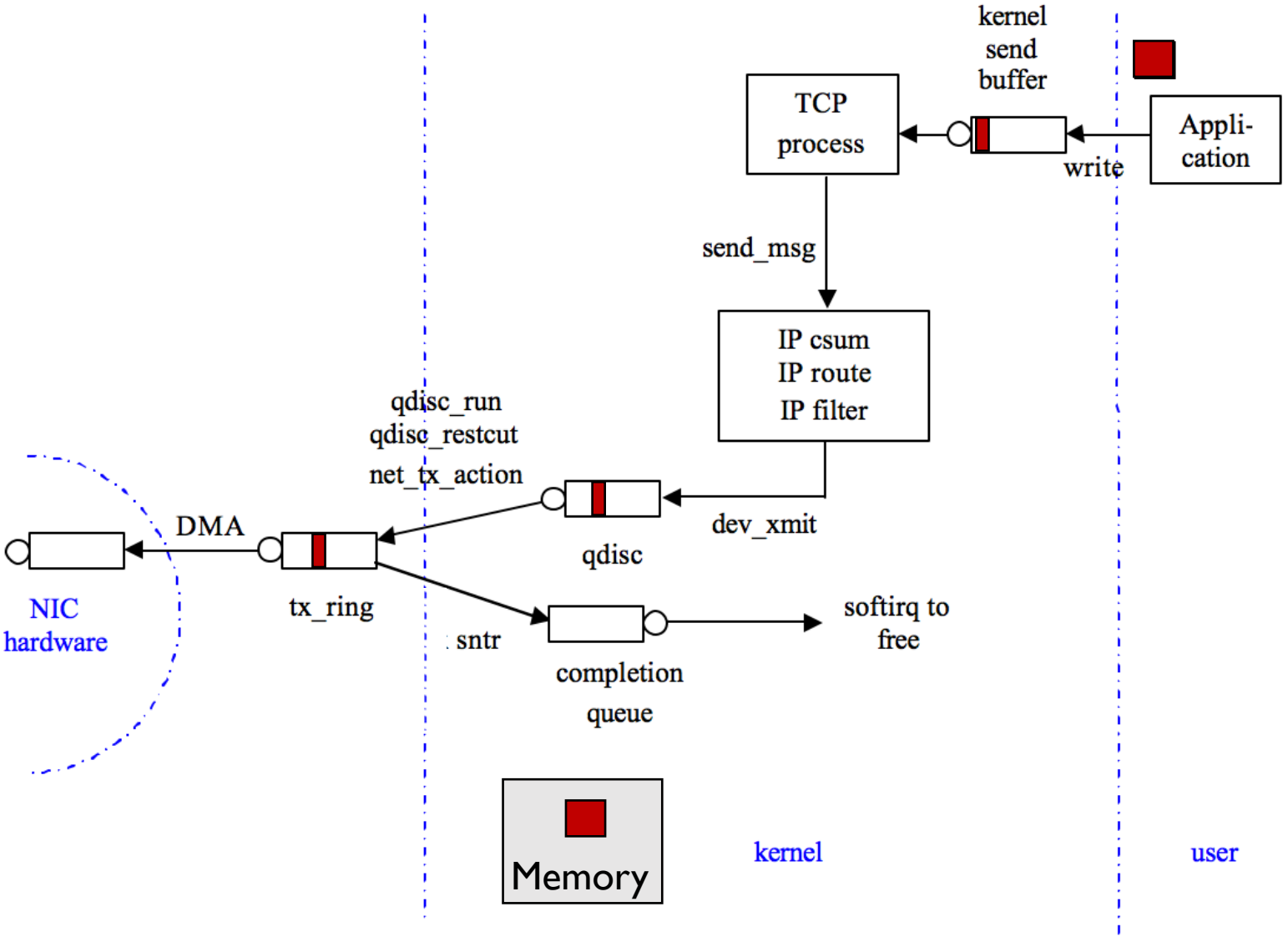
High Performance Network Stack

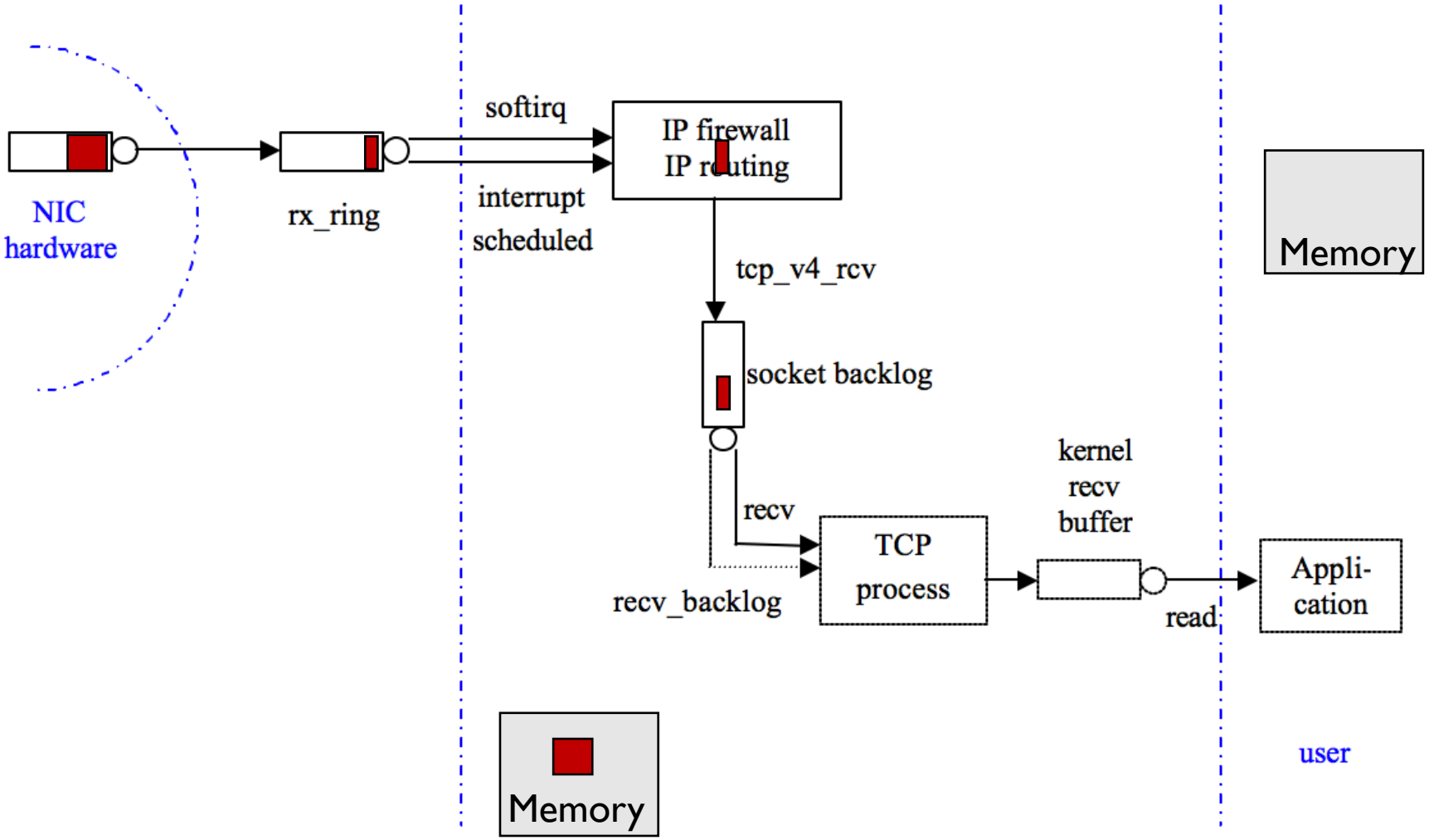
ECE/CS598HPN

Radhika Mittal

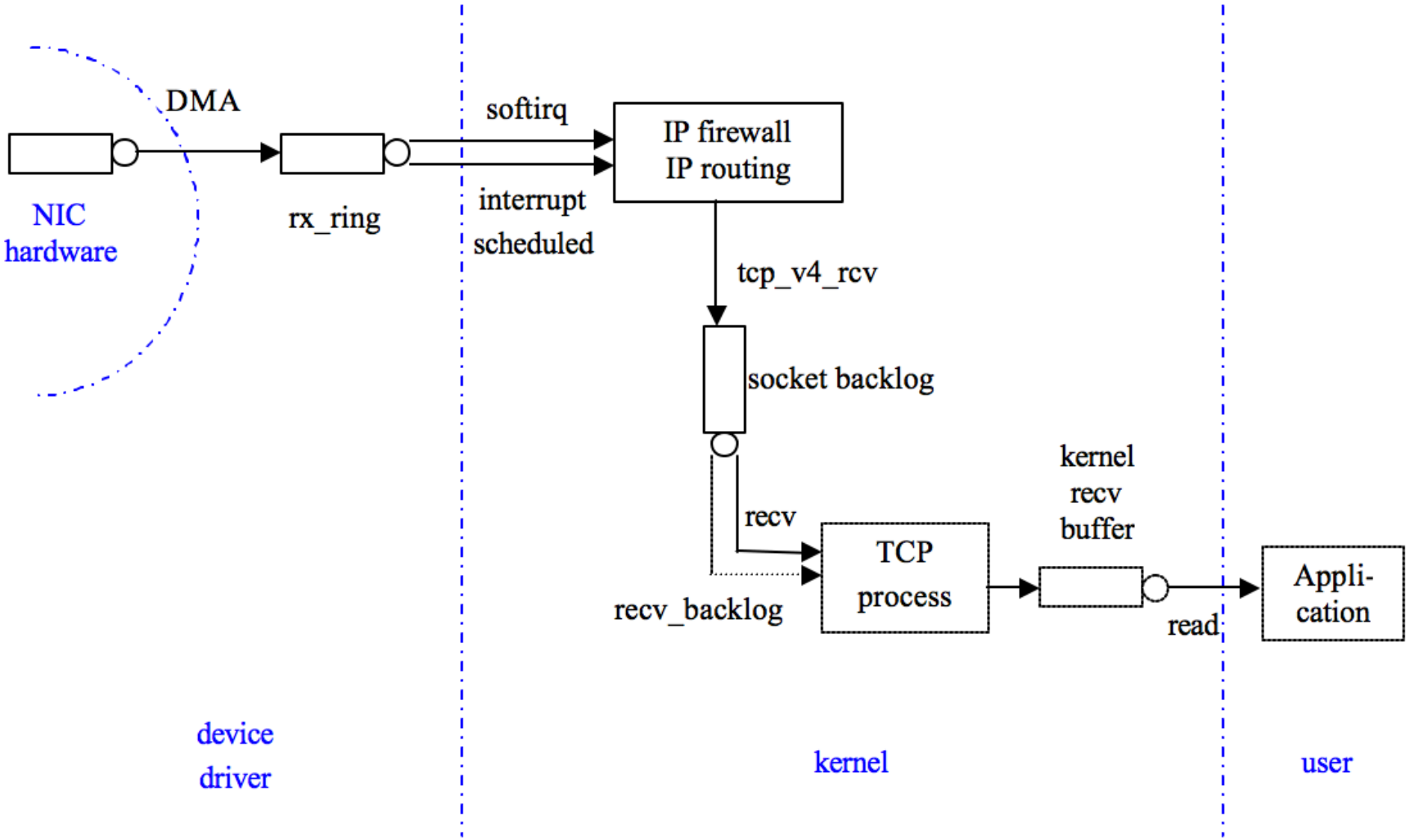
Tx Processing in the kernel



Rx Processing in the kernel



Rx Processing in the kernel



What are some sources of performance overheads?

MegaPipe: A New Programming Interface for Scalable Network I/O

Sangjin Han, Scott Marshal,
Byung-Gon Chun, Sylvia Ratnasamy

OSDI'12

Content borrowed from Sangjin's OSDI talk

Two Types of Network Workloads

- **Bulk Transfer**
  - Large files (HDFS)

- **Message-oriented**
  - Short connections or small messages (HTTP, RPCs, DB, key-value stores, etc)

Two Types of Network Workloads

- **Bulk Transfer**
  - Large files (HDFS)
  - A half CPU core can saturate 10Gbps link
- **Message-oriented**
  - Short connections or small messages (HTTP, RPCs, DB, key-value stores, etc)
  - CPU-intensive

BSD Socket API Performance Issues

```
n_events = epoll_wait(…);    // wait for I/O readiness
for (…) {
    …
    new_fd = accept(listen_fd); //  new connection
    …
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- Issues with message-oriented workloads
  - System call overhead

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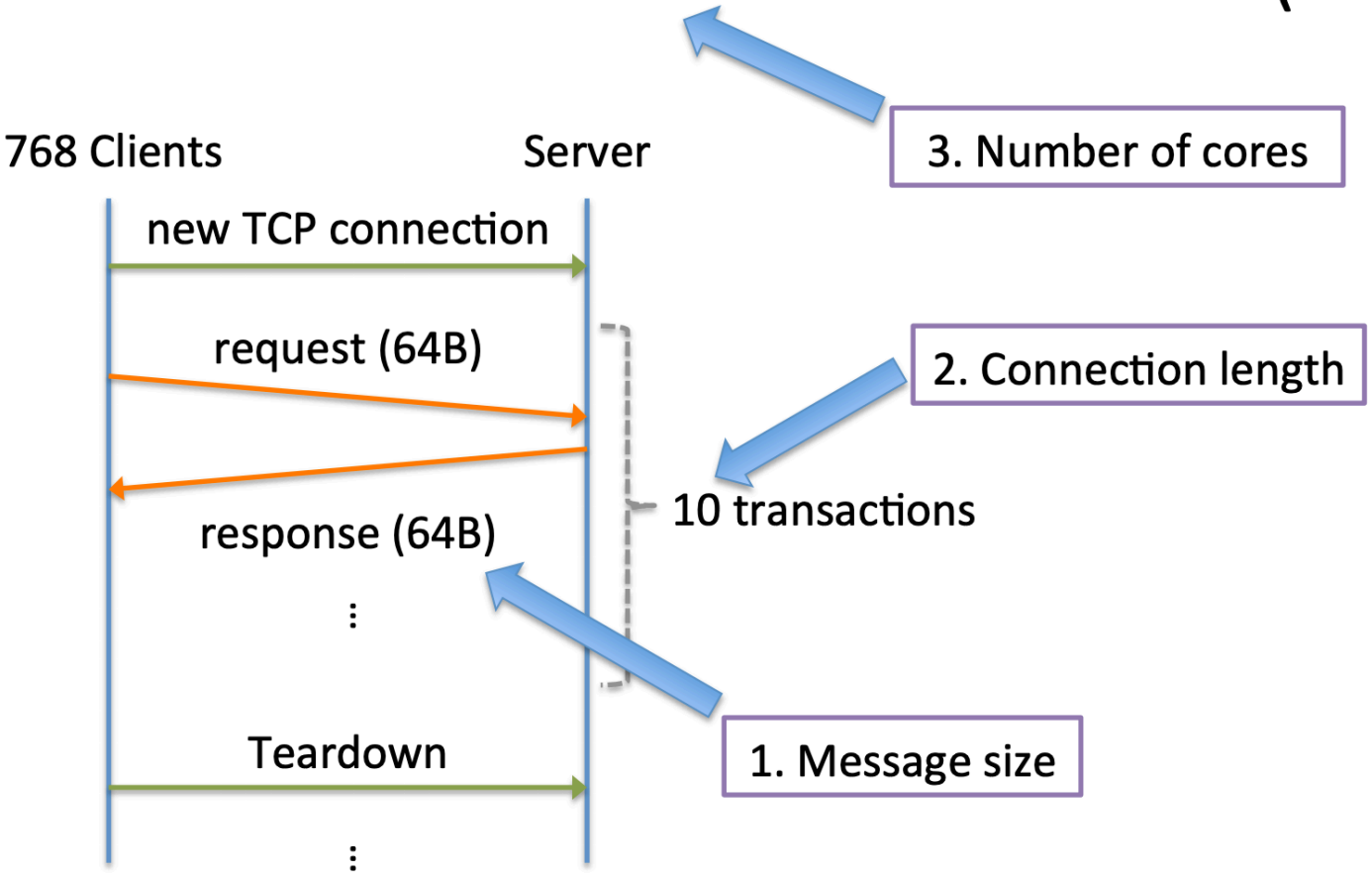
- Issues with message-oriented workloads
  - System call overhead
  - Shared listening socket
  - File abstraction overhead

Microbenchmarks: how bad?

RPC-like test on an 8-core Linux server (with epoll)



Microbenchmarks: how bad?

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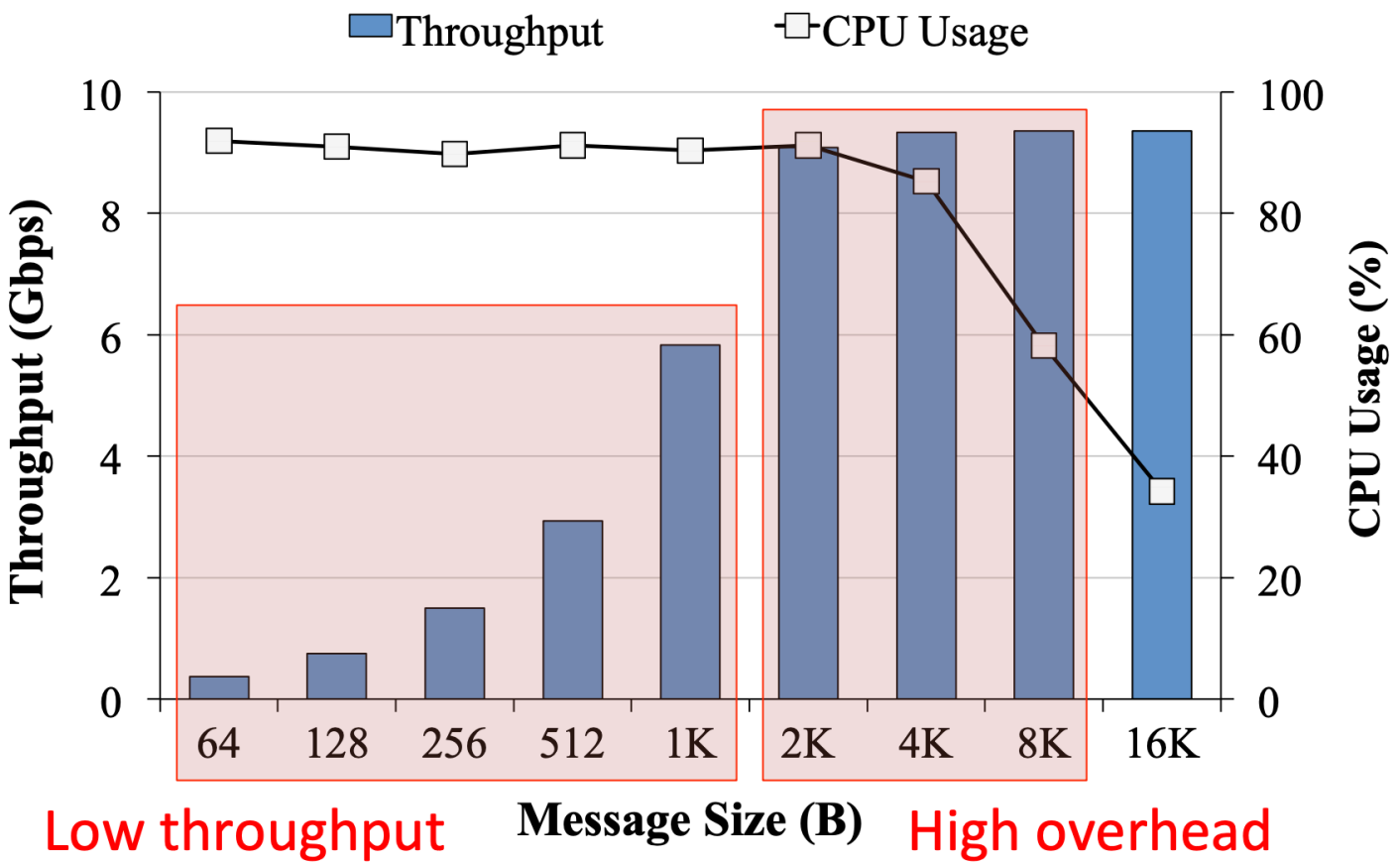

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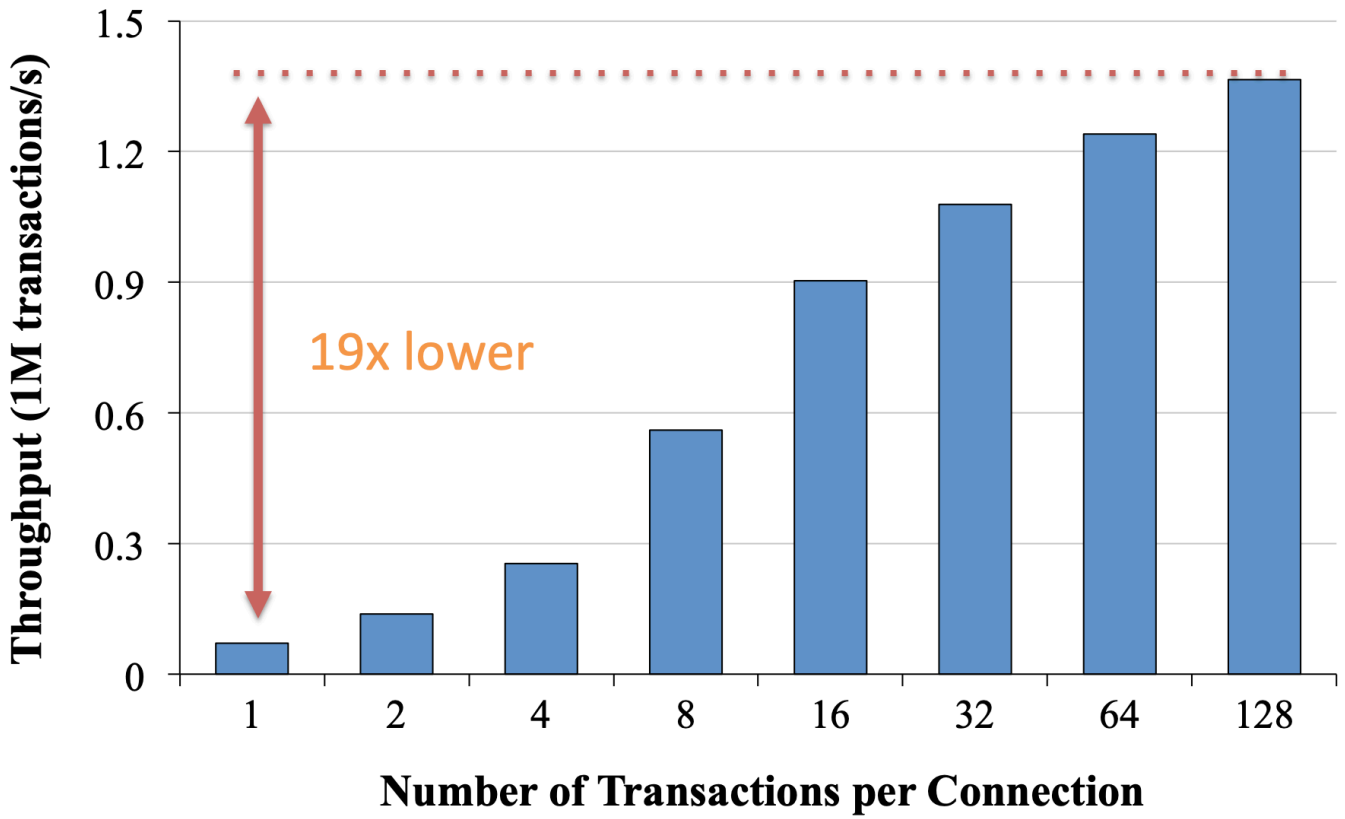
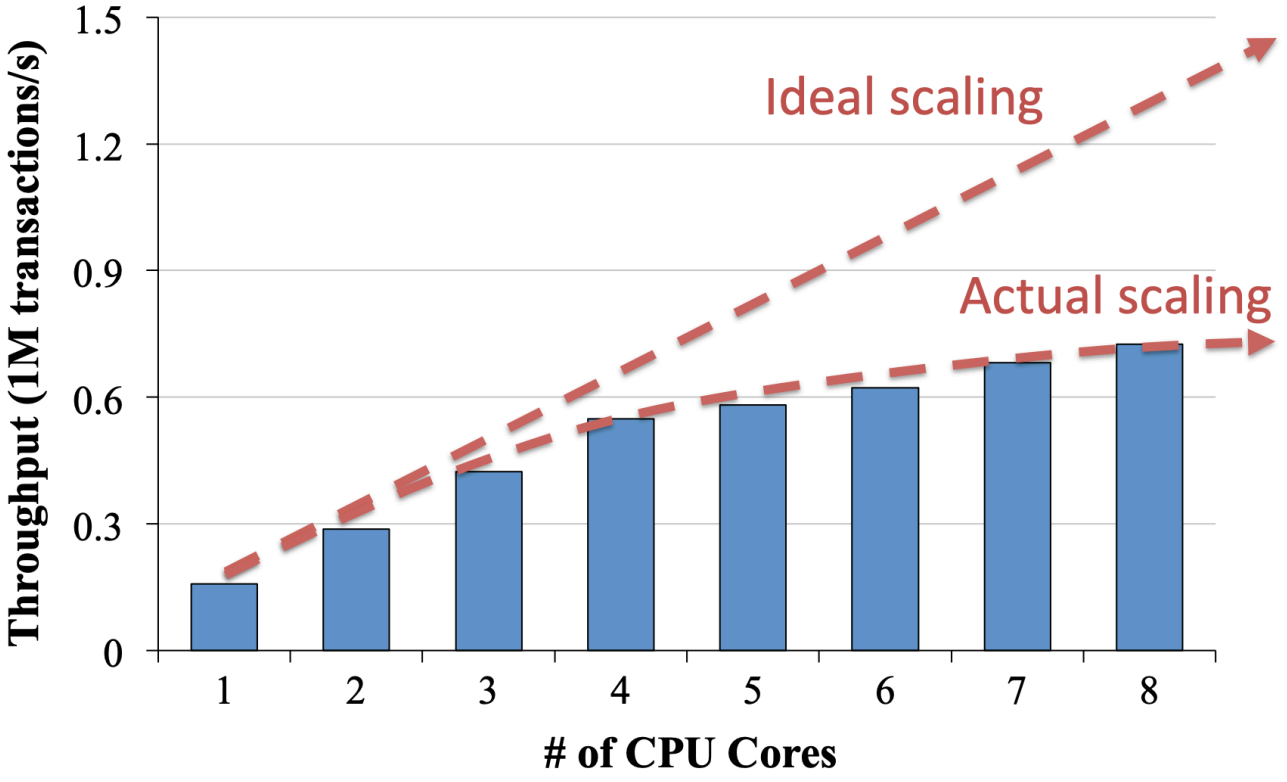


Microbenchmarks: how bad?

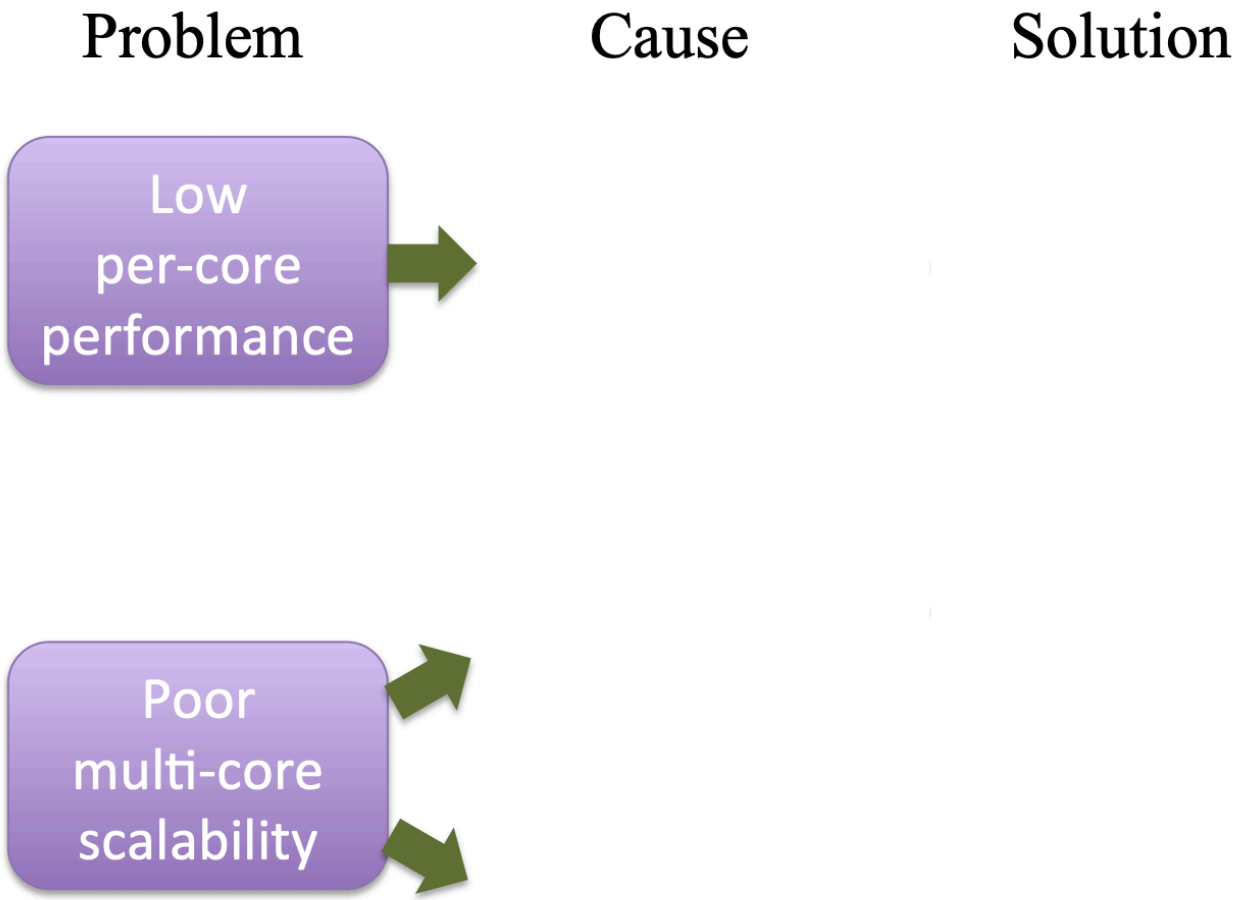
3. Multi-Core Will Not Help (Much)



MegaPipe Design

Focus: low-overhead and multi-core scalability.

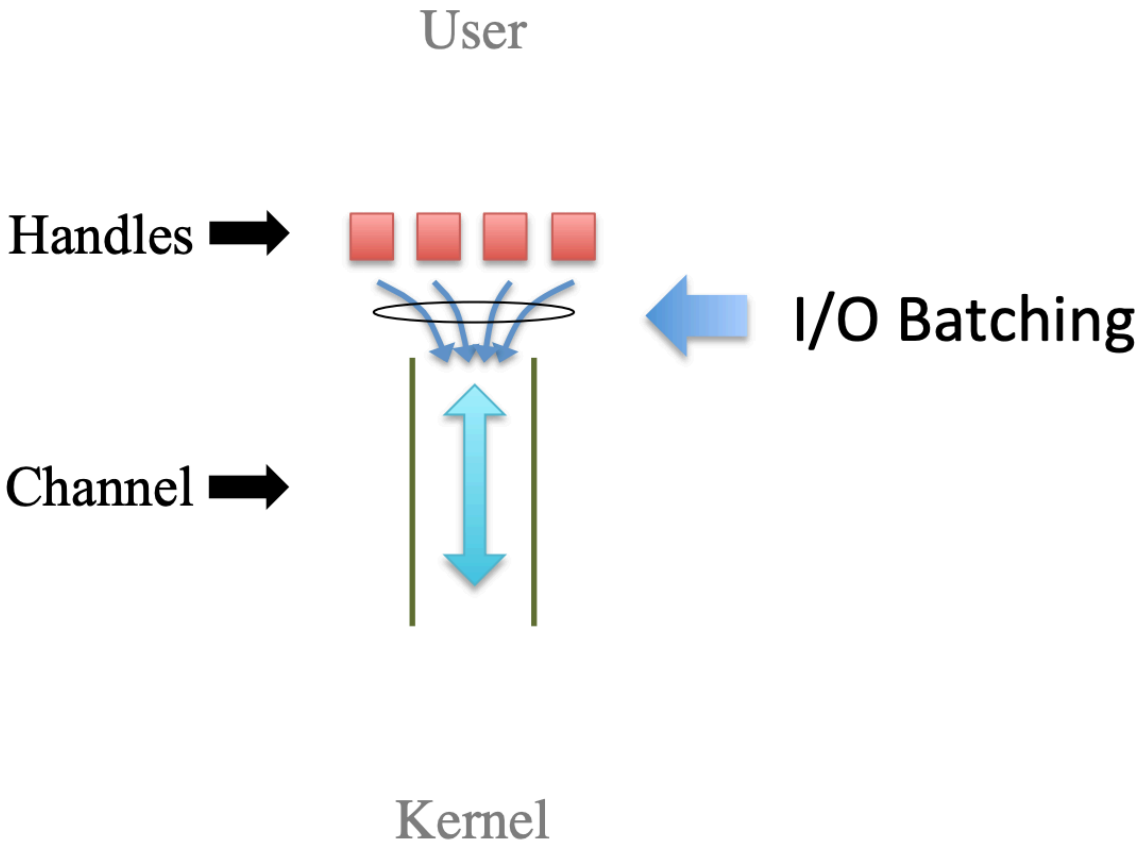
MegaPipe: Overview



Key Primitives

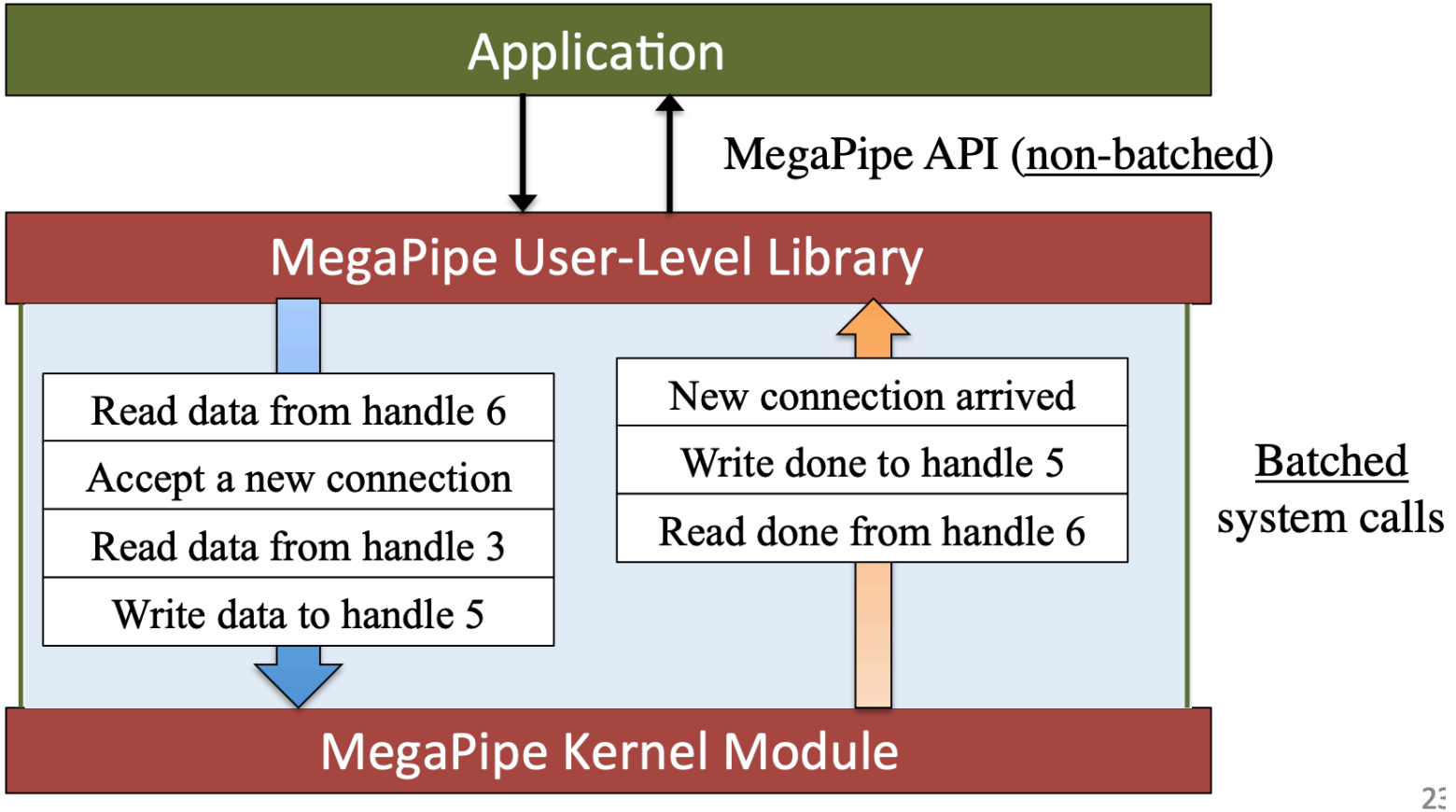
- Handle
  - Similar to file descriptor
    - But only valid within a channel
  - TCP connection, pipe, disk file, …
- Channel
  - Per-core, bidirectional pipe between user and kernel
  - Multiplexes I/O operations of its handles

How channels help?



1. I/O Batching

- Transparent batching
  - Exploits parallelism of independent handles



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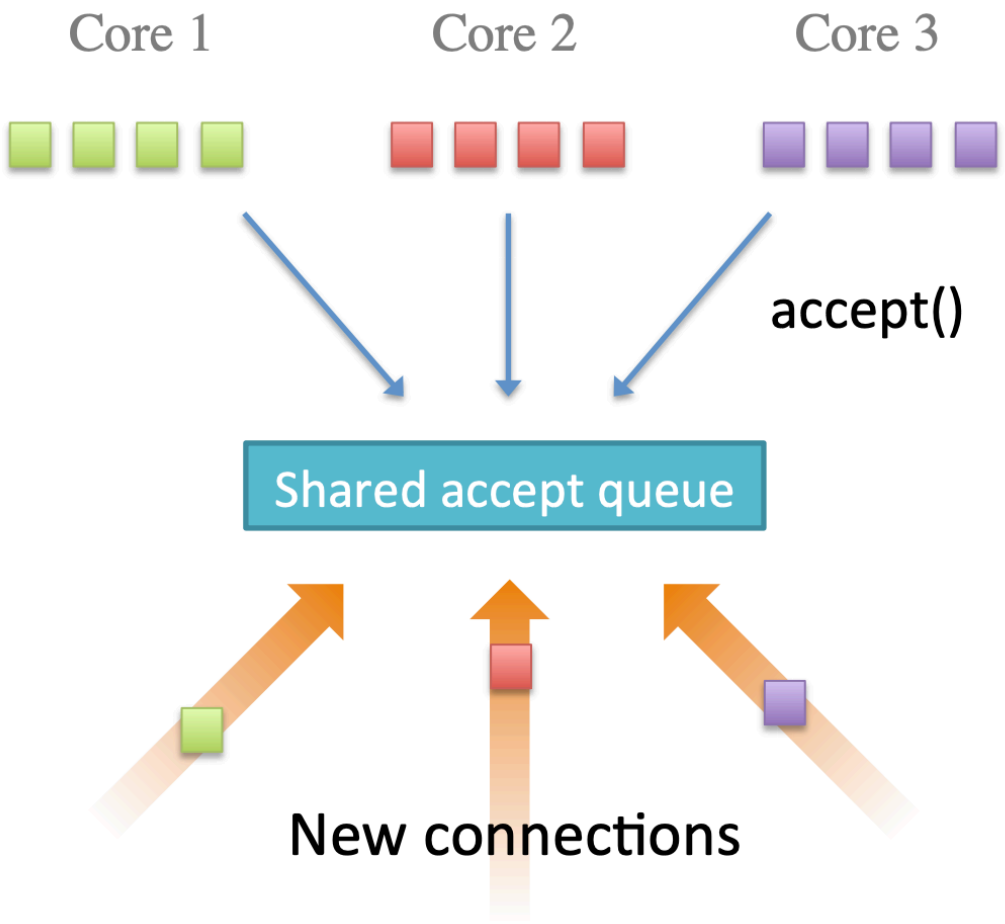

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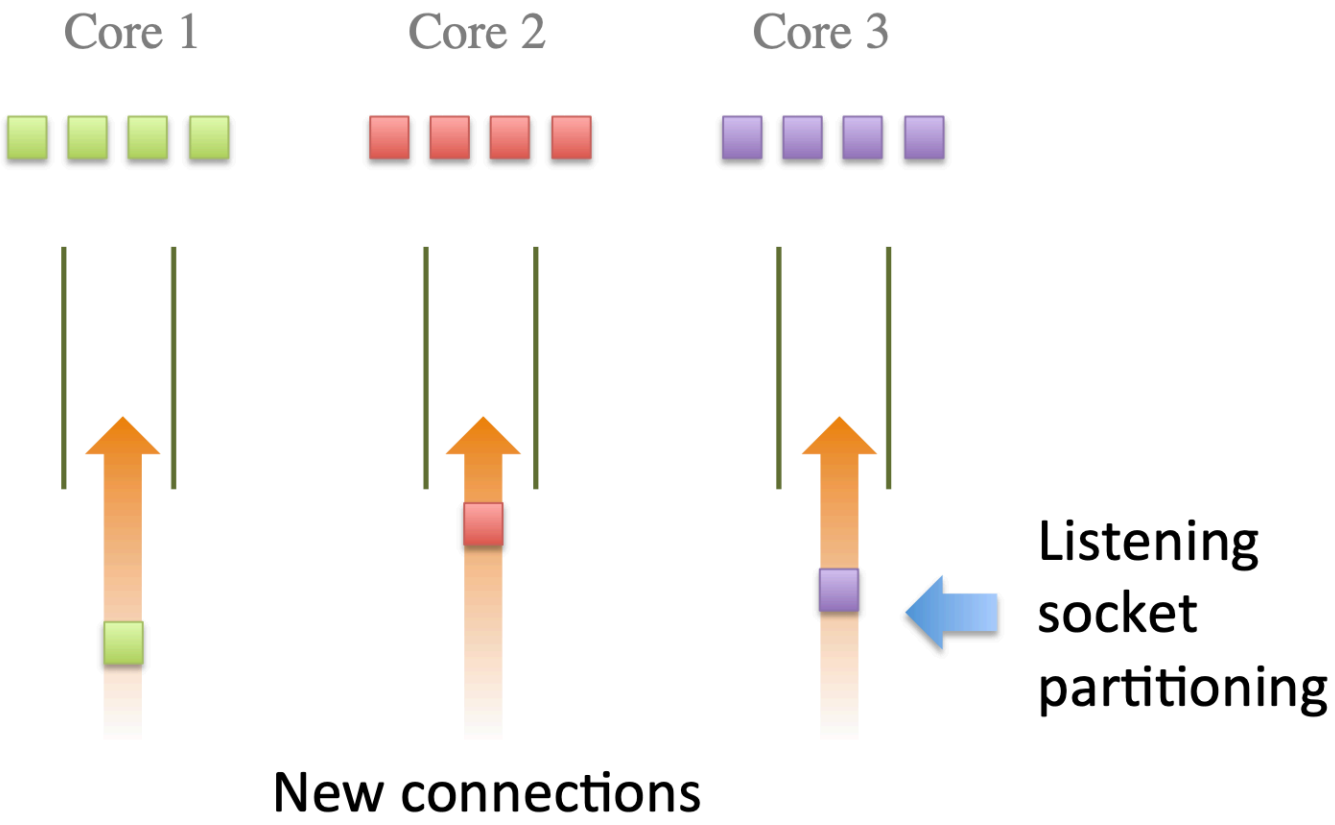
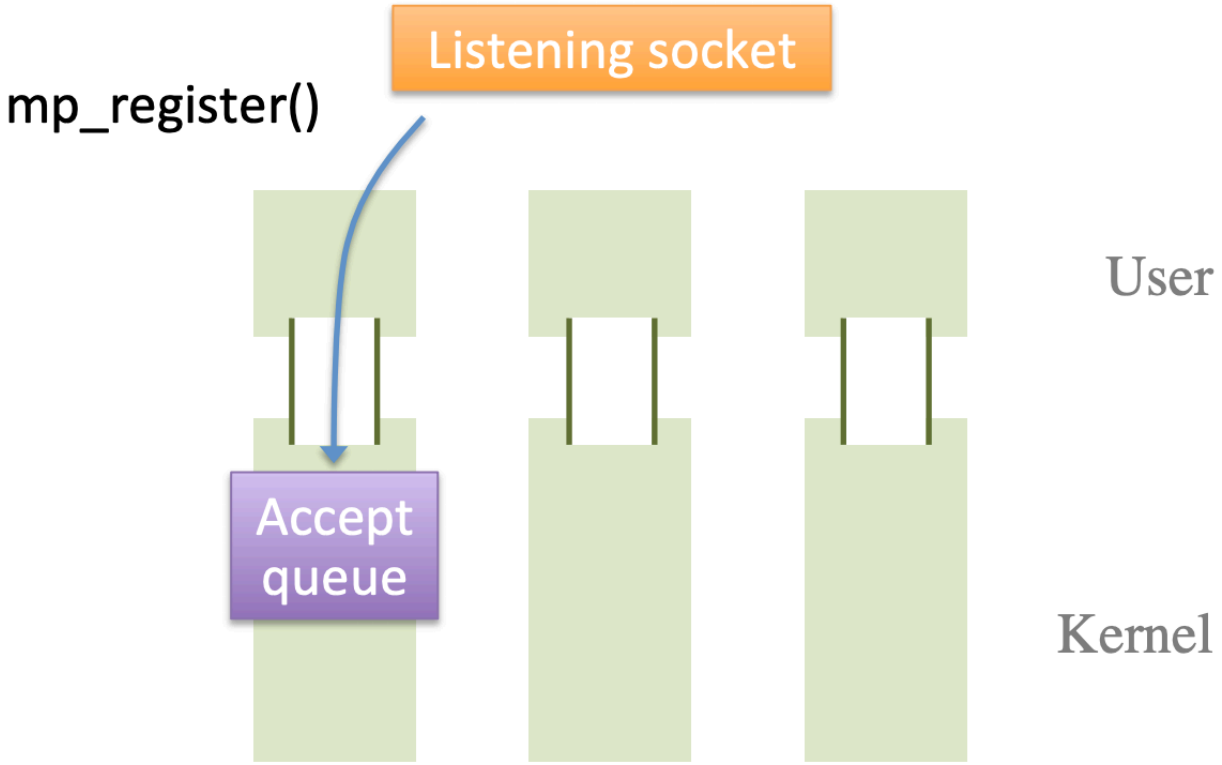


2. Listening Socket Partitioning

- Per-core accept queue for each channel
  - Instead of the globally shared accept queue



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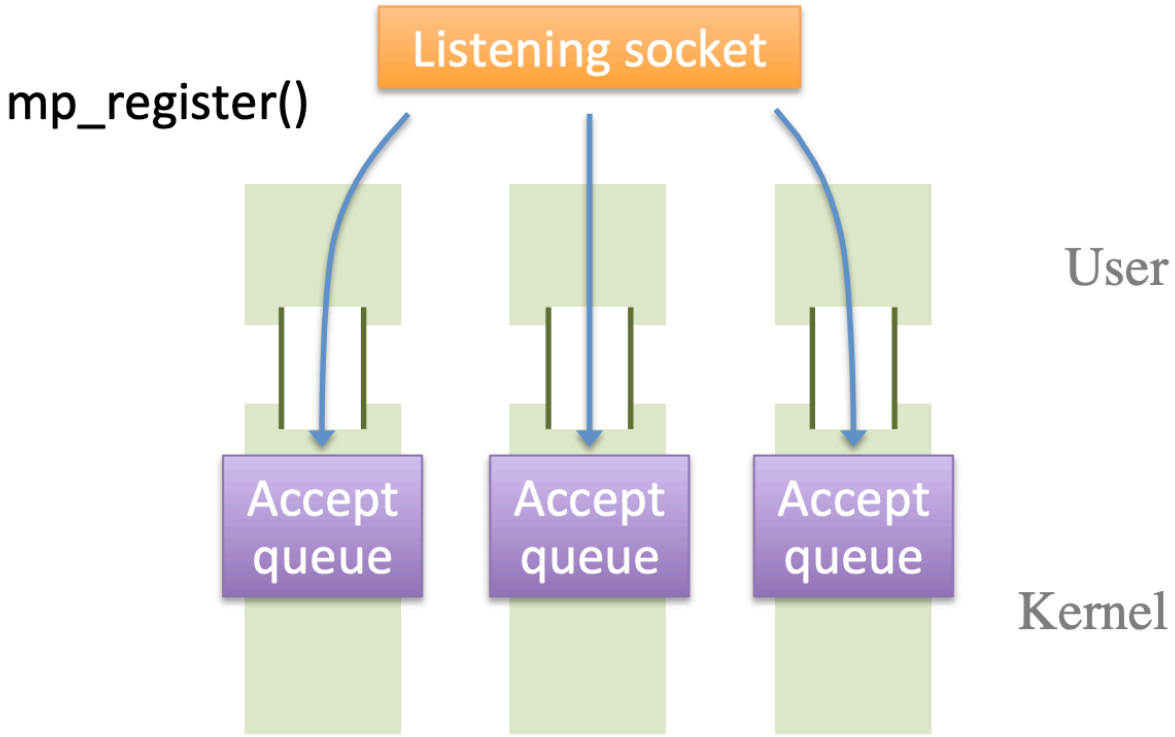

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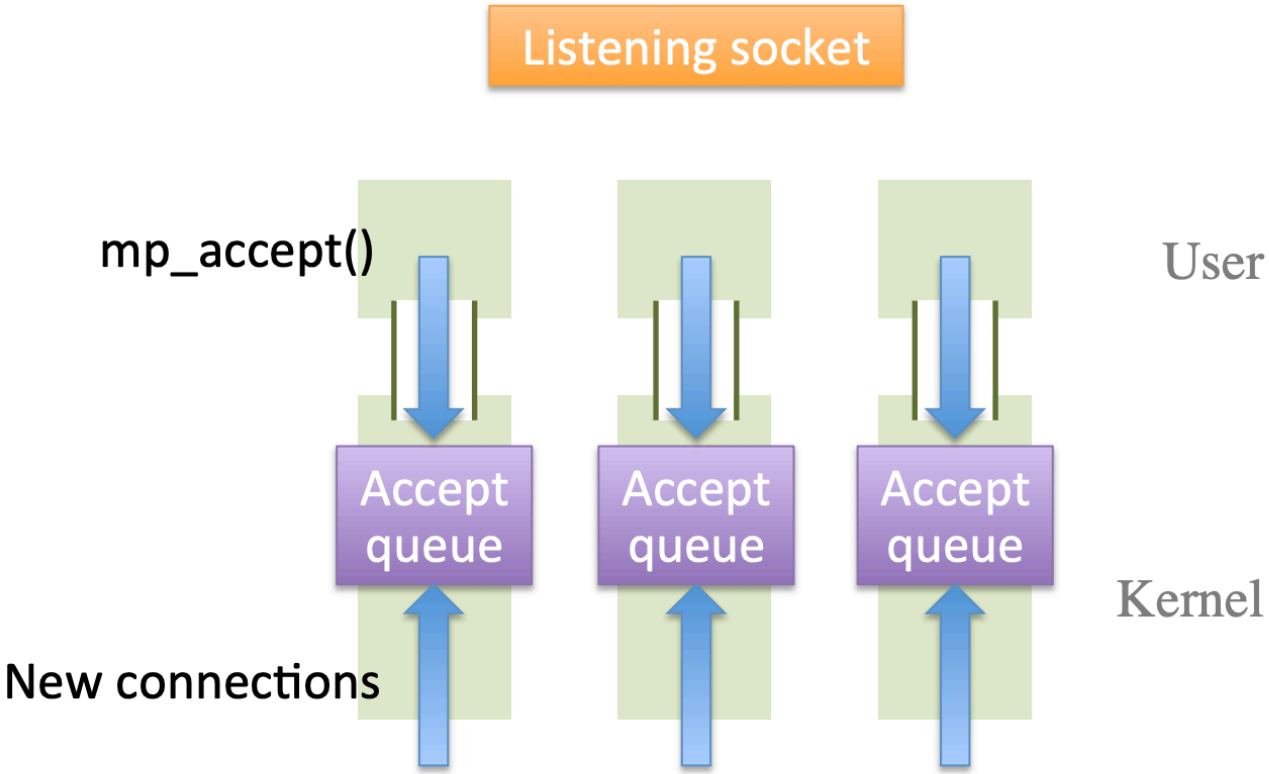

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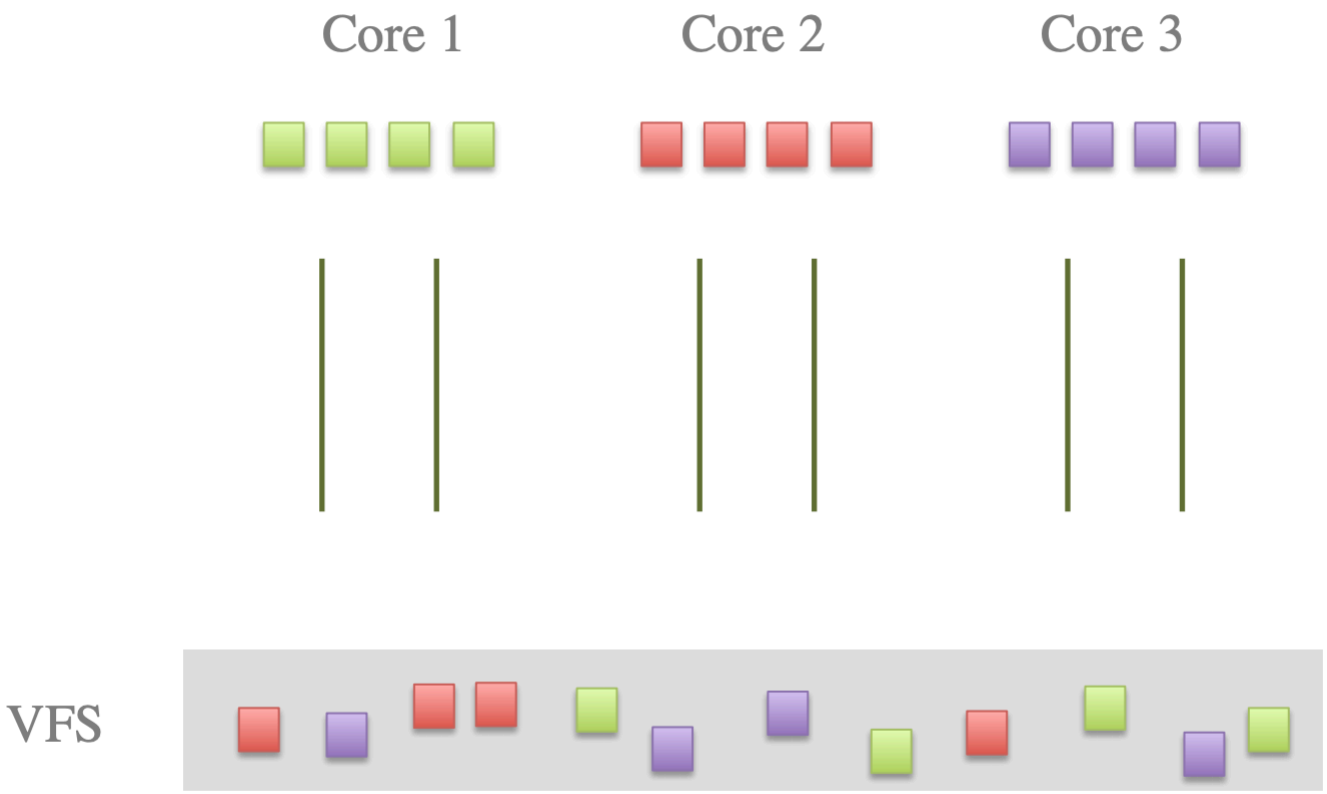

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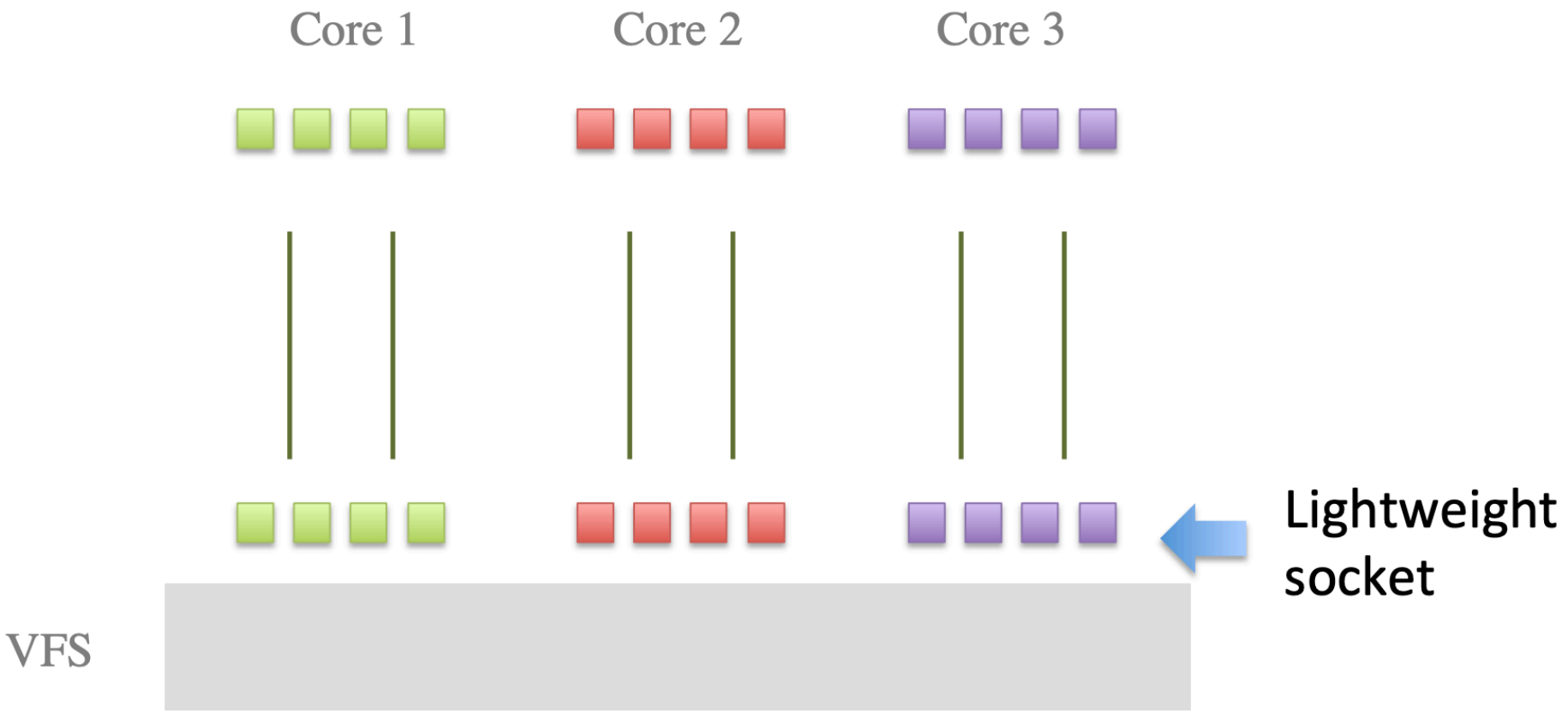
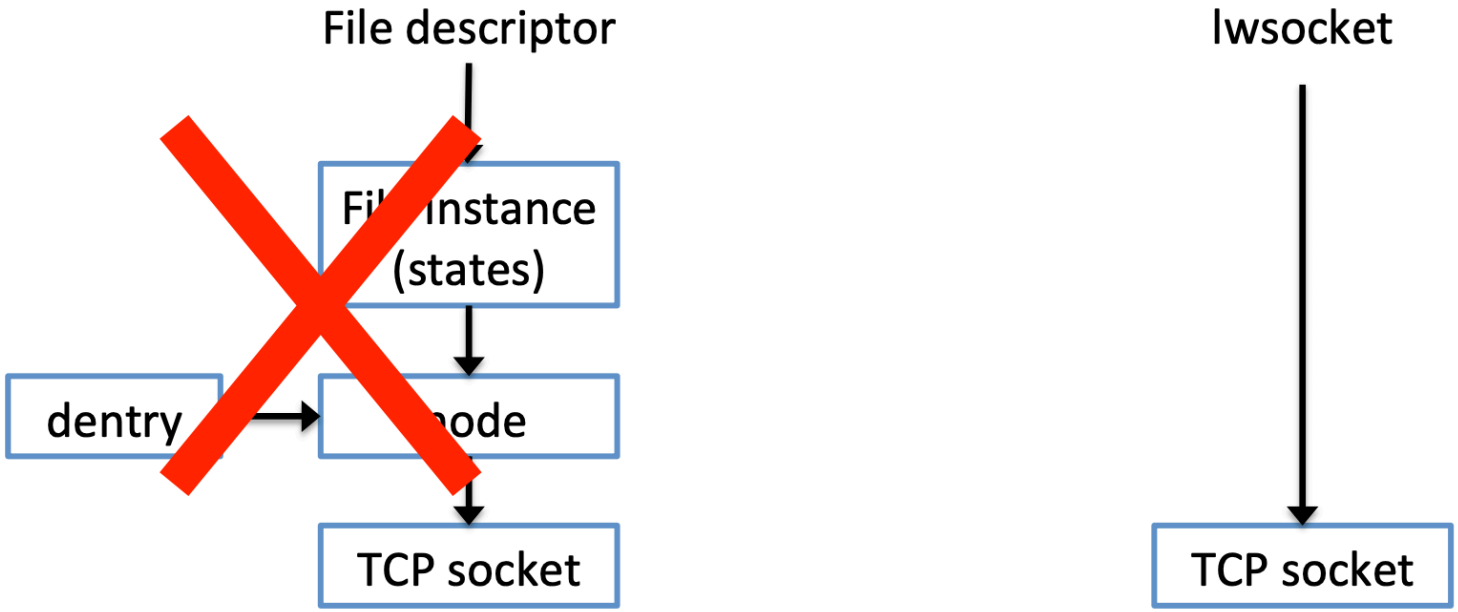


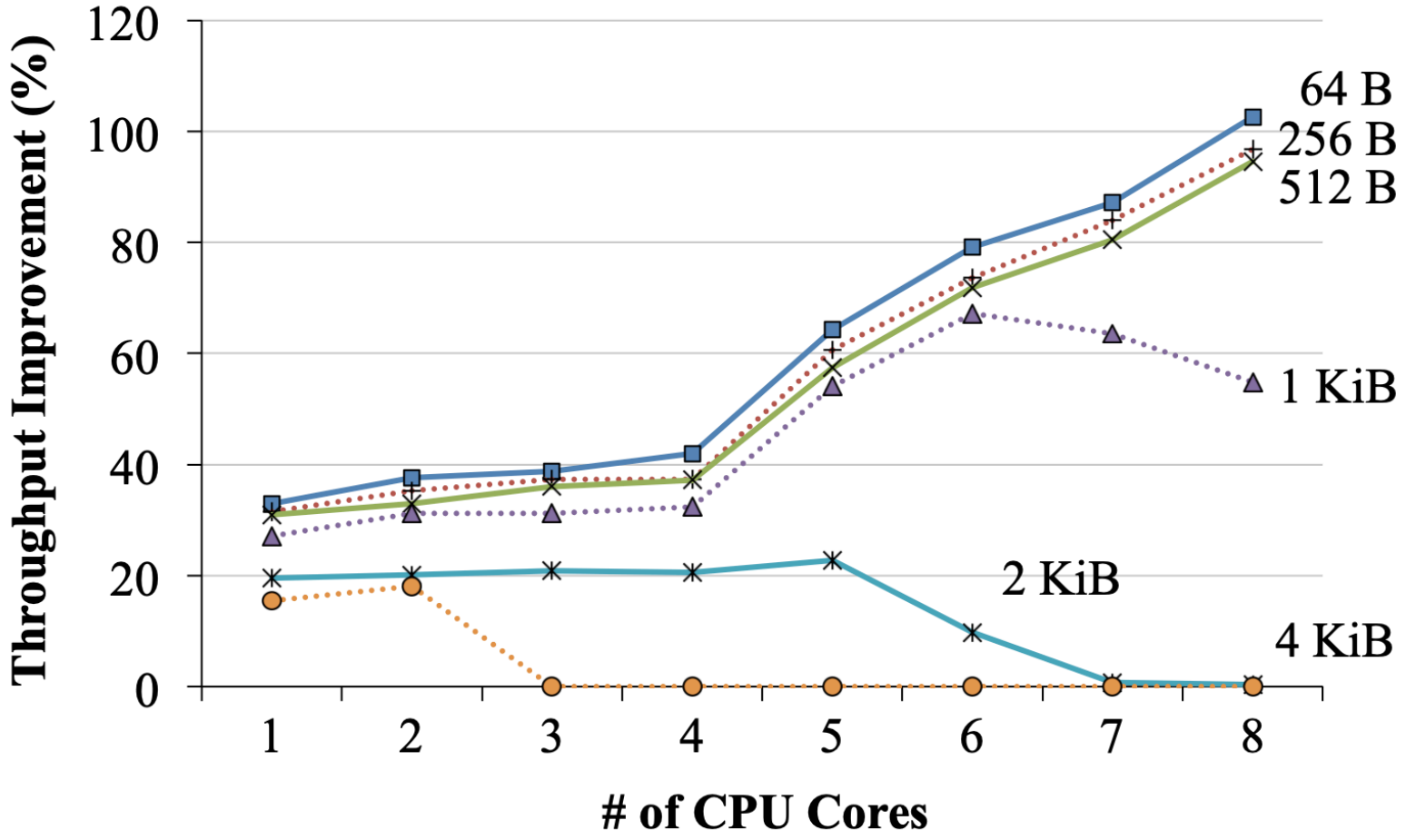
3. Light-weight Sockets

- Common-case optimization for sockets
  - Sockets are ephemeral and rarely shared
    - Bypass the VFS layer
    - Convert into a regular file descriptor only when necessary



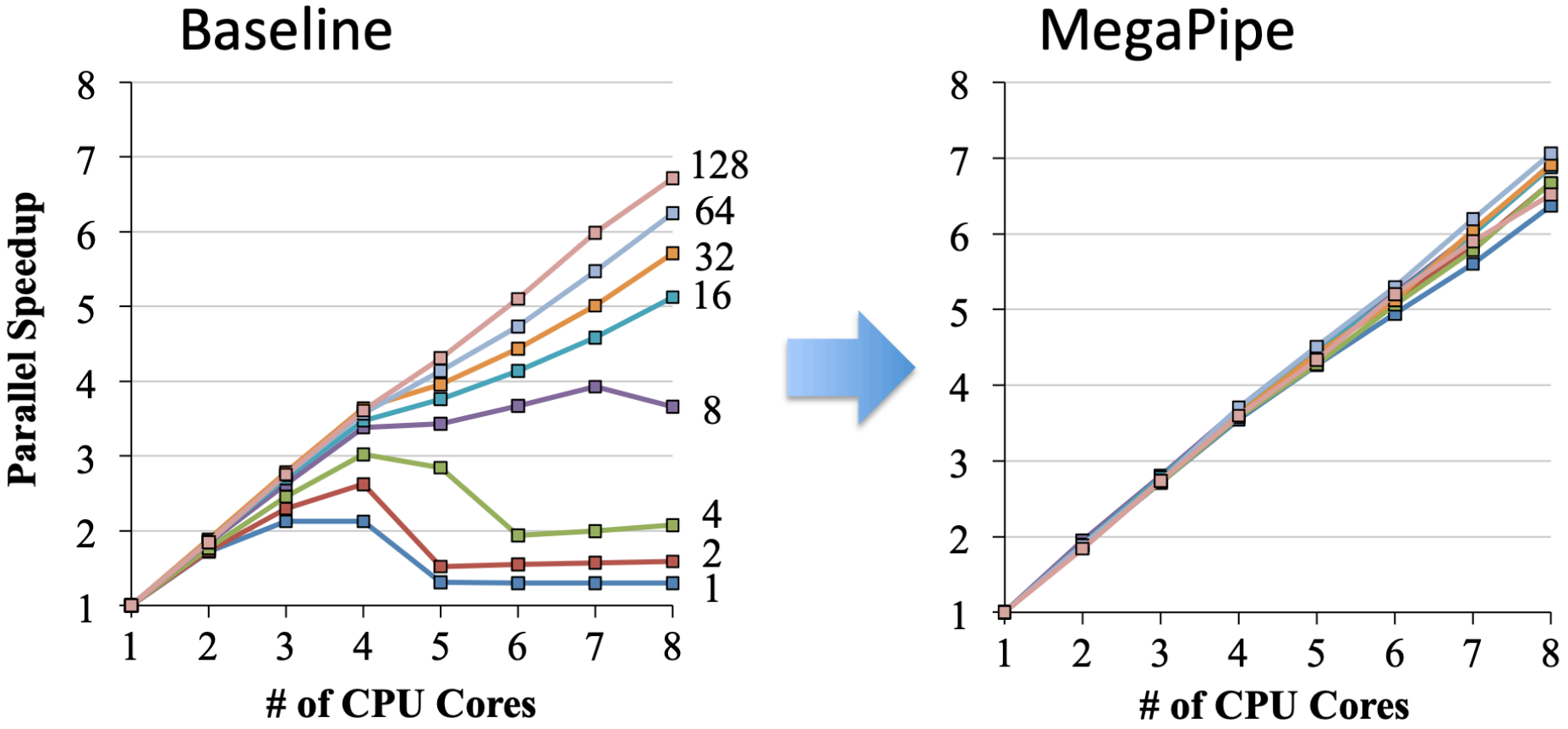
Evaluation: Microbenchmarks

- Throughput improvement with various message sizes



Evaluation: Microbenchmarks

- Multi-core scalability
  - with various connection lengths (# of transactions)



Evaluation: Macrobenchmarks

- memcached
  - In-memory key-value store
  - Limited scalability
    - Object store is shared by all cores with a global lock
- nginx
  - Web server
  - Highly scalable
    - Nothing is shared by cores, except for the listening socket

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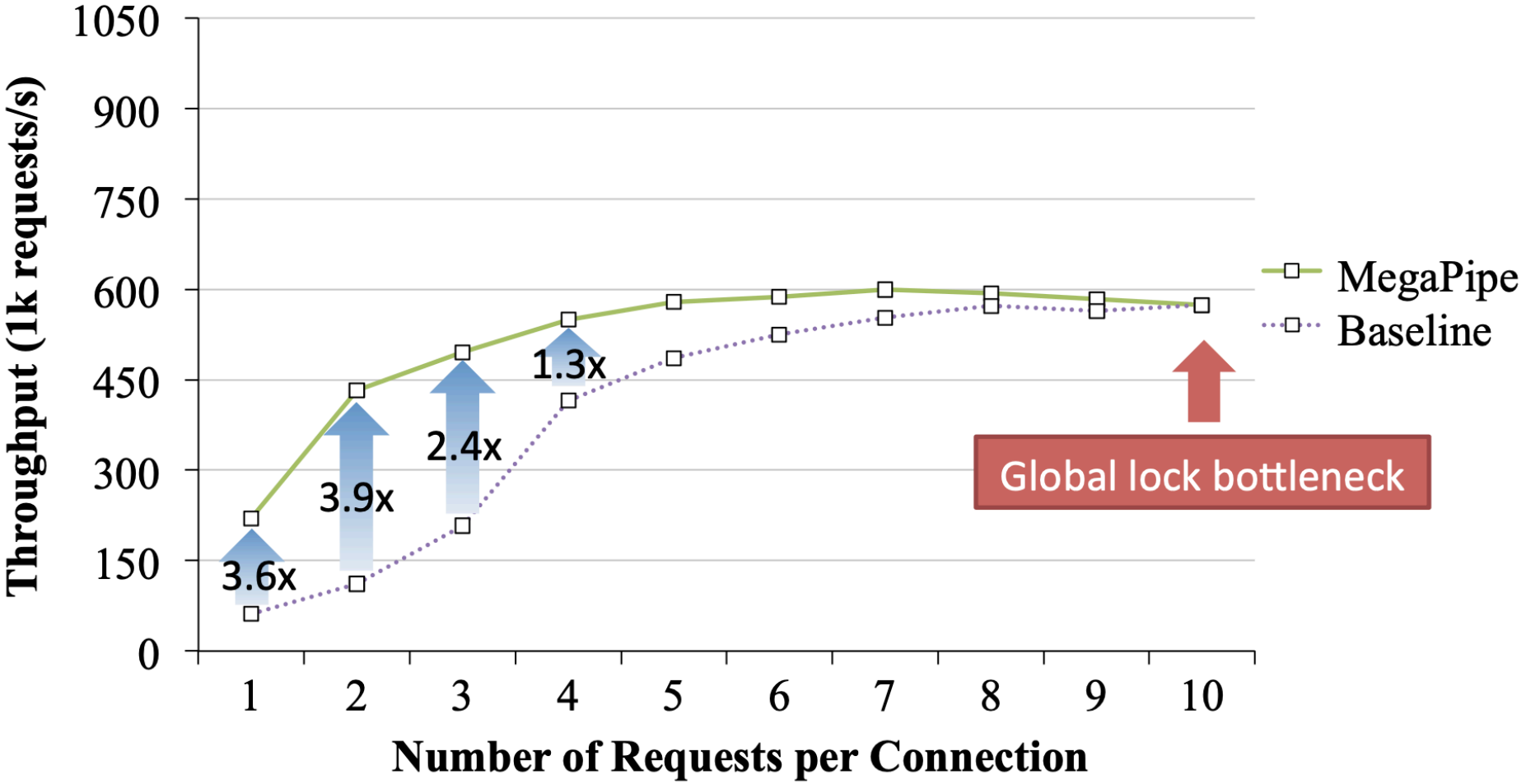

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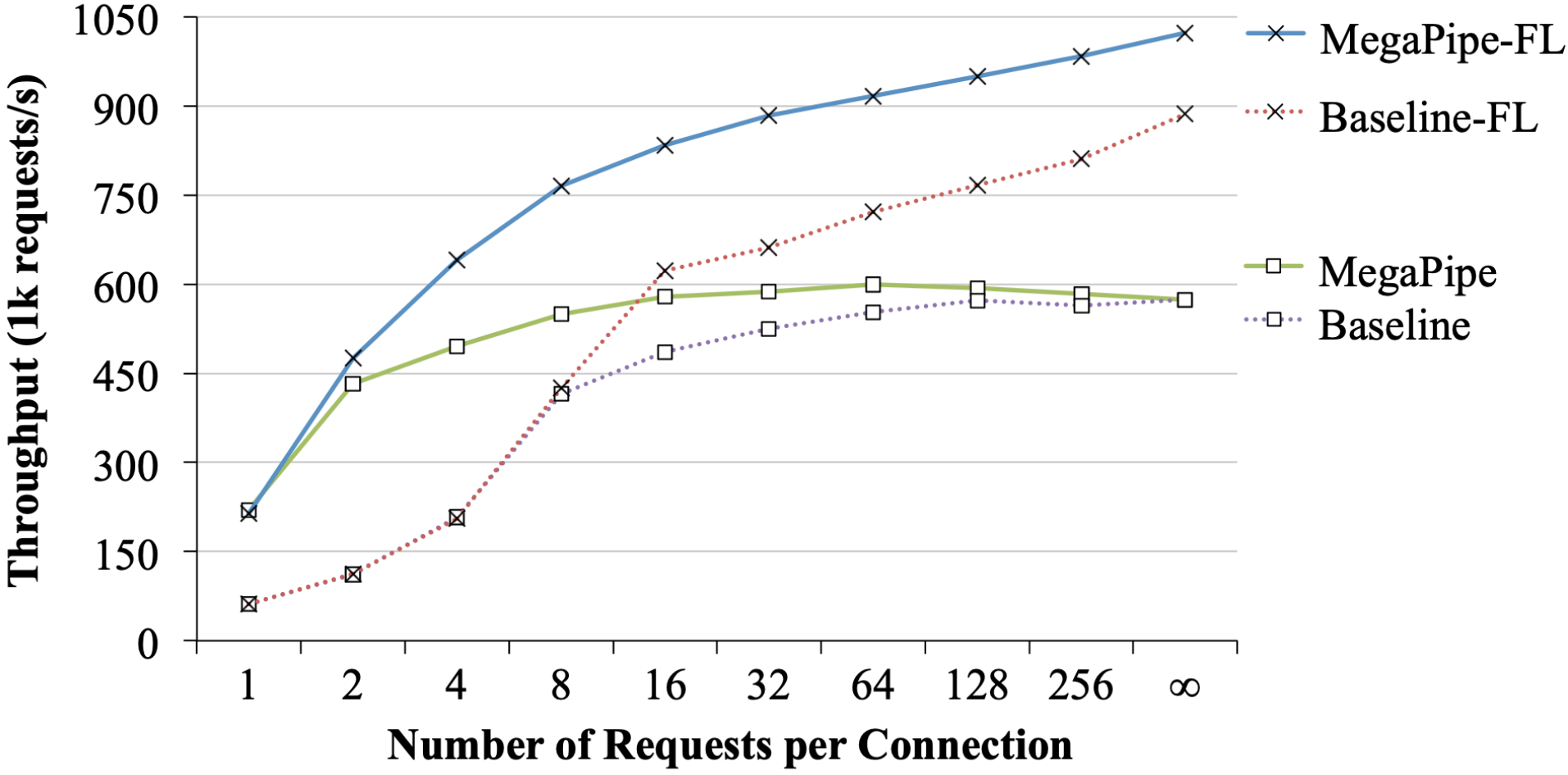
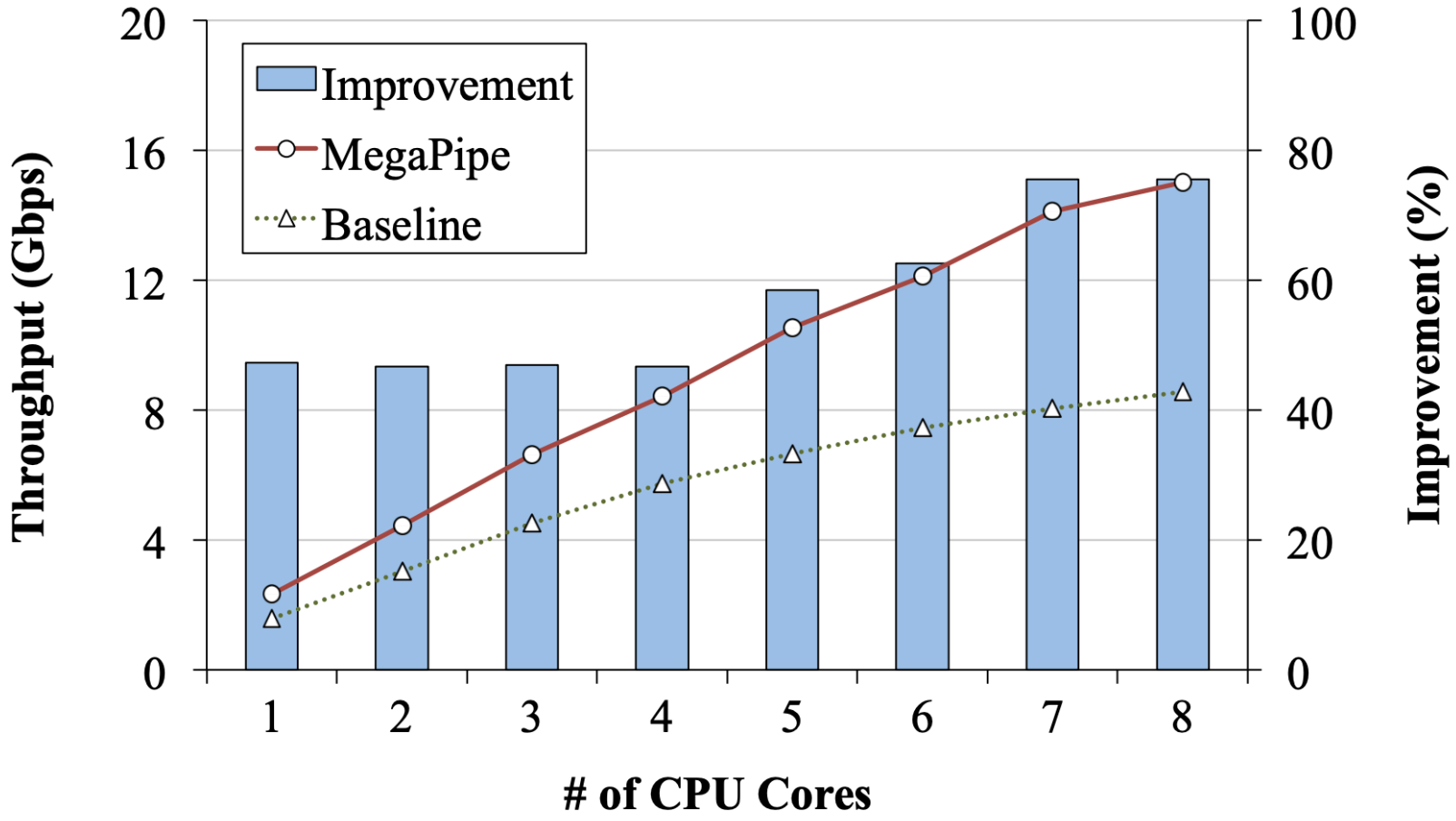


Evaluation: nginx



Conclusion

- Short connections or small messages:
  - High CPU overhead
  - Poorly scaling with multi-core CPUs
- MegaPipe
  - Key abstraction: per-core channel
  - Enabling three optimization opportunities:
    - Batching, partitioning, lwsocket
  - 15+% improvement for memcached, 75% for nginx

Your thoughts?

- What did you like about the paper?
- What are some of its limitations?
- What other sources of performance overhead remain?