IX: A Protected Dataplane Operating System for High Throughput and Low Latency

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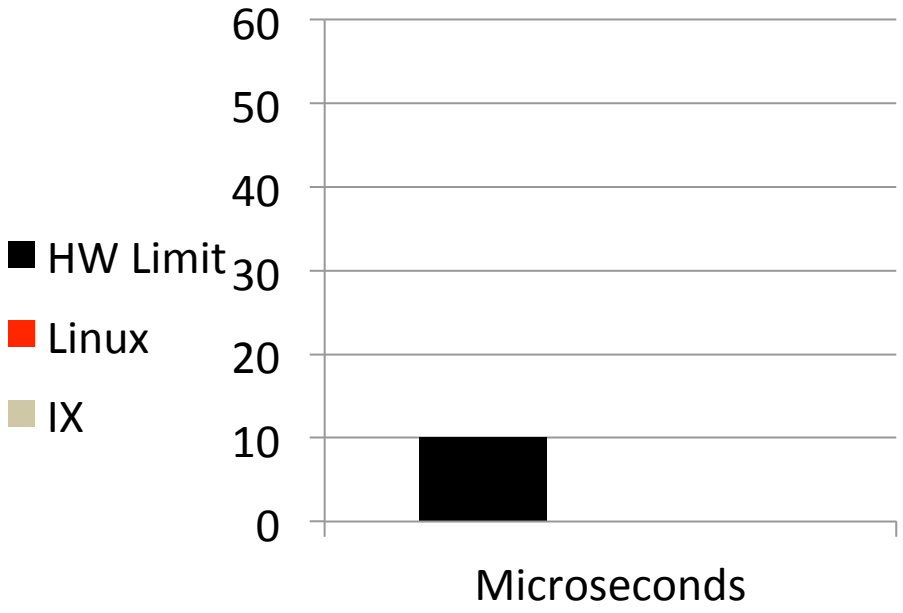
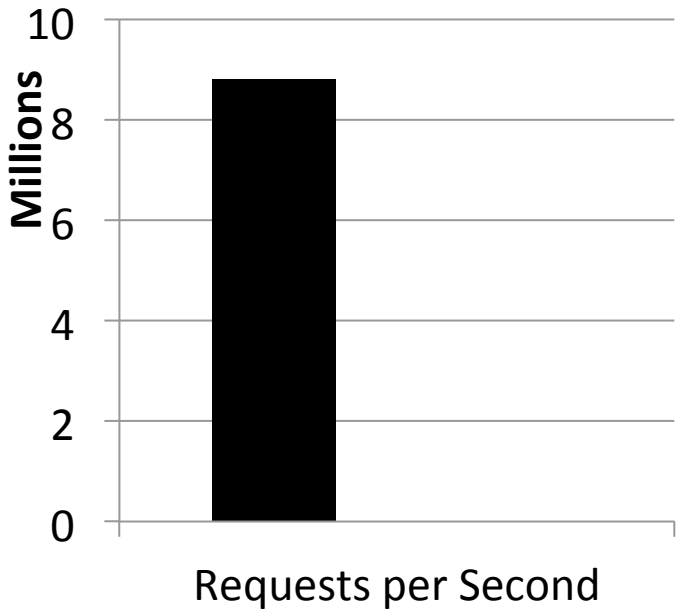
HW is fast

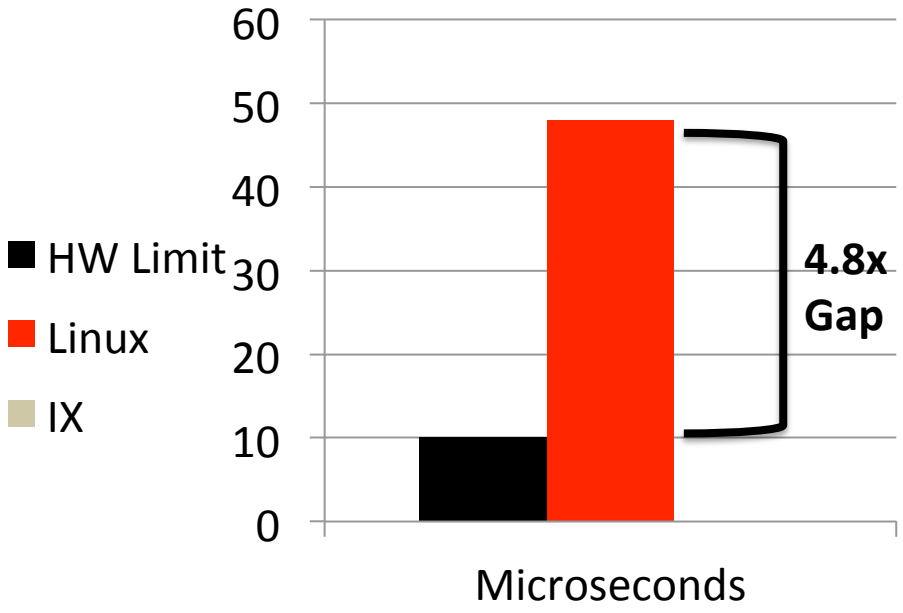
64-byte TCP Echo:

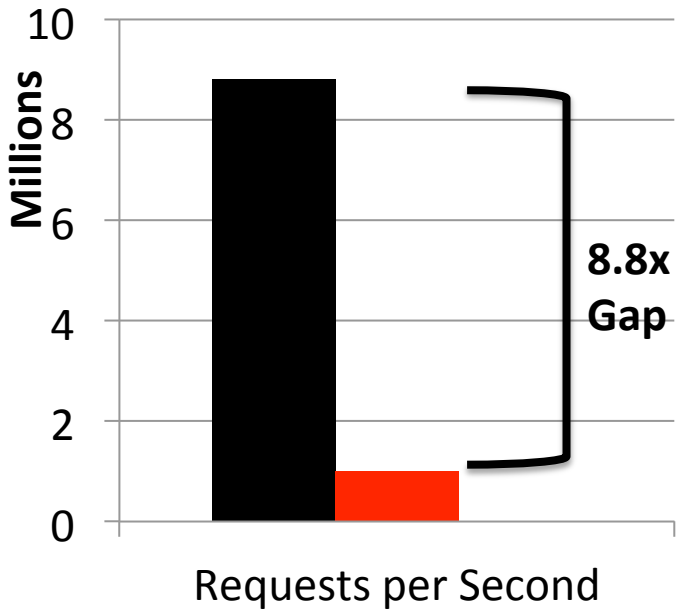




HW is fast, but SW is a Bottleneck

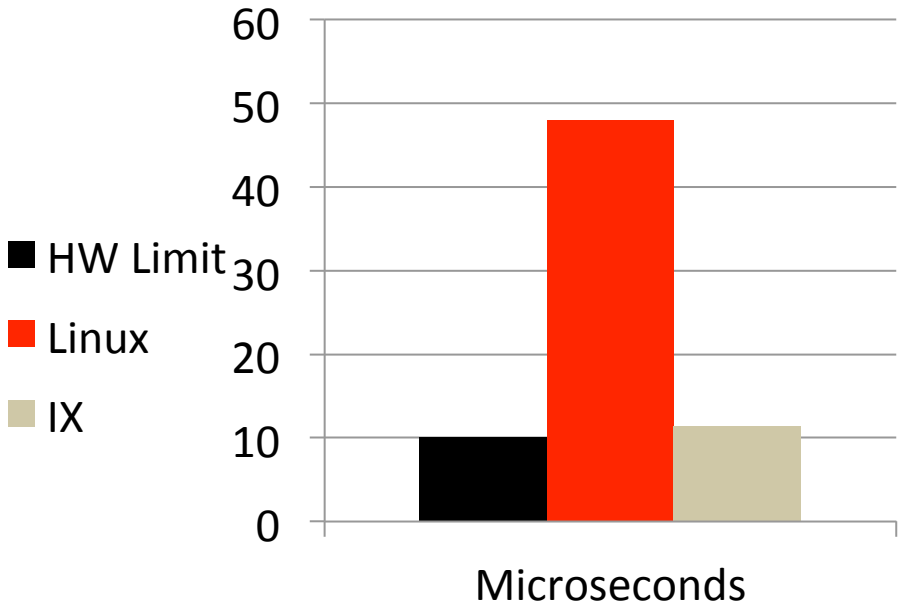
64-byte TCP Echo:

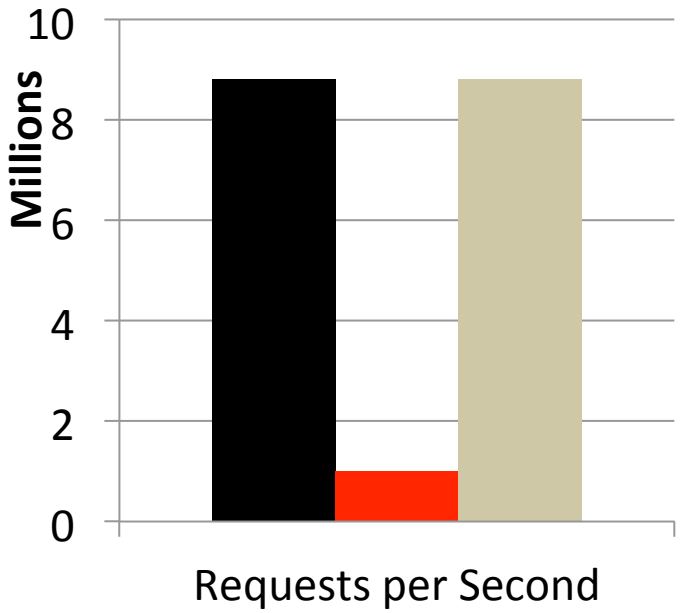




IX Closes the SW Performance Gap

64-byte TCP Echo:

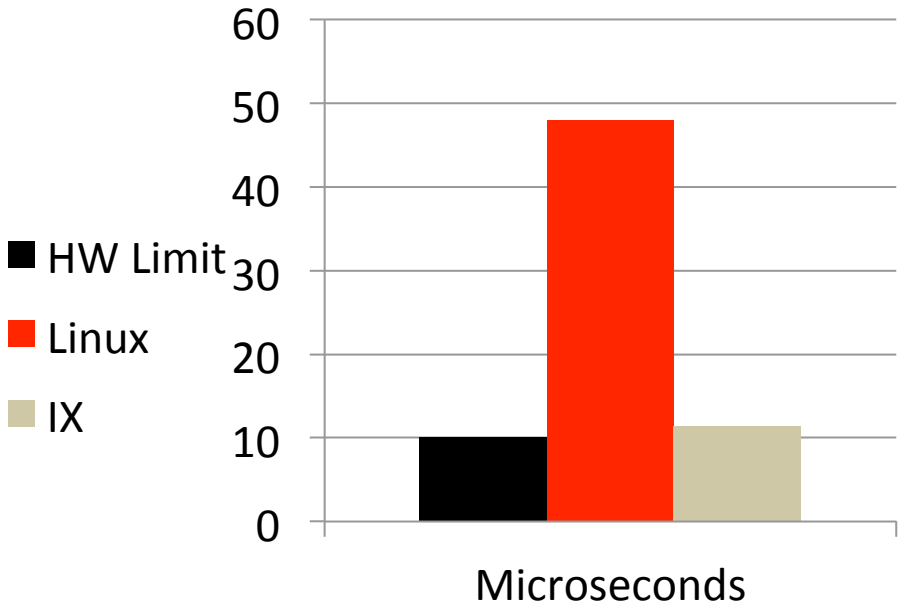


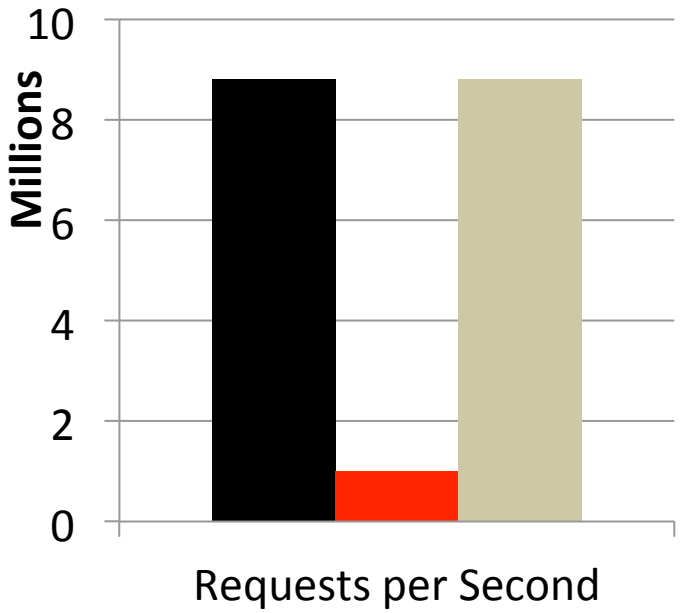


Two Contributions

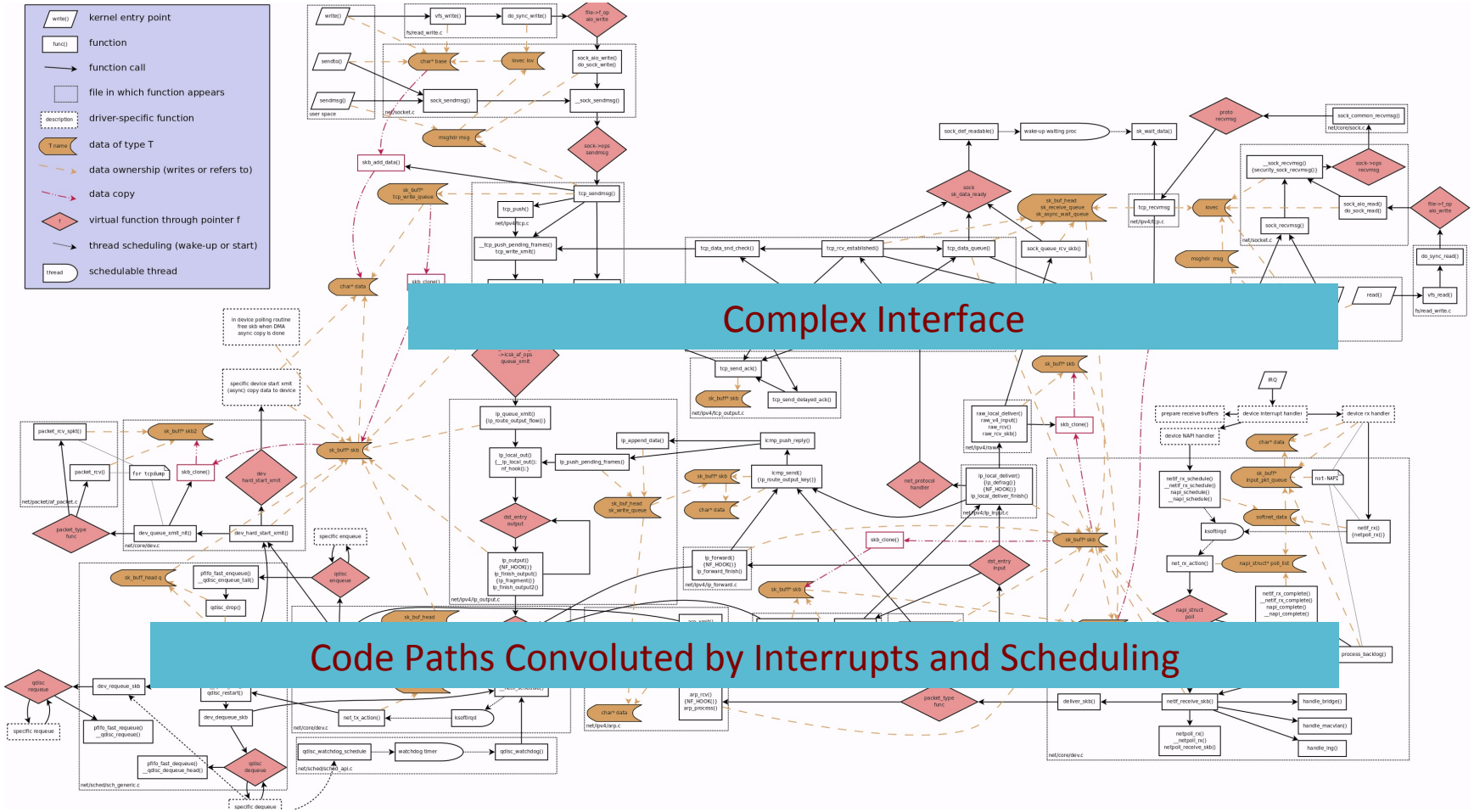
#1: Protection and direct HW access through virtualization

#2: Execution model for low latency and high throughput





Why is SW Slow?



Created by: Arnout Vandecappelle
http://www.linuxfoundation.org/collaborate/workgroups/networking/kernel_flow

Problem: 1980s Software Architecture

- Berkeley sockets, designed for CPU time sharing
- Today's large-scale datacenter workloads:

Hardware: Dense Multicore + 10 GbE (soon 40)

- API scalability critical!
- Gap between compute and RAM -> Cache behavior matters
- Packet inter-arrival times of 50 ns

Scale out access patterns

- Fan-in -> Large connection counts, high request rates
- Fan-out -> Tail latency matters!

Conventional Wisdom

- Bypass the kernel
  - Move TCP to user-space (Onload, mTCP, Sandstorm)
  - Move TCP to hardware (TOE)
- Avoid the connection scalability bottleneck
  - Use datagrams instead of connections (DIY congestion management)
  - Use proxies at the expense of latency
- Replace classic Ethernet
  - Use a lossless fabric (Infiniband)
  - Offload memory access (rDMA)

- **Common thread: Give up on systems software**

Our Approach

- Bypass the kernel
  - Move TCP to user space (Onload, mTCP, Sandstor
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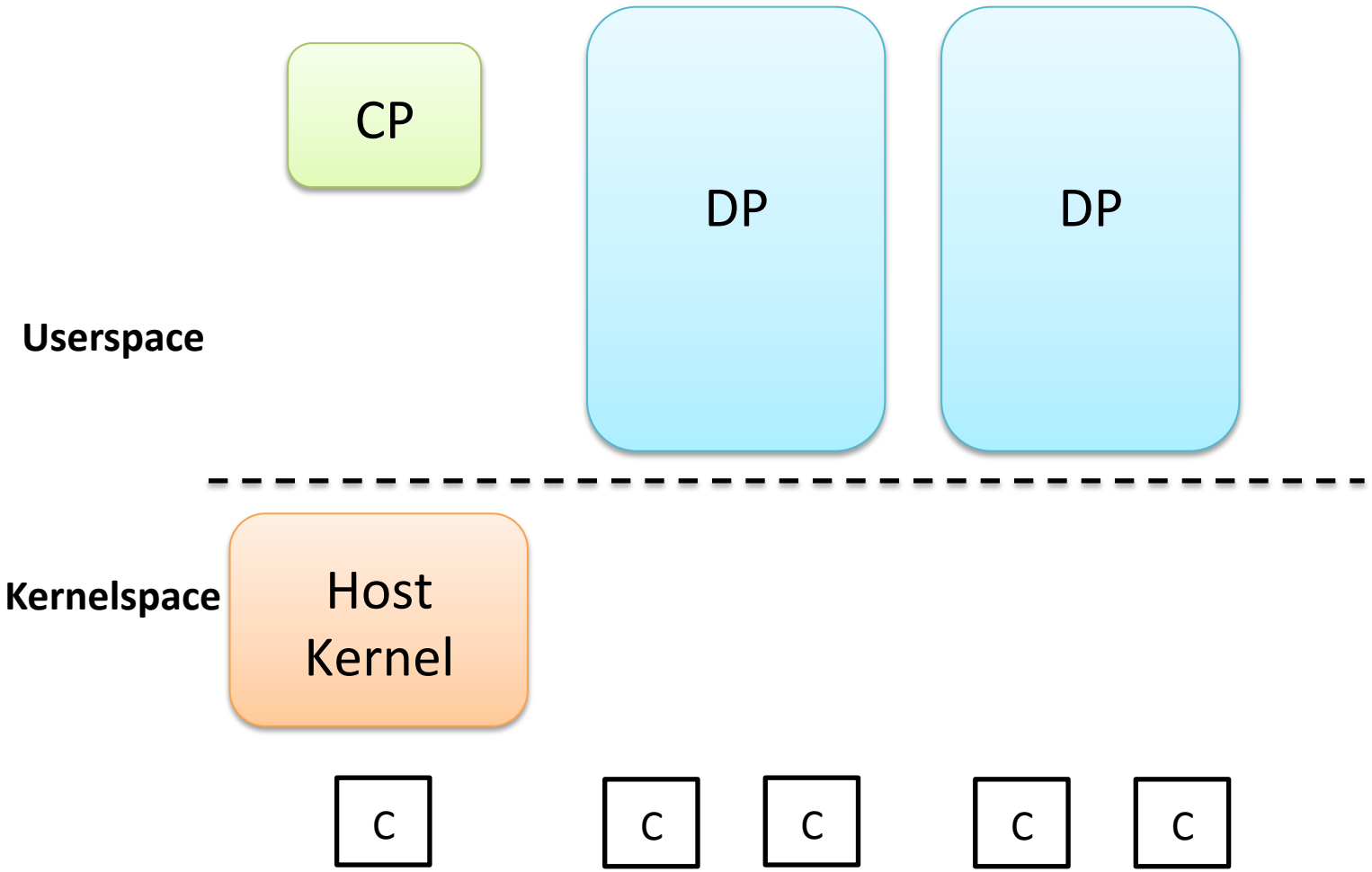
Robust Protection Between App and Netstack

Connection Scalability

Commodity 10Gb Ethernet

- **Tackle the problem head on…**

Separation of Control and Data Plane



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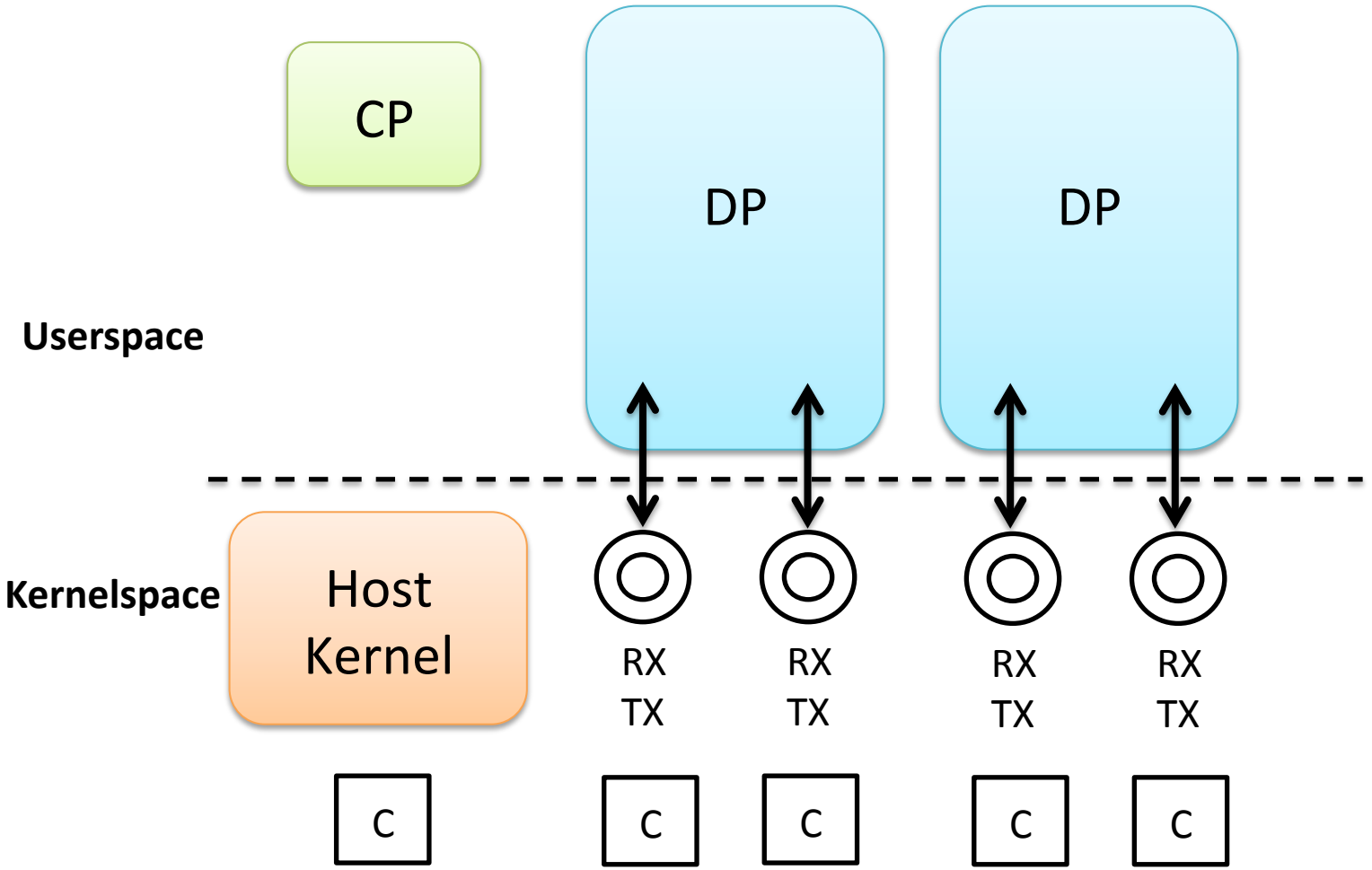

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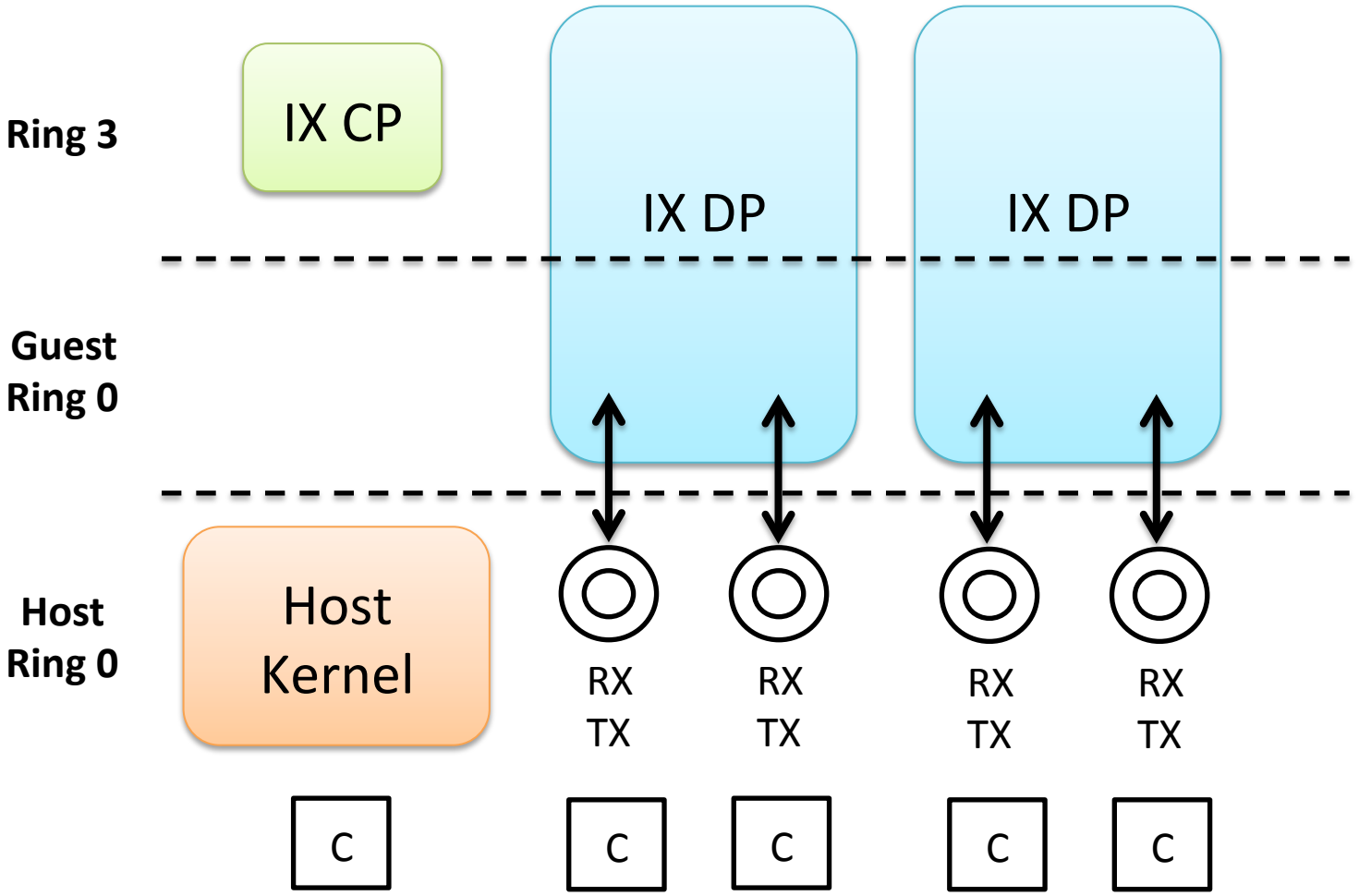

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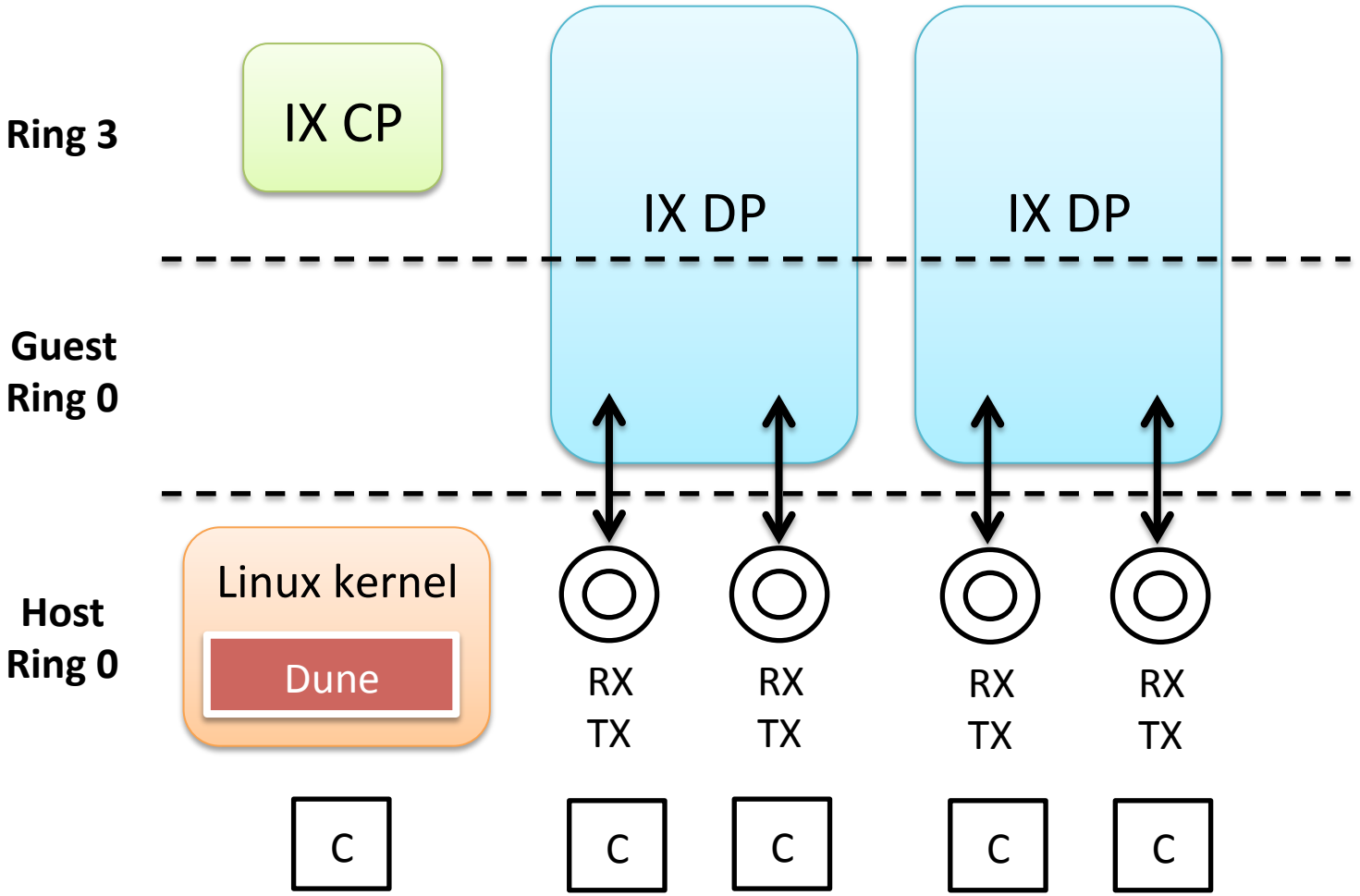

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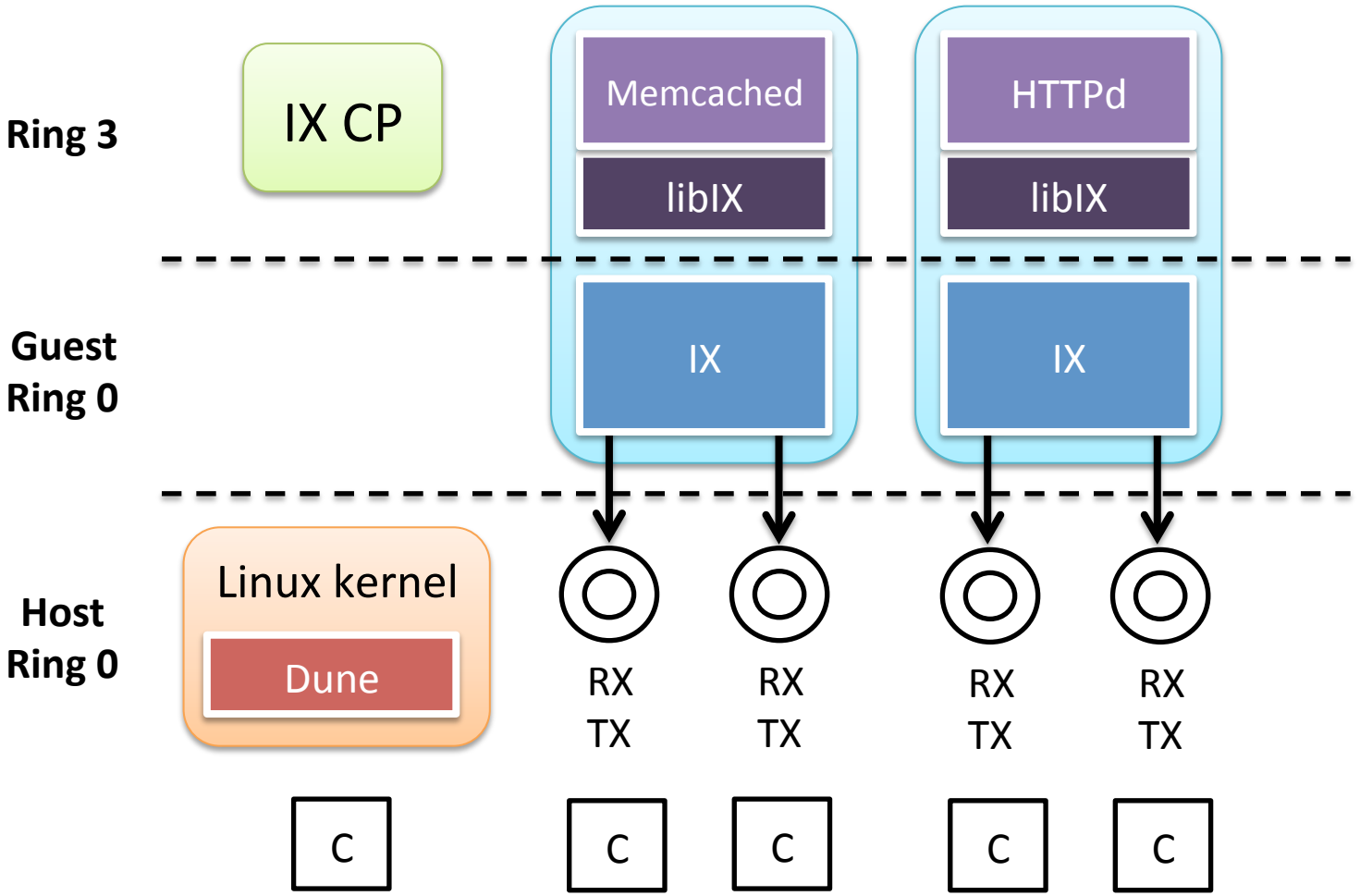
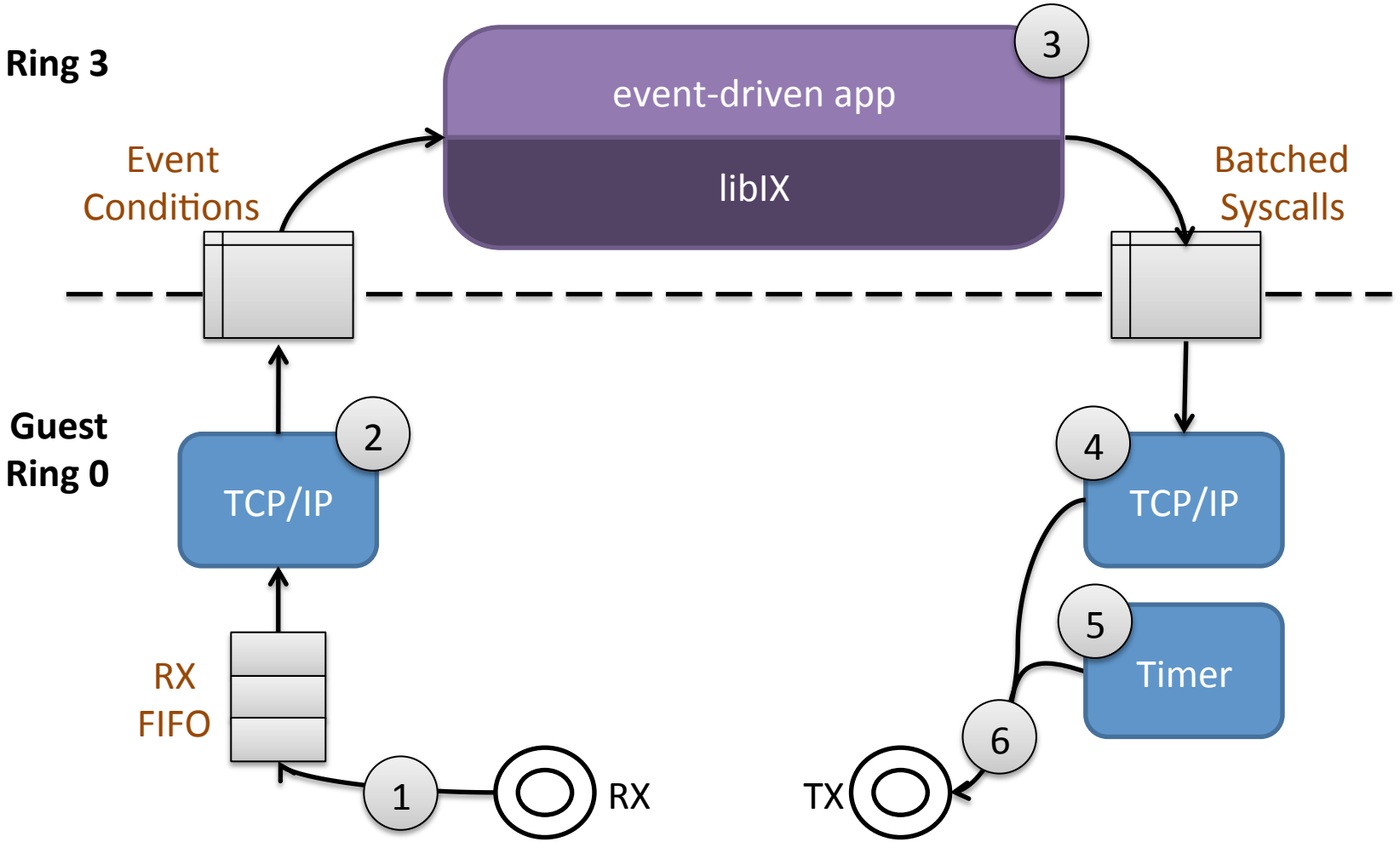
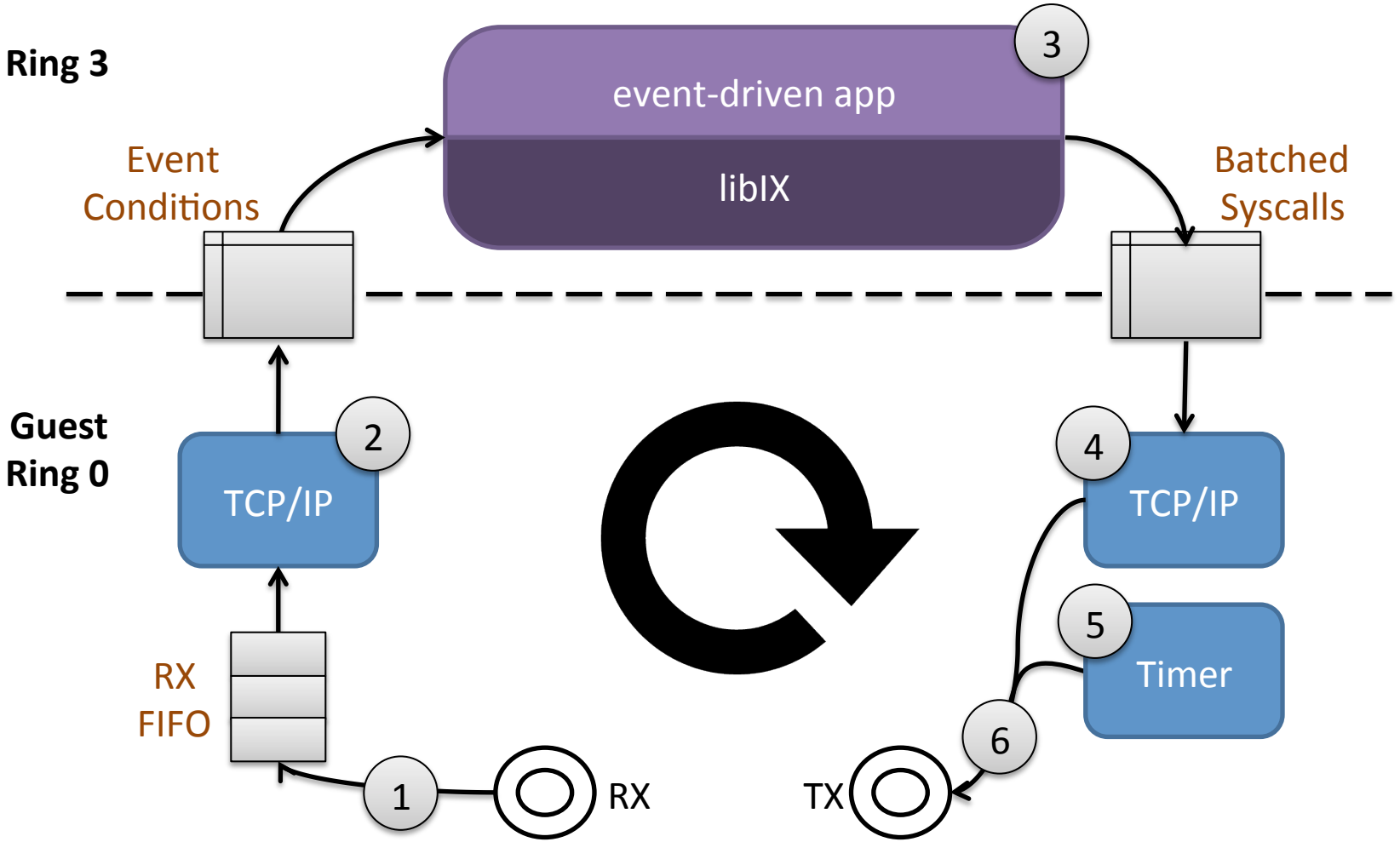


The IX Execution Pipeline



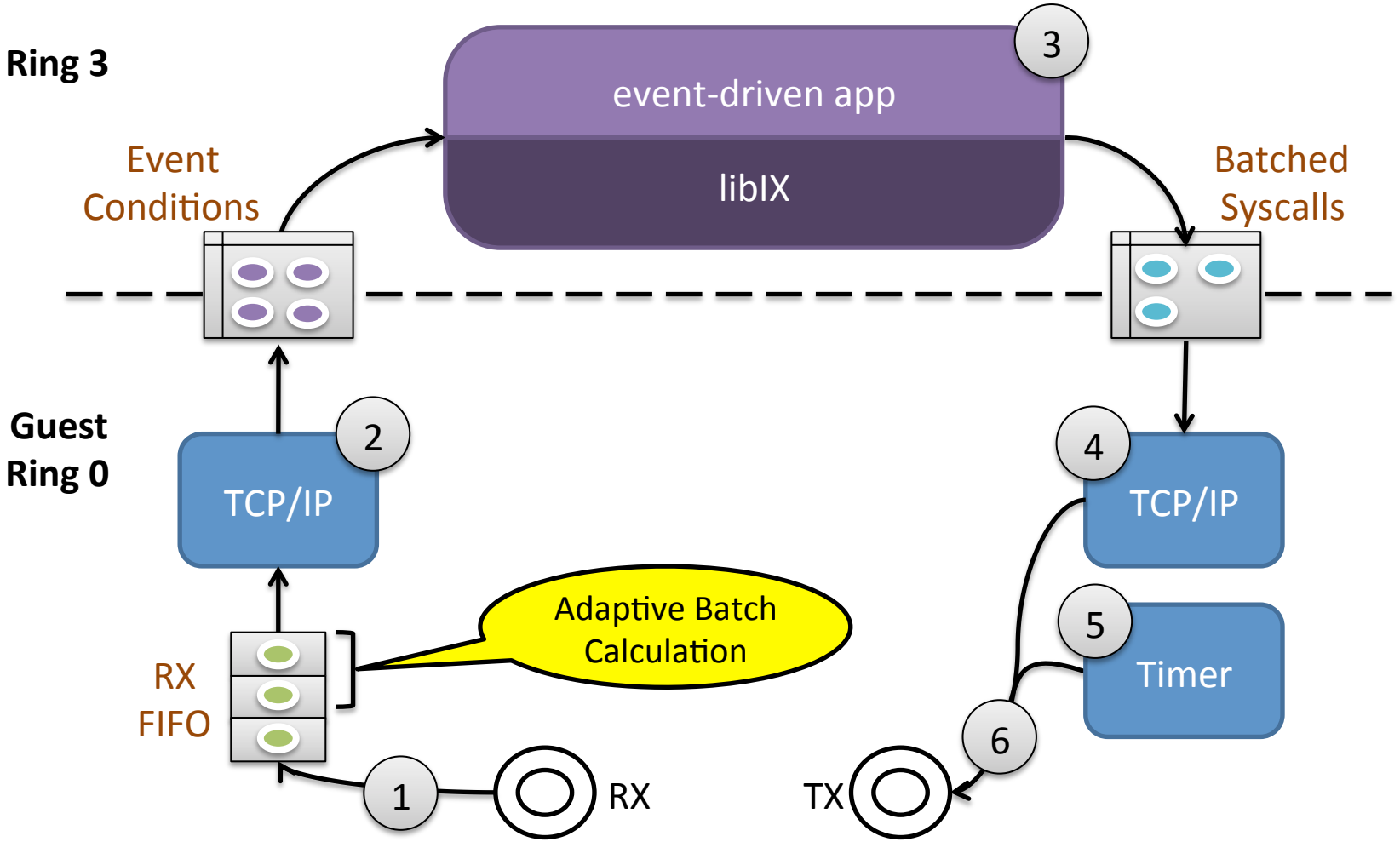
Design (1): Run to Completion



Improves Data-Cache Locality

Removes Scheduling Unpredictably

Design (2): Adaptive Batching



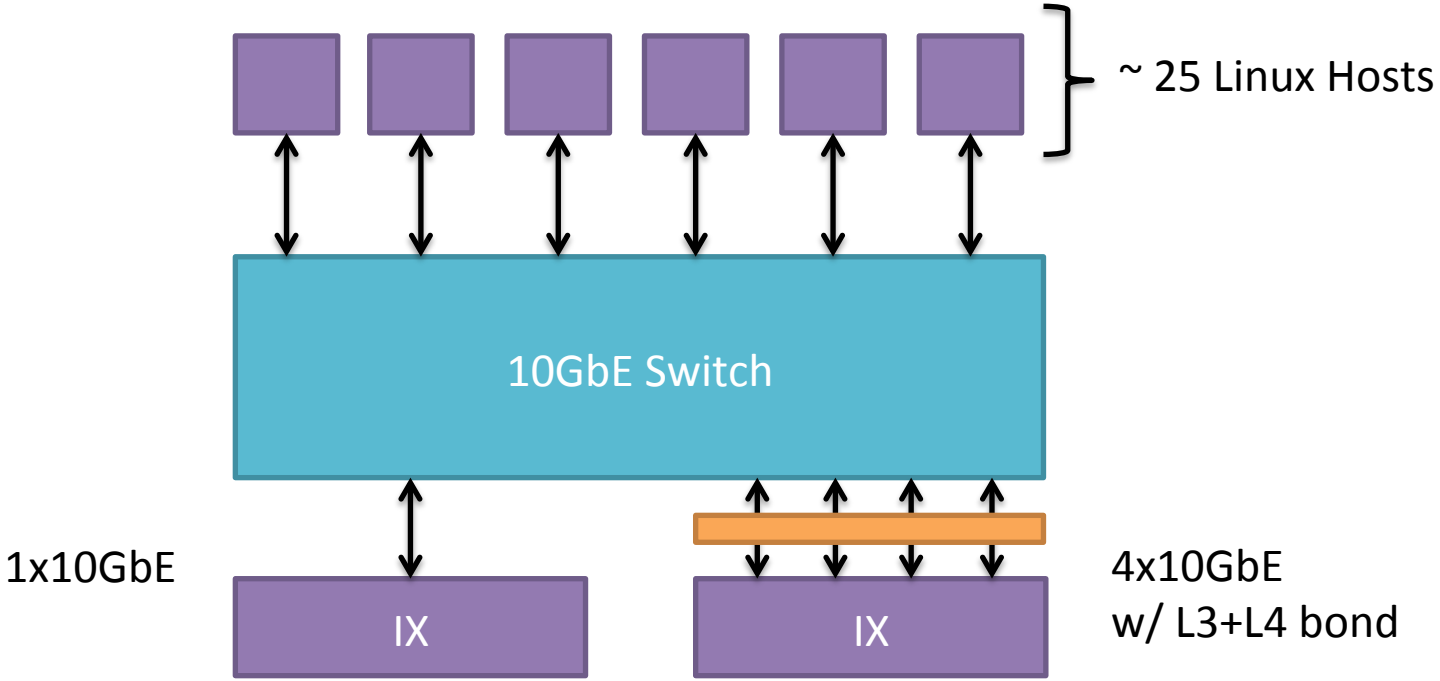
Improves Instruction-Cache Locality and Prefetching

See the Paper for more Details

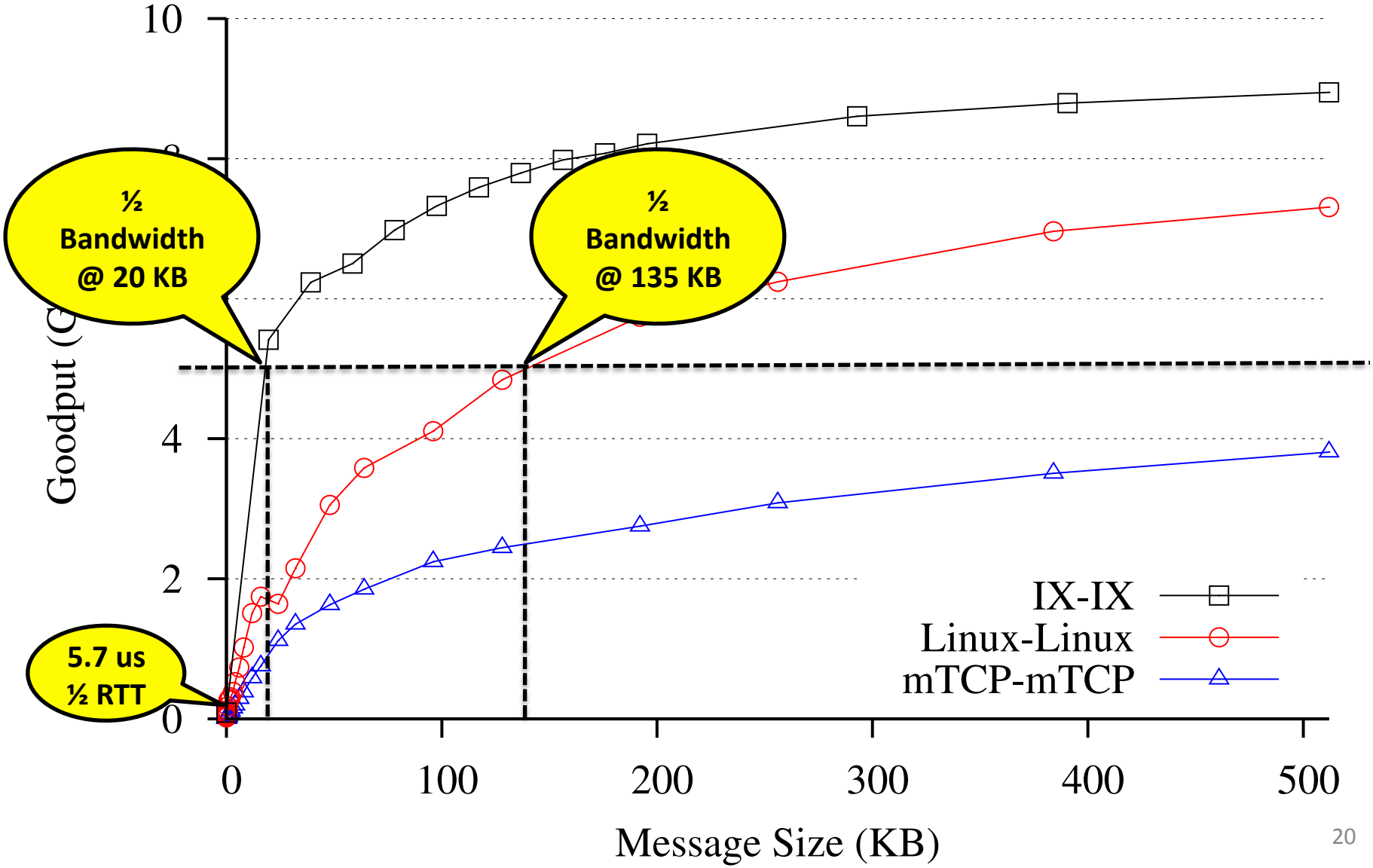
- Design (3): Flow consistent hashing
  - Synchronization & coherence free operation
- Design (4): Native zero-copy API
  - Flow control exposed to application
- Libix: Libevent-like event-based programming
- IX prototype implementation
  - Dune, DPDK, LWIP, ~40K SLOC of kernel code

Evaluation

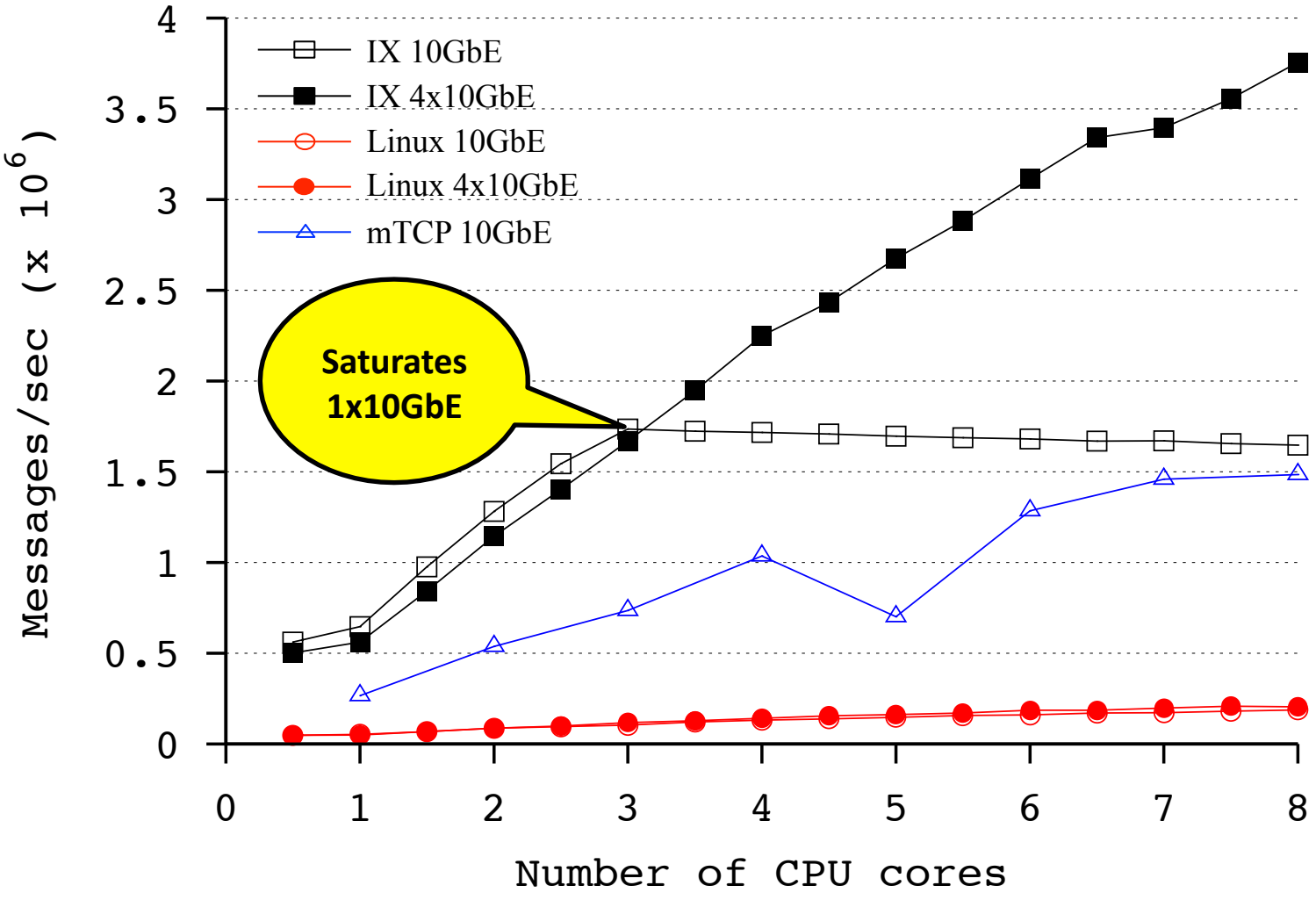
- Comparison IX to Linux and mTCP [NSDI '14]
- TCP microbenchmarks and Memcached



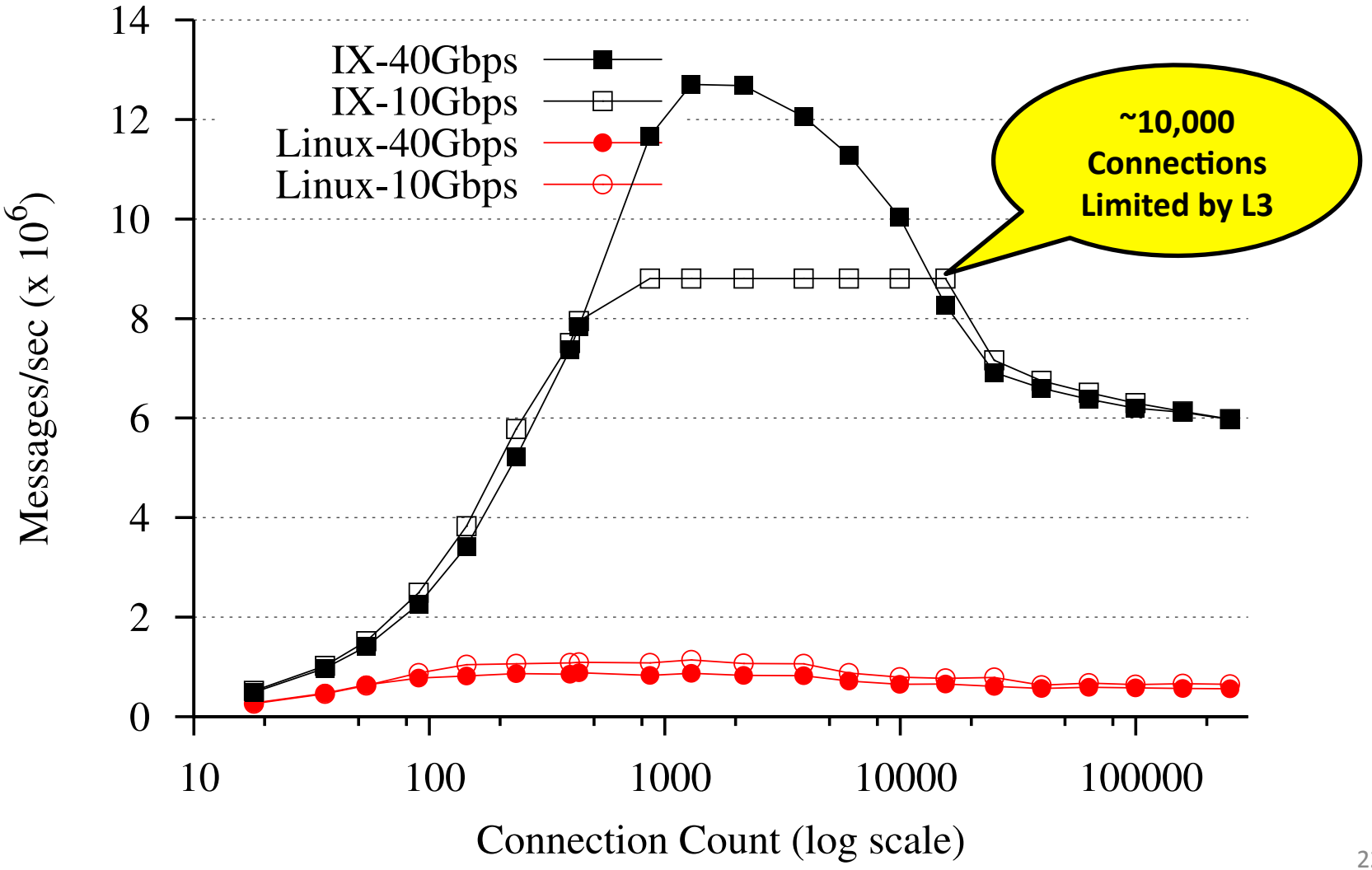
TCP Netpipe


10
4
2
0
Goodput (G
½ Bandwidth @ 20 KB
½ Bandwidth @ 135 KB
5.7 us ½ RTT
IX-IX
Linux-Linux
mTCP-mTCP
0
100
200
300
400
500
Message Size (KB)

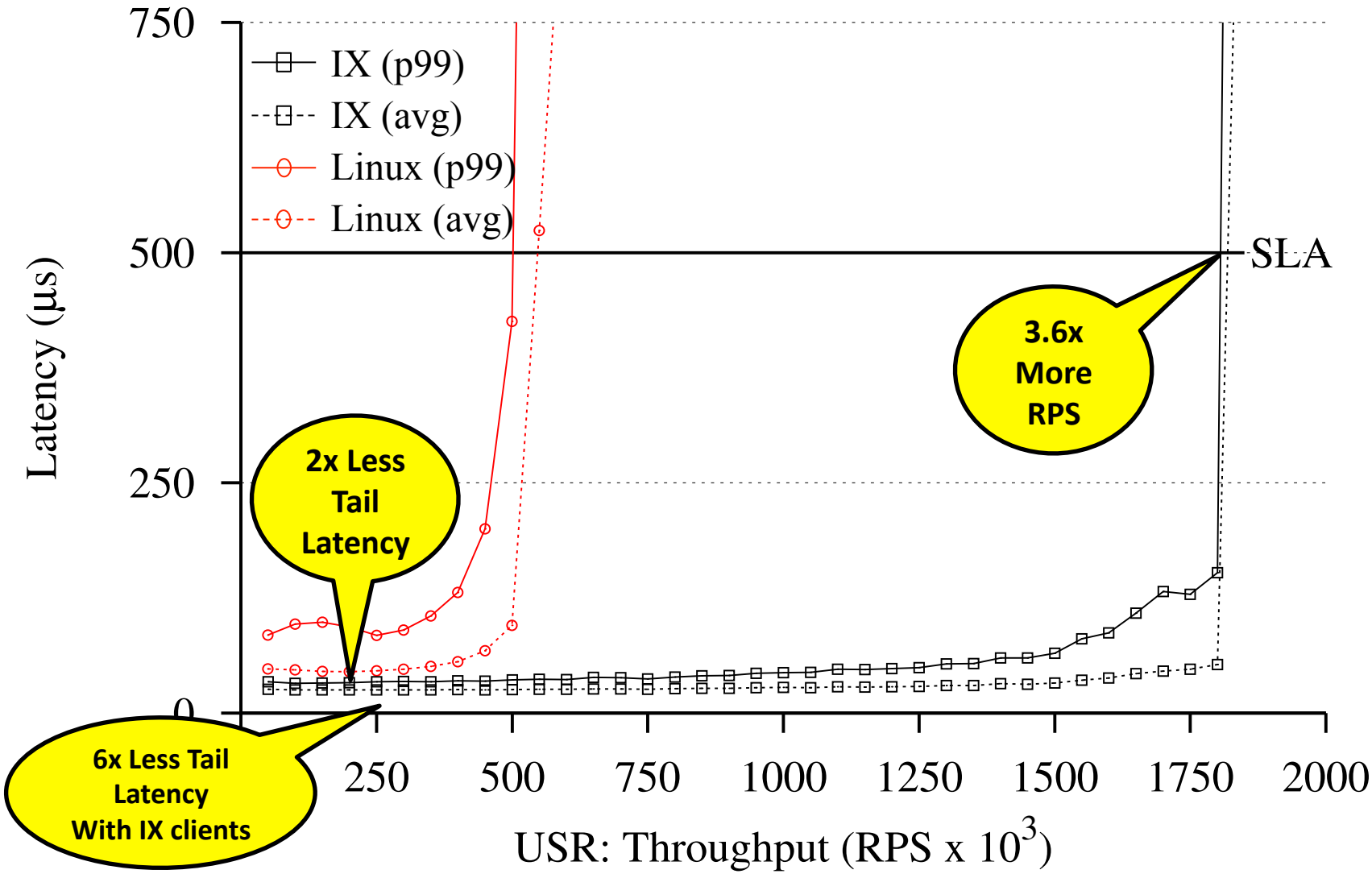
TCP Echo: Multicore Scalability for Short Connections



Connection Scalability



Memcached over TCP



IX Conclusion

- A protected dataplane OS for datacenter applications with an event-driven model and demanding connection scalability requirements
- Efficient access to HW, without sacrificing security, through virtualization
- High throughput and low latency enabled by a dataplane execution model