The Chemistry of Concurrent and Distributed Programming Workshop
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Concurrent Data Structures: Fast but Relaxed versus Strict but Slow Semantics

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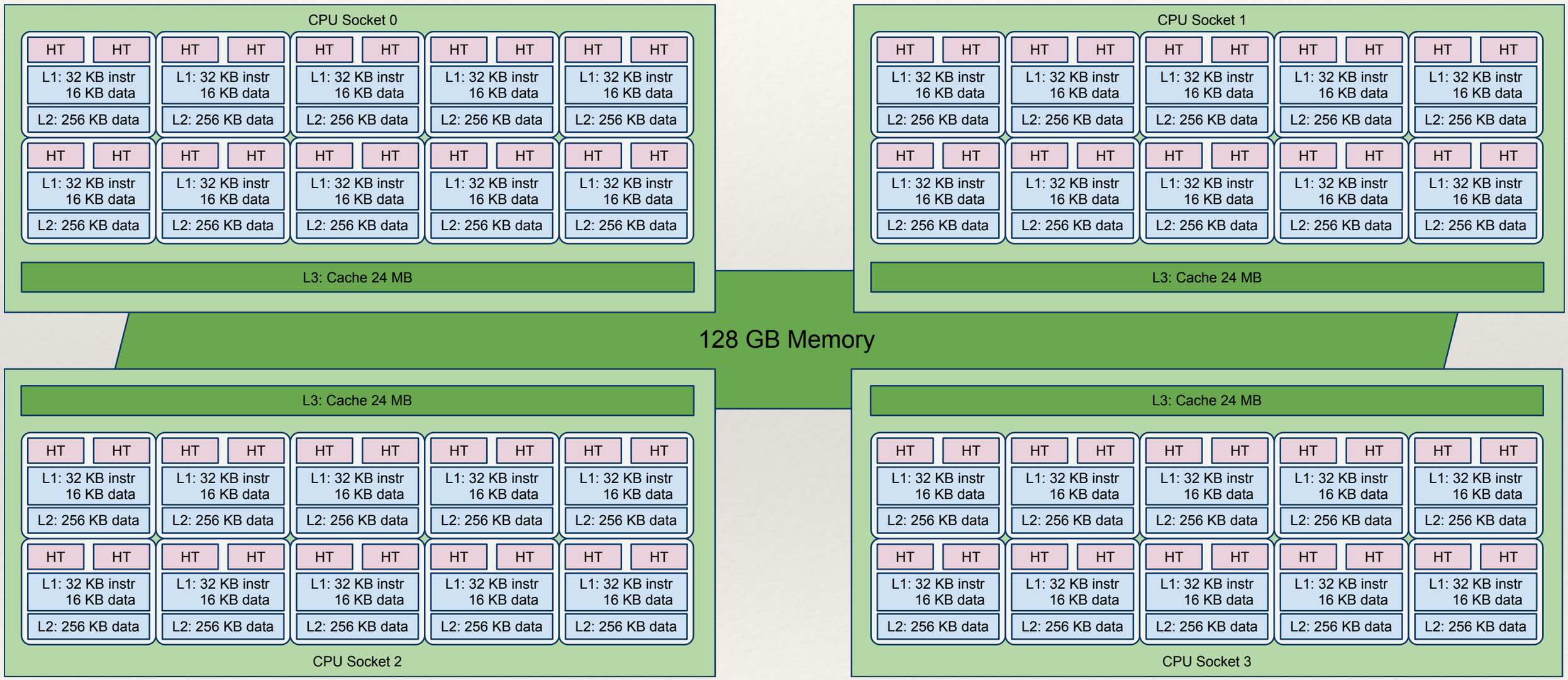
Joint work with A. Haas, M. Lippautz, H. Payer, and A. Sokolova

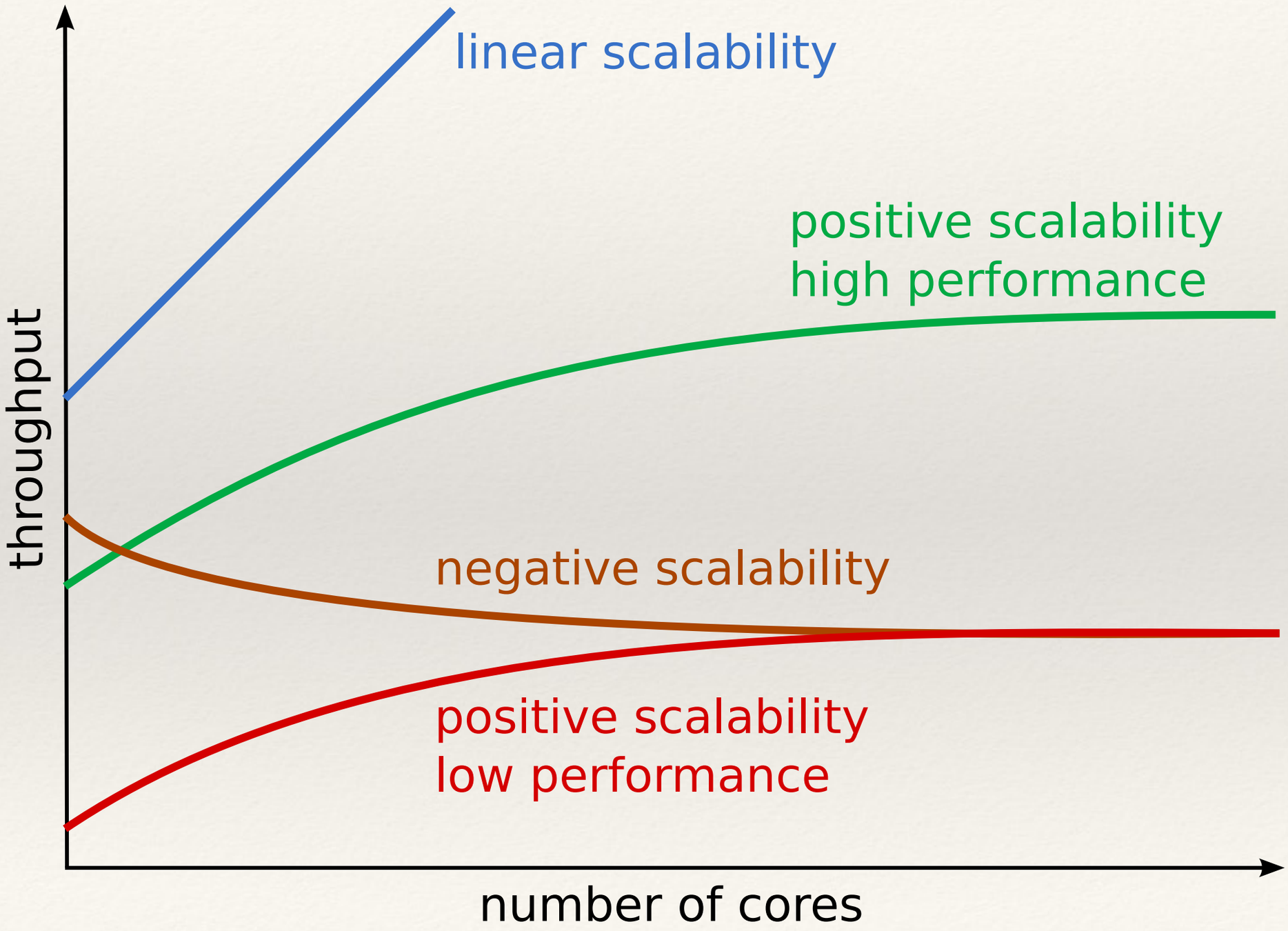
Concurrent Data Structures

- We are interested in designing and implementing concurrent data structures that are fast and scale on multicore hardware.

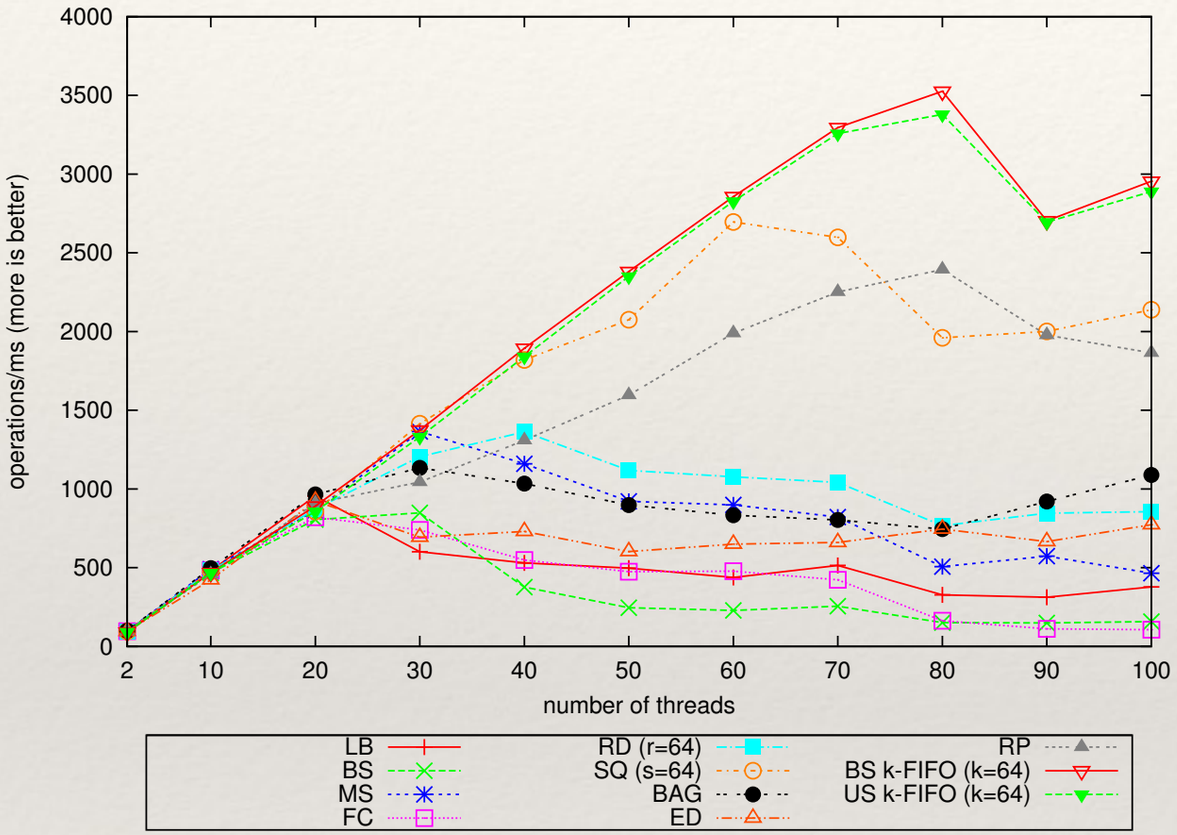
4 Processors w/ 10 Cores each w/ 2 Hyperthreads each



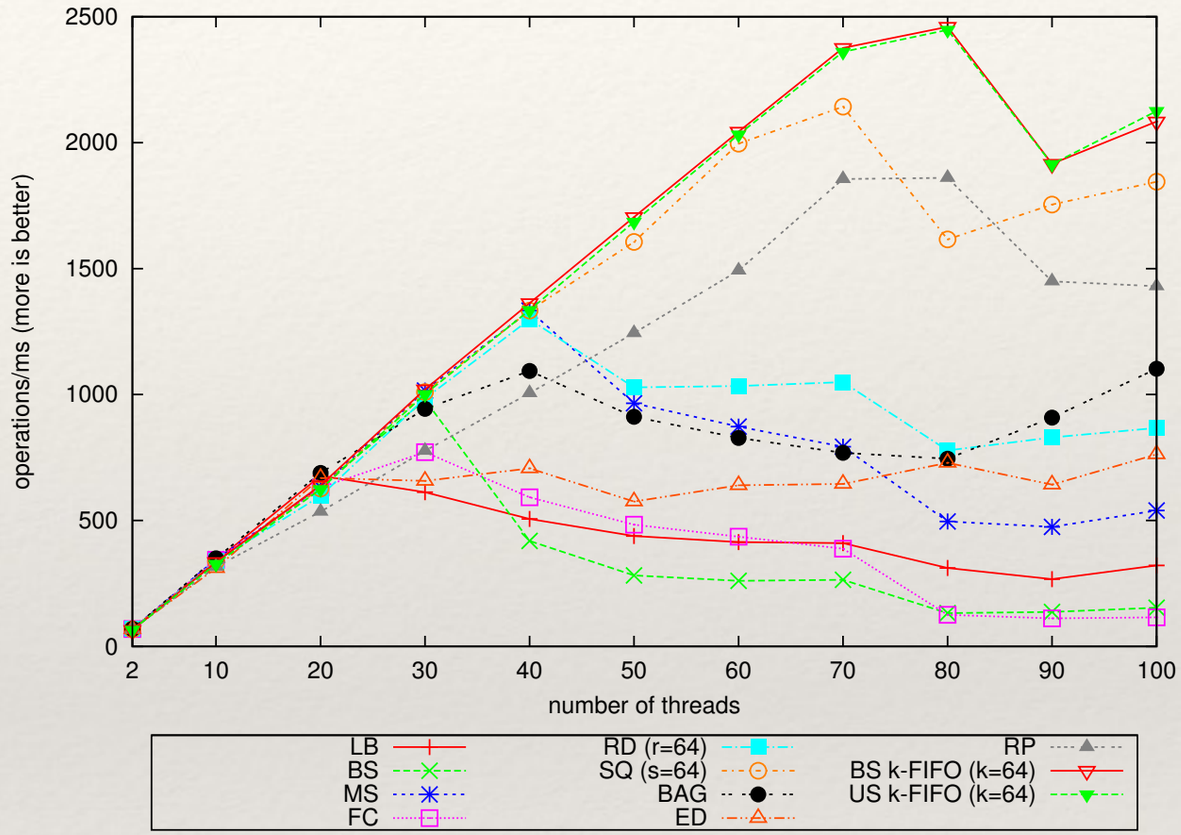
Multicore Scalability



Example



(c) Medium contention ($c = 7000$, $i = 0$)



(d) Low contention ($c = 10000$, $i = 0$)

Fig. 2. Performance and scalablity of producer/consumer microbenchmarks with an increasing number of threads

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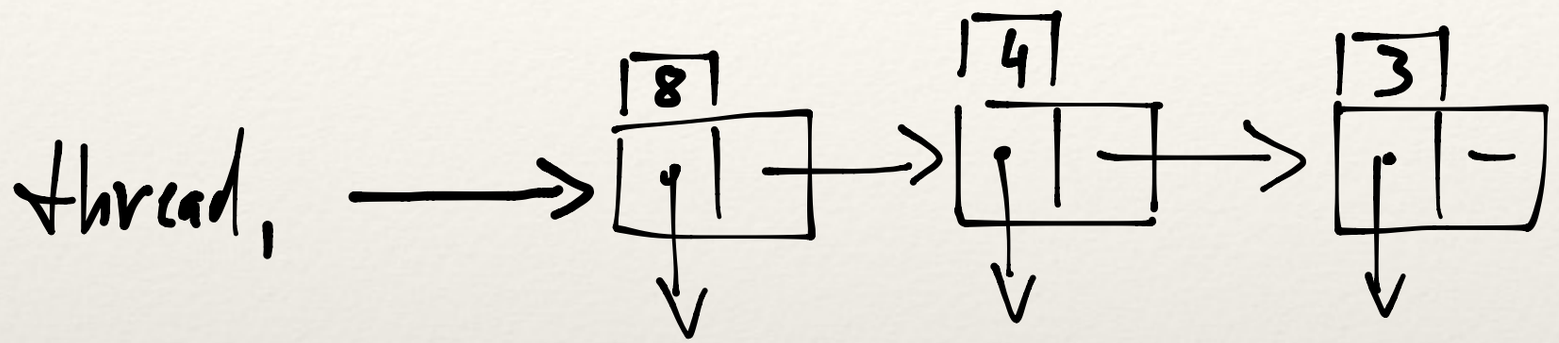
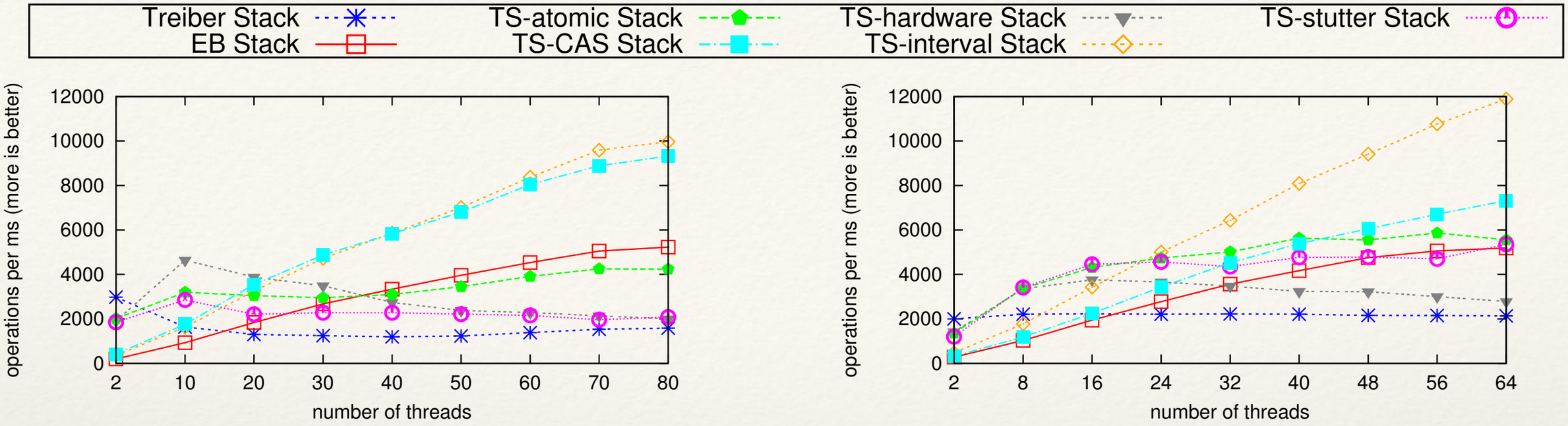
- Scal is a collection of concurrent data structures designed by us (underlined) and others, plus a benchmarking framework:
- Treiber Stack [IBM86]
  - Timestamped Stack [POPL15], k-Stack (relaxed) [POPL13]
- Michael-Scott Queue [PODC96]
- LCRQ [PPoPP13], Segment Queue (relaxed) [OPODIS10]
  - Timestamped Queue [POPL15], Distributed Queue (relaxed) [CF13], k-FIFO Queue (relaxed) [PaCT13]
  - Timestamped Deque [POPL15]
- …

Timestamping



Time Sources

- TS-atomic: fetch and increment counter
- TS- stutter: stuttering counter (Lamport clock)
- TS-hardware: hardware clock
- TS-interval: interval hardware clock
- TS-CAS: compare-and-swap interval counter



(a) High contention benchmark on the 40-core machine.

(b) High contention benchmark on the 64-core machine.

(c) Low contention benchmark on the 40-core machine.

(d) Low contention benchmark on the 64-core machine.

Figure 2.5: TS stack performance on the 40-core machine (left) and on the 64-core machine (right) in the producer-consumer benchmark.

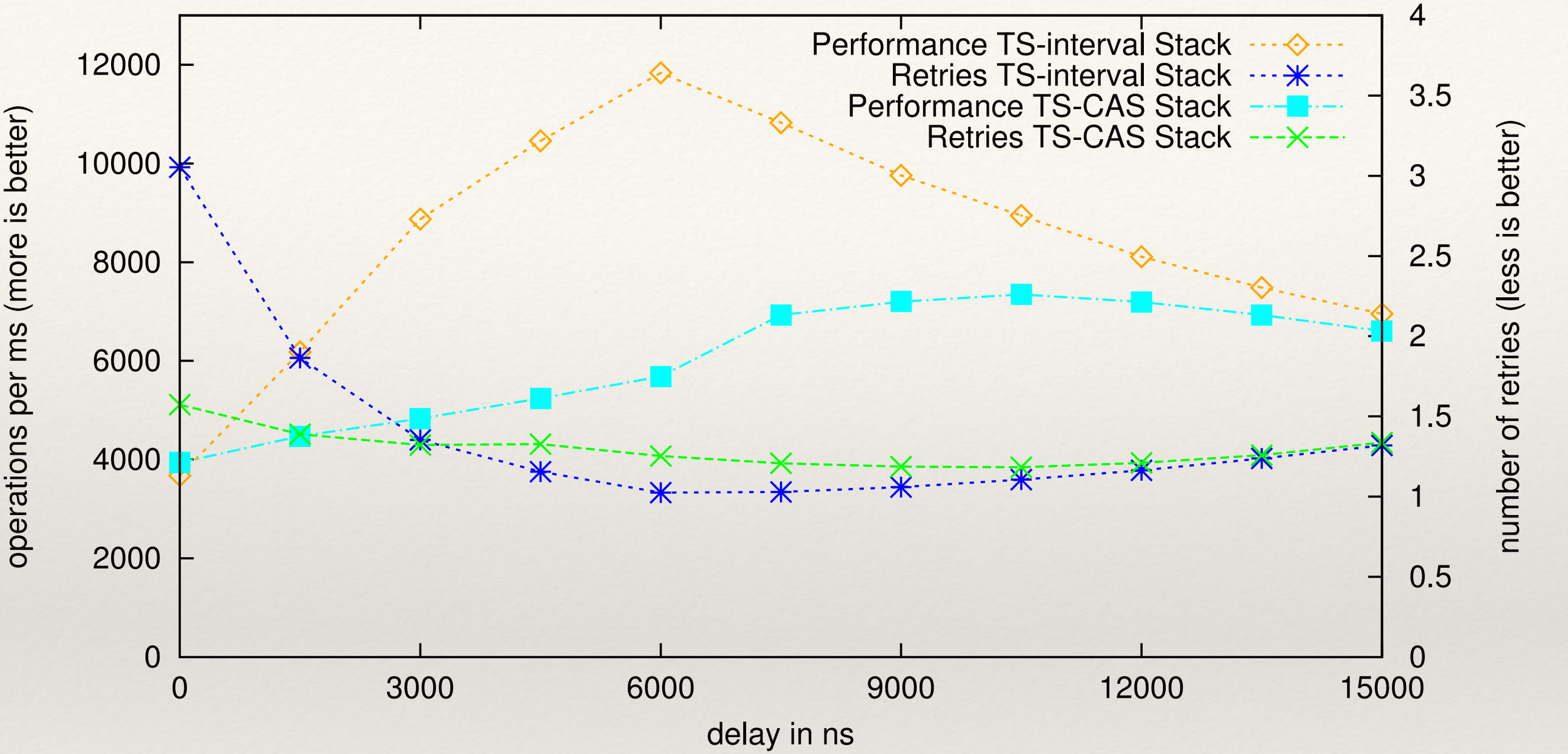


Figure 2.9: High-contention producer-consumer benchmark using TS-interval and TS-CAS timestamping with increasing delay on the 64-core machine, exercising 32 producers and 32 consumers.

Semantics

vs.

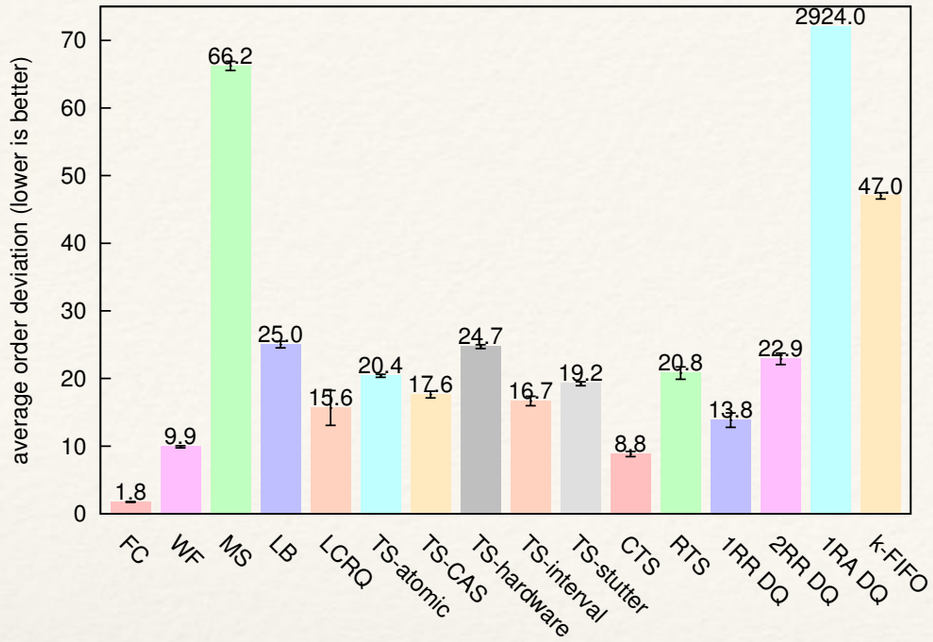
Non-Determinism

vs.

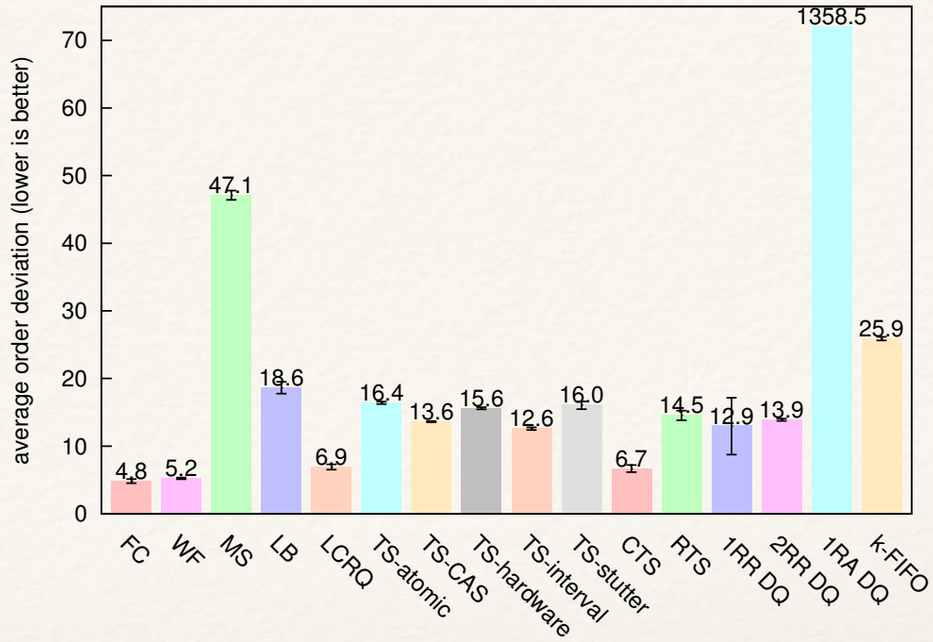
Performance

Order Deviation (Queues) [RACES12]

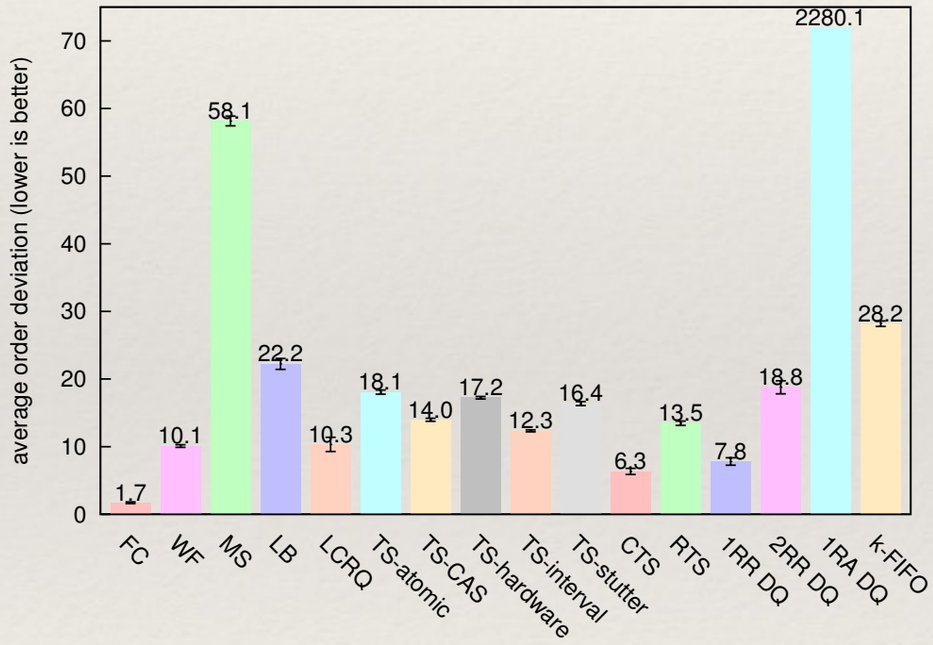
- We record the times when enqueue and dequeue operations are invoked on a concurrent queue
- For each element E inserted by an enqueue operation invoked at time T_e and removed by a dequeue operation invoked at time T_d we compute the order deviation of E as:
  - the number of elements that were inserted by enqueue operations invoked before T_e and removed by dequeue operations invoked after T_d
- We present the average order deviation of all elements inserted and removed in a run



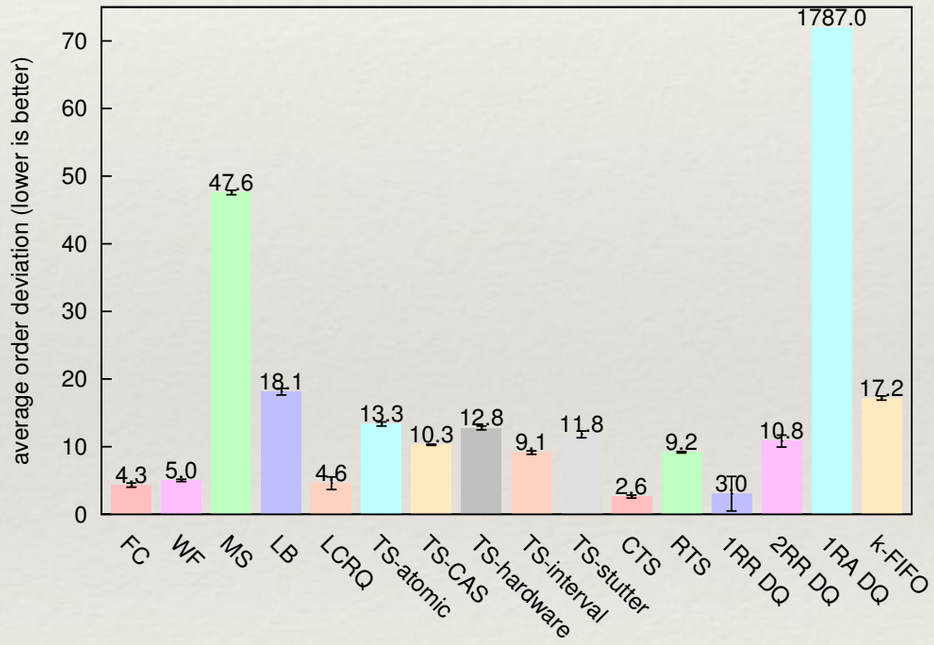
(a) High-contention producer-consumer benchmark on the 40-core machine.



(b) High-contention producer-consumer benchmark on the 64-core machine.

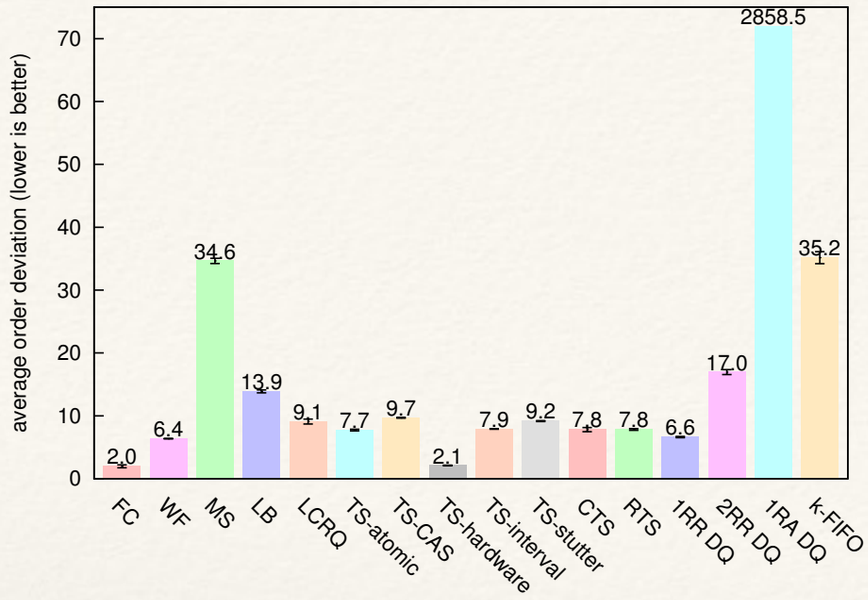


(c) Low-contention producer-consumer benchmark on the 40-core machine.

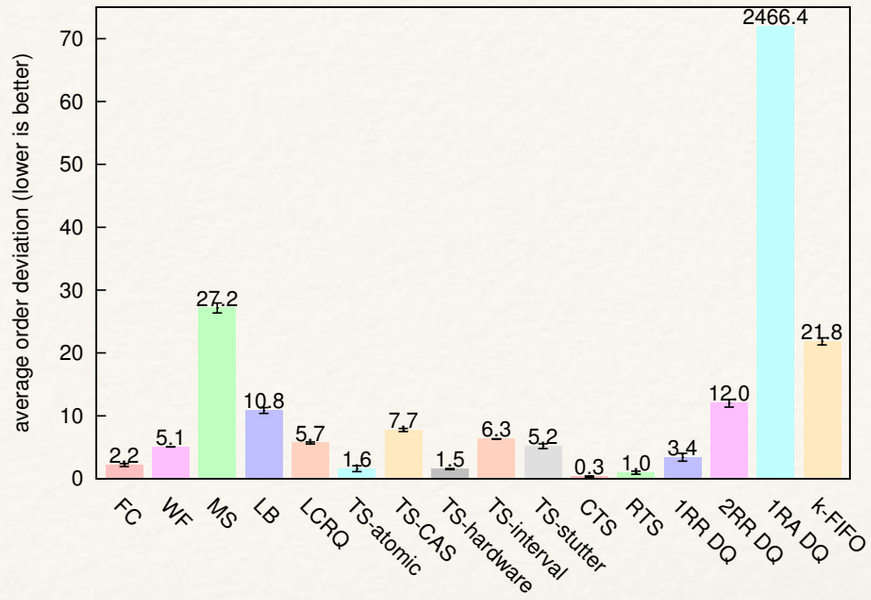


(d) Low-contention producer-consumer benchmark on the 64-core machine.

Figure 7.1: Order deviation in the producer-consumer benchmark on the 40-core machine with 40 producers and 40 consumers (left), and on the 64-core machine with 32 producers and 32 consumers (right).



(a) High contention multiple-producer single-consumer benchmark on the 40-core machine.

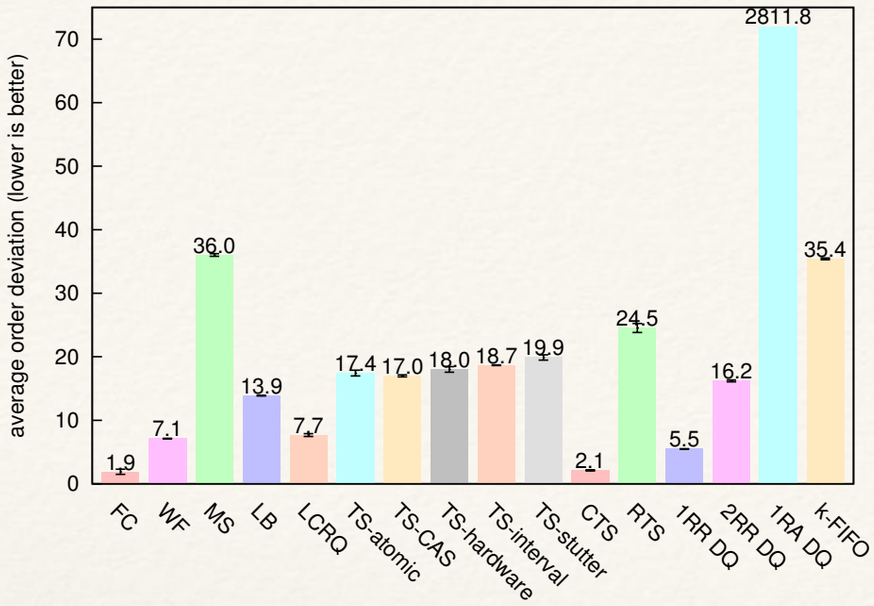


(b) High contention multiple-producer single-consumer benchmark on the 64-core machine.

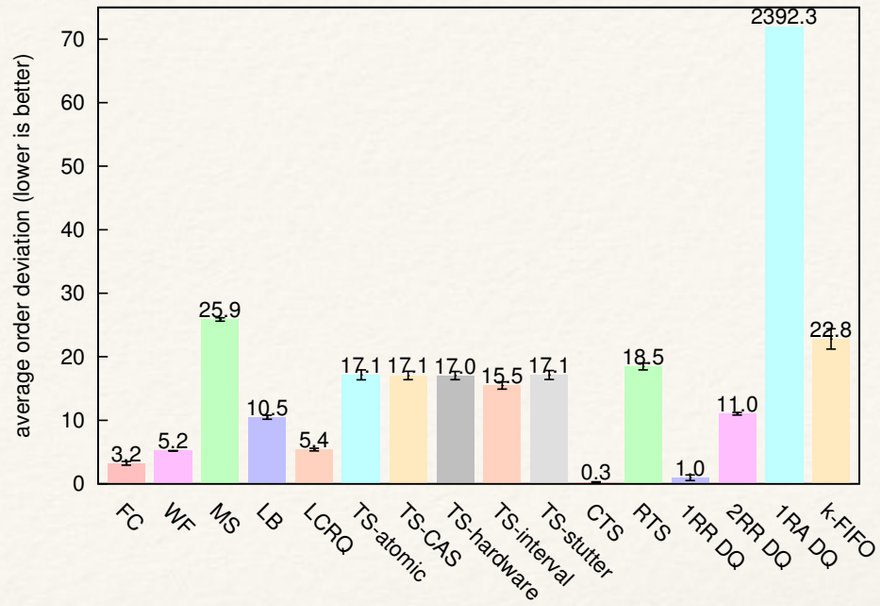
(c) Low contention multiple-producer single-consumer benchmark on the 40-core machine.

(d) Low contention multiple-producer single-consumer benchmark on the 64-core machine.

Figure 7.2: Order deviation in the multiple-producer single-consumer benchmark on the 40-core machine with 40 producers (left), and on the 64-core machine with 32 producers (right).



(a) High-contention single-producer multiple consumer benchmark on the 40-core machine.



(b) High-contention single-producer multiple consumer benchmark on the 64-core machine.

(c) Low-contention single-producer multiple consumer benchmark on the 40-core machine.

(d) Low-contention single-producer multiple consumer benchmark on the 64-core machine.

Figure 7.3: Order deviation in the single-producer multiple-consumer benchmark on the 40-core machine with 40 producers (left), and on the 64-core machine with 32 producers (right).

Thank you