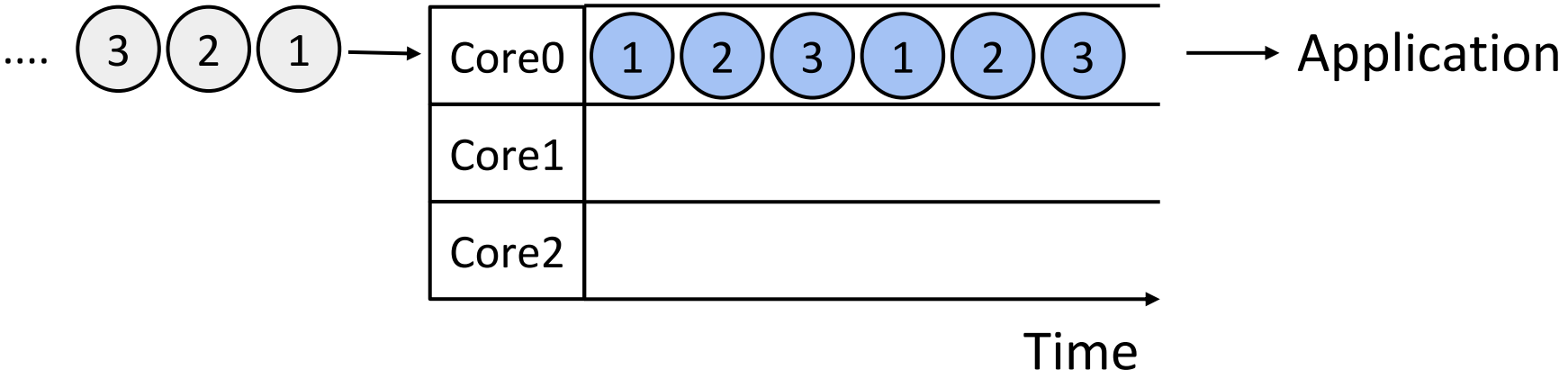
- Single-flow and multi-flow microbenchmarks
- Cloudsuite benchmark (memcached & nginx)
- Load balancing

Single-flow performance

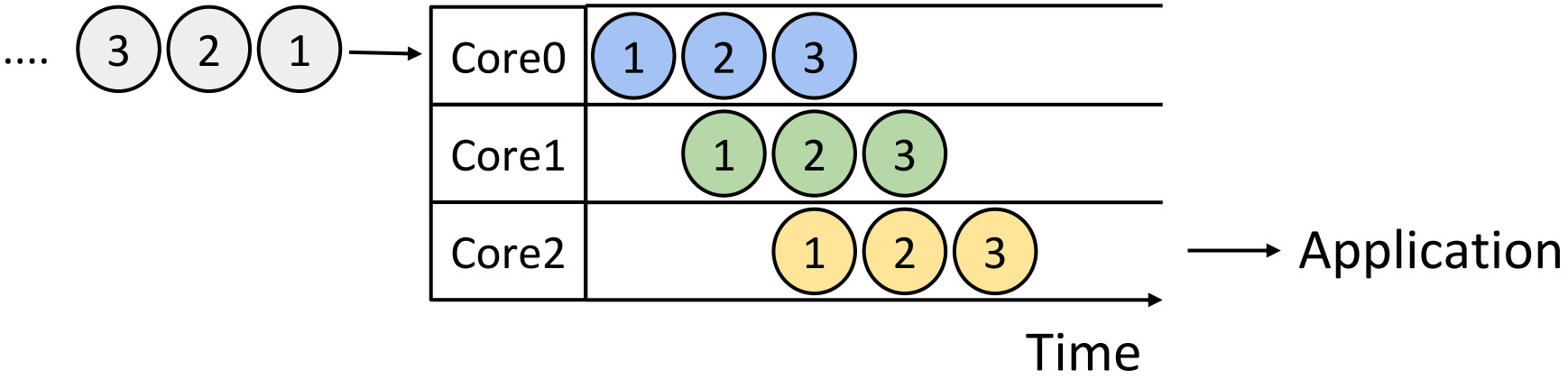




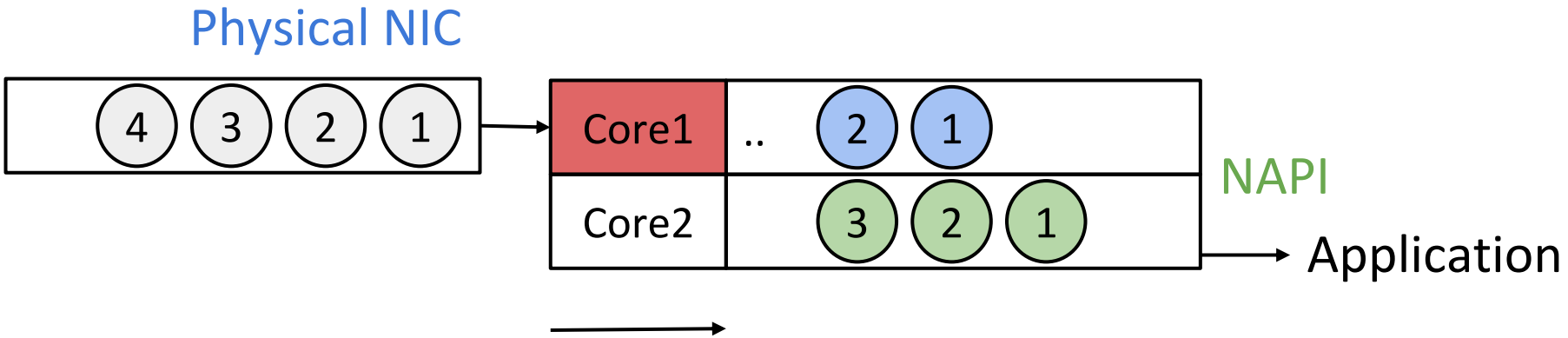
FALCON Design - SoftIRQ Pipelining



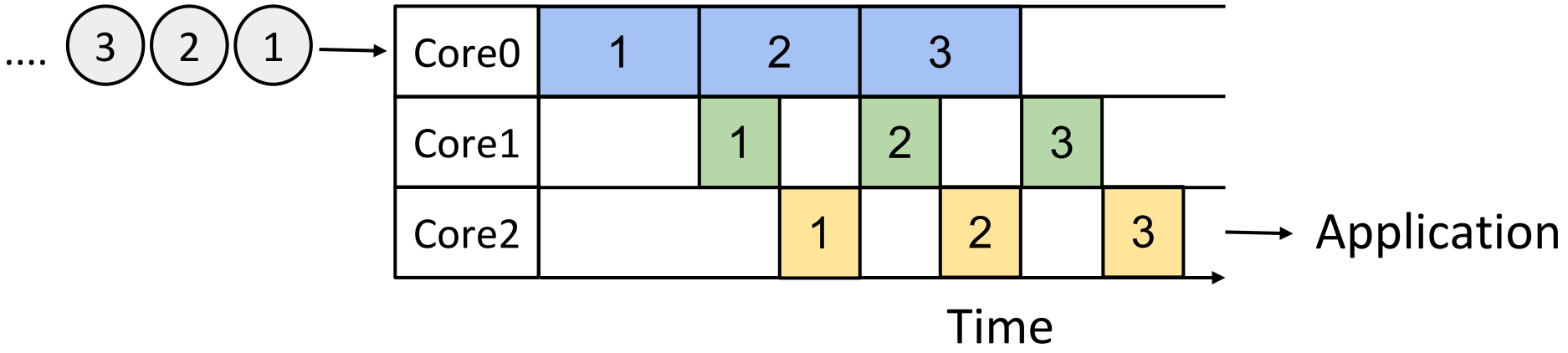
FALCON Design - SoftIRQ Pipelining



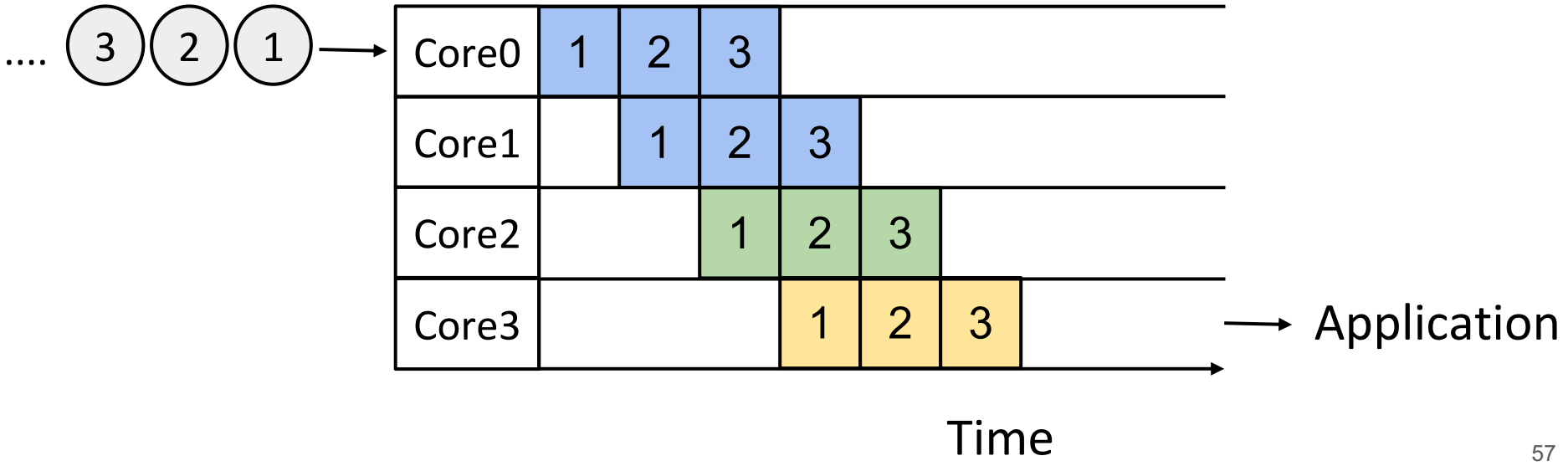
FALCON Design - SoftIRQ Splitting



FALCON Design - SoftIRQ Splitting



FALCON Design - SoftIRQ Splitting



Load Balancing