How FIFO is Your Concurrent FIFO Queue?

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Strict vs. Relaxed FIFO Queues

strict FIFO queue implementations

relaxed FIFO queue implementations

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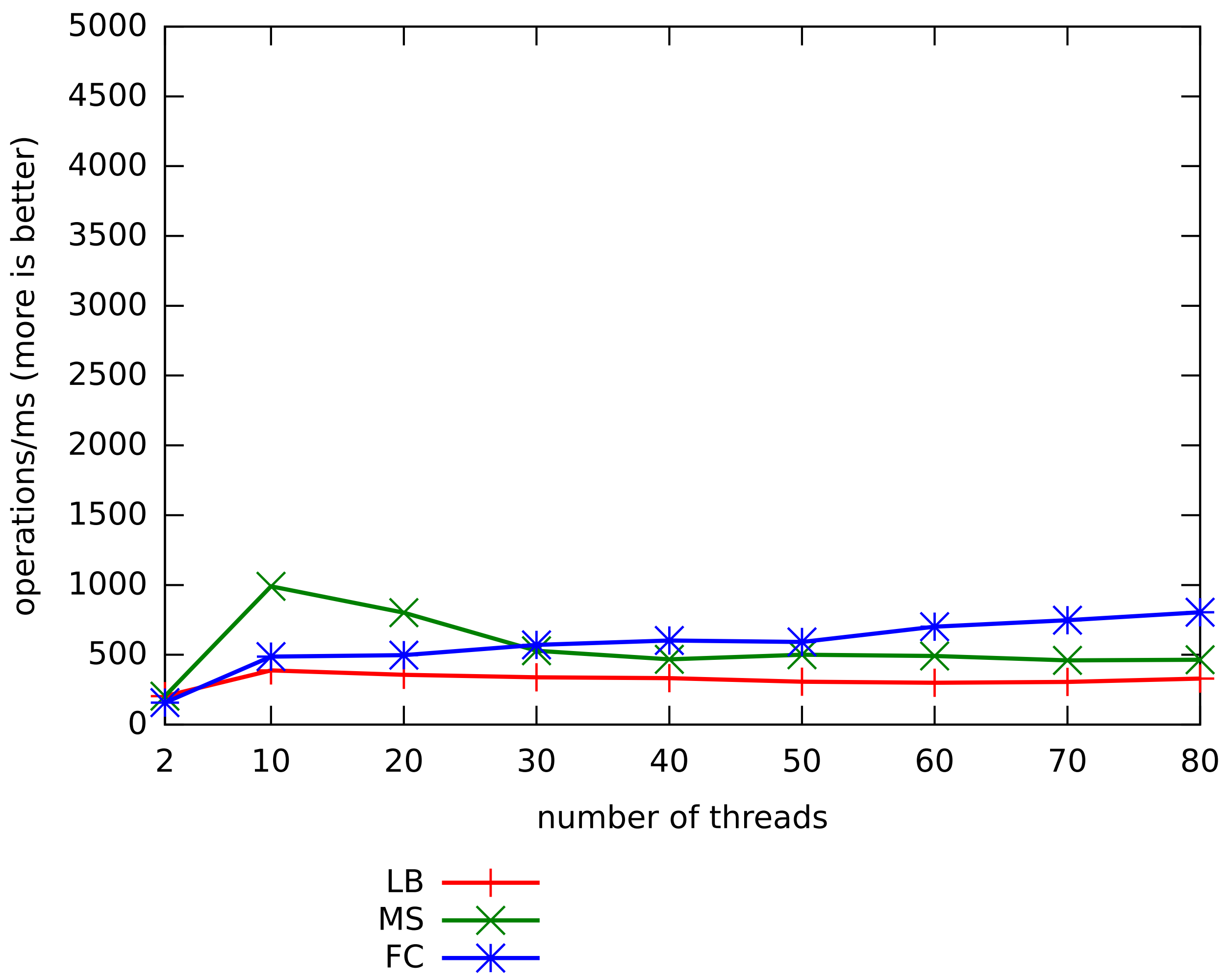

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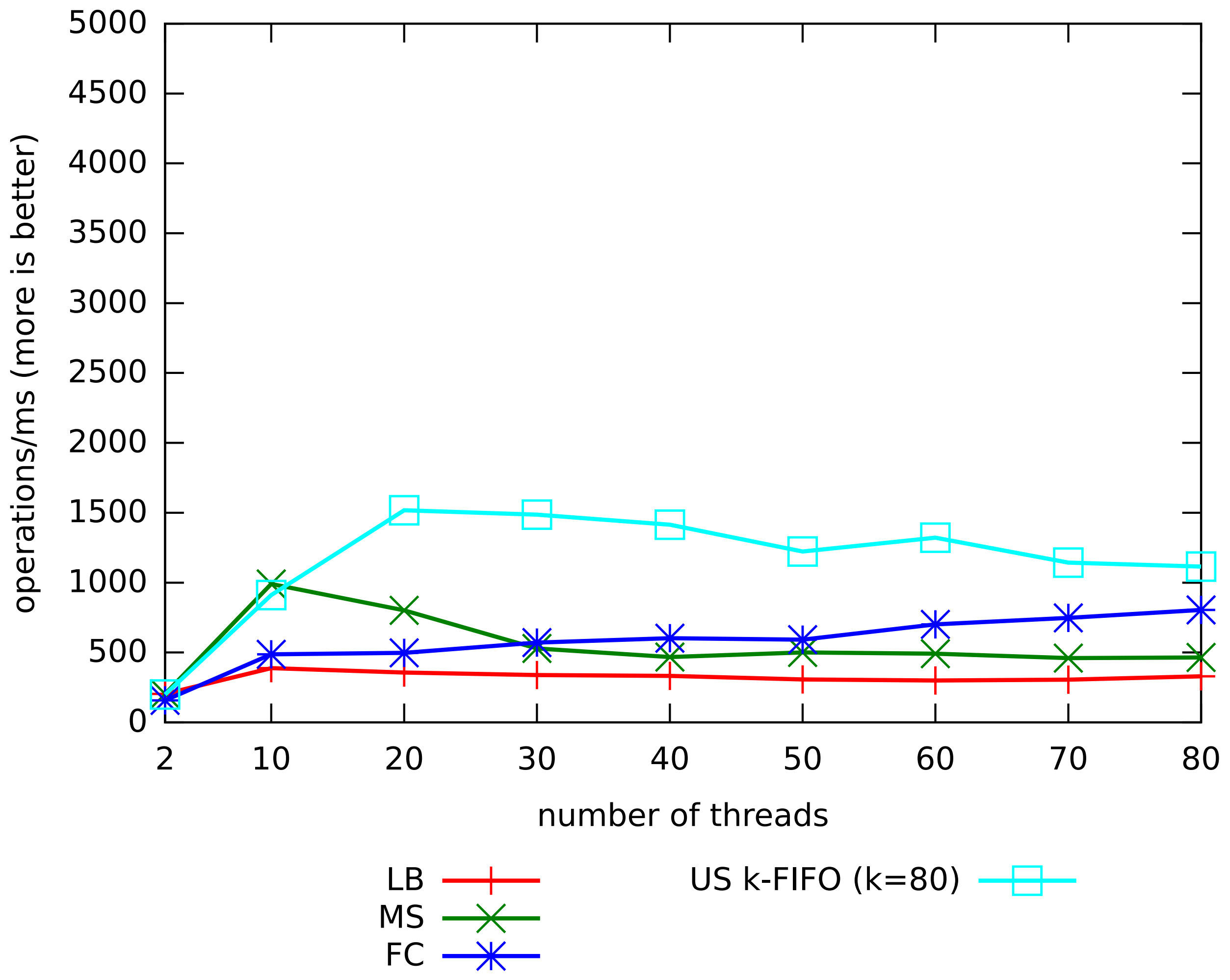

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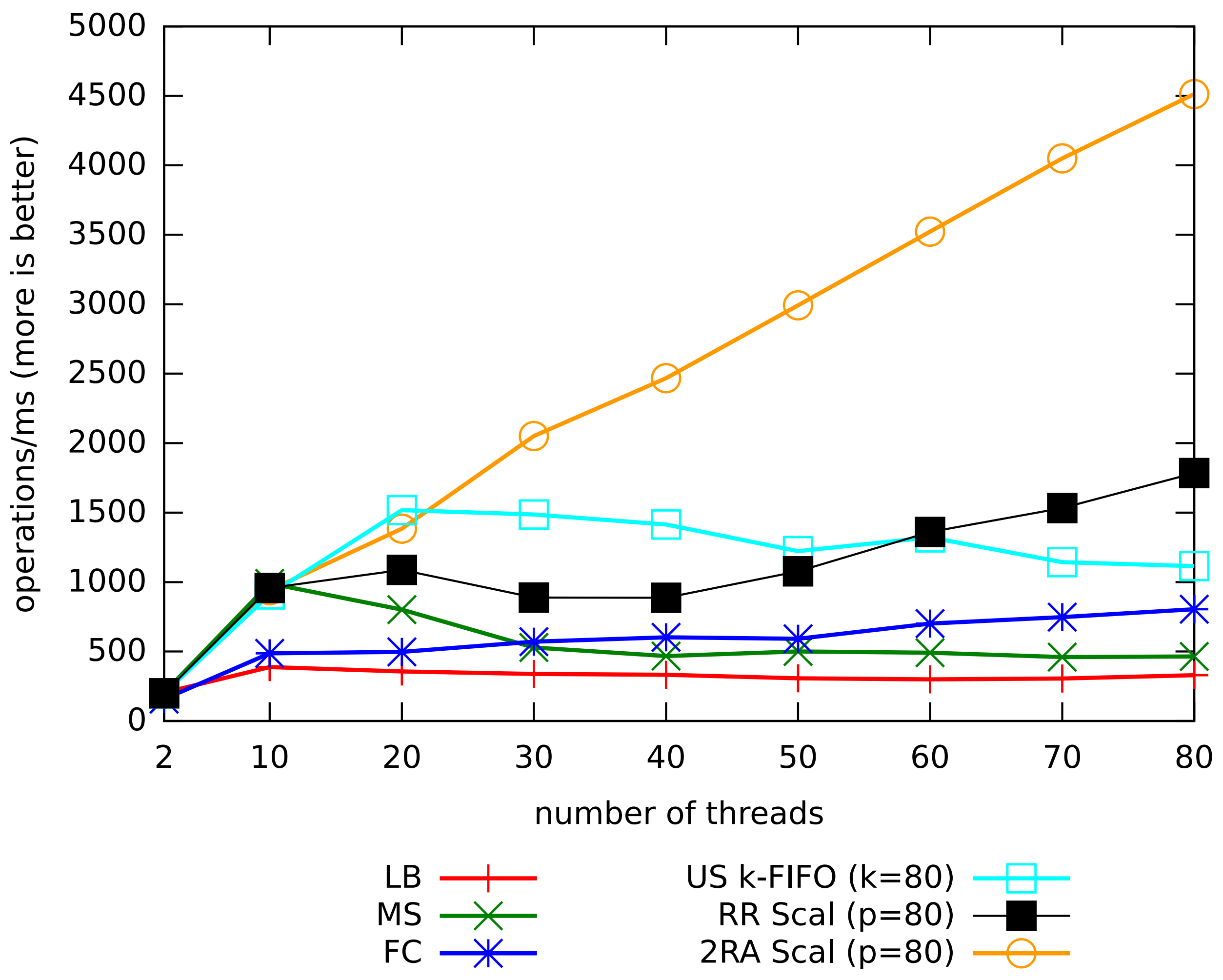

How FIFO are Relaxed FIFO Queues?

- Some people say relaxed FIFO queues are not enough FIFO.
  - No applications for relaxed FIFO queues.

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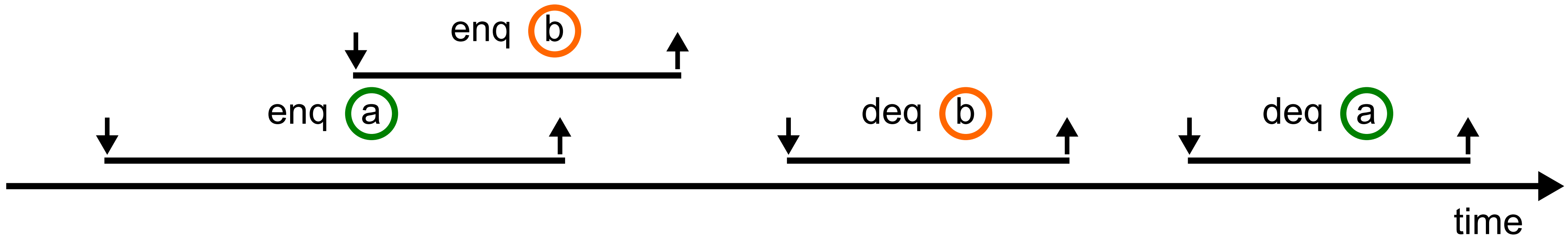
We say relaxed FIFO queue implementations can be even more FIFO than strict FIFO queue implementations.

Example



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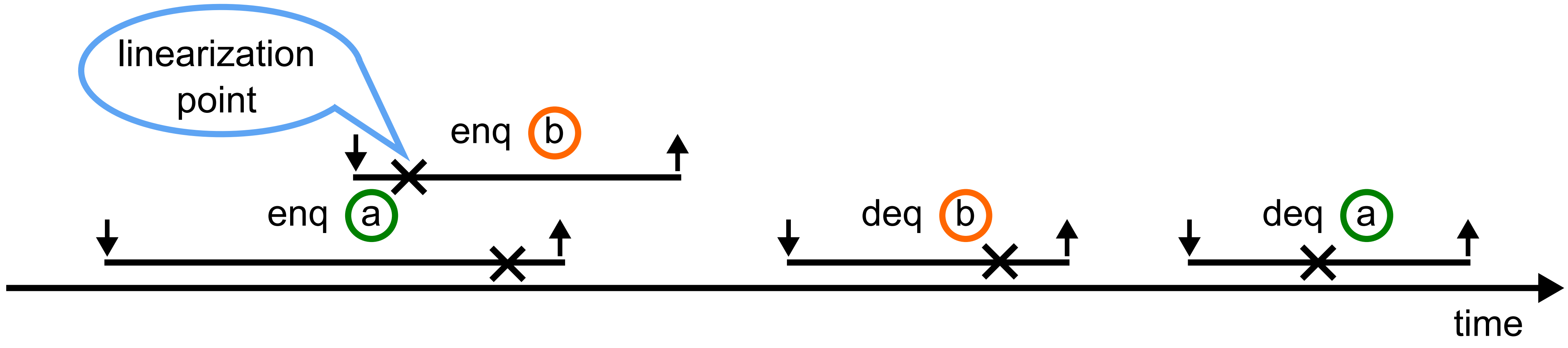

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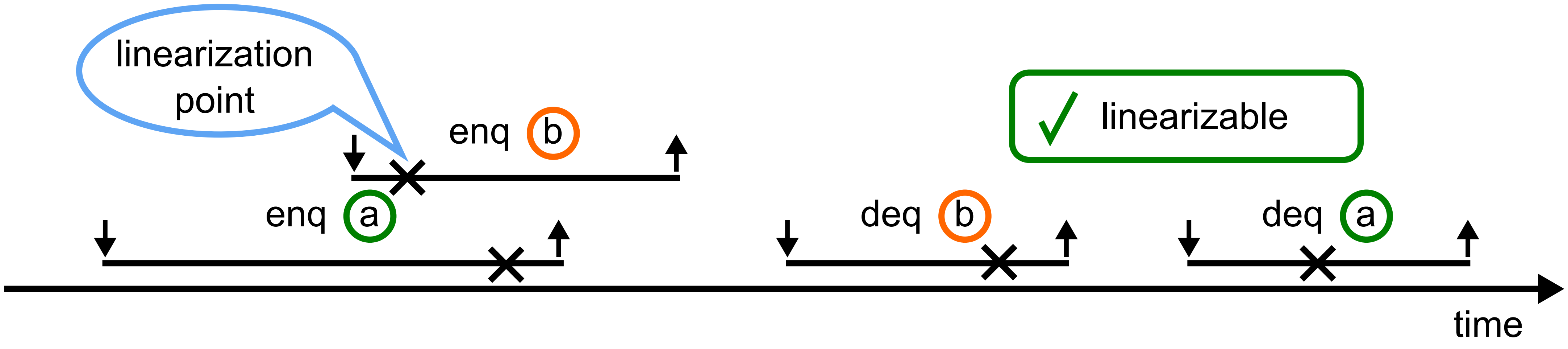
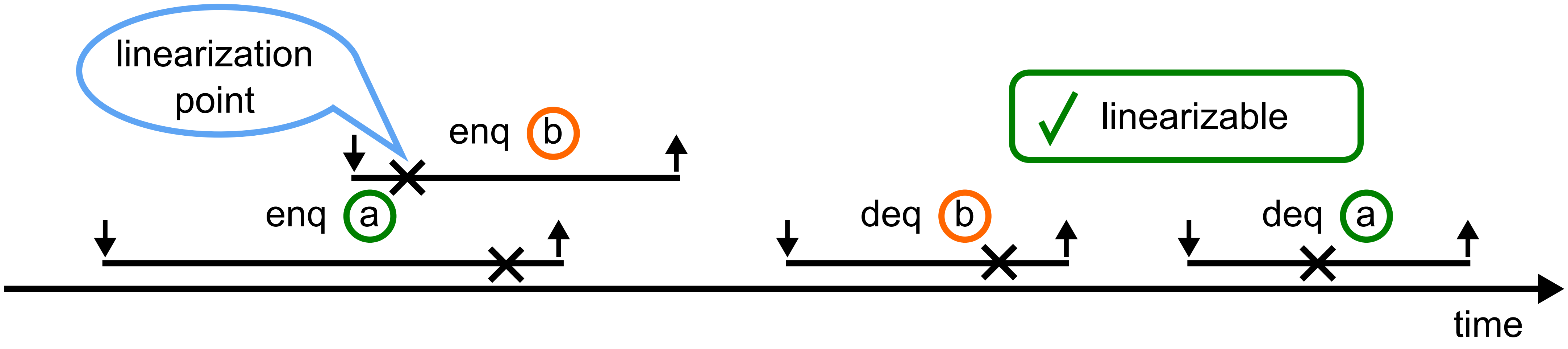

linearization point
enq b
enq a
deq b
deq a
✓ linearizable
time

Example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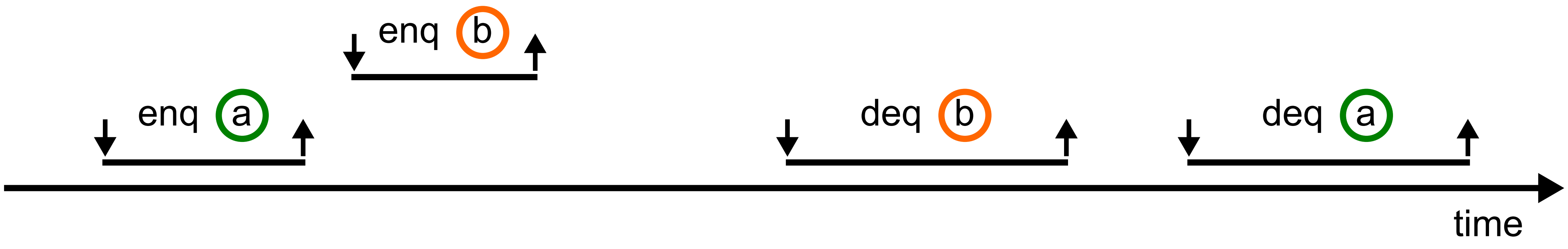
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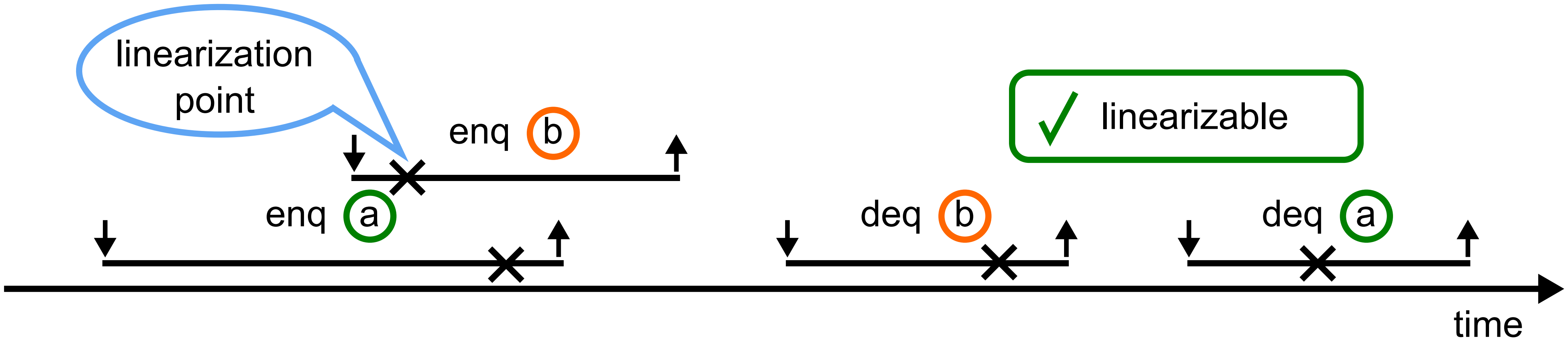

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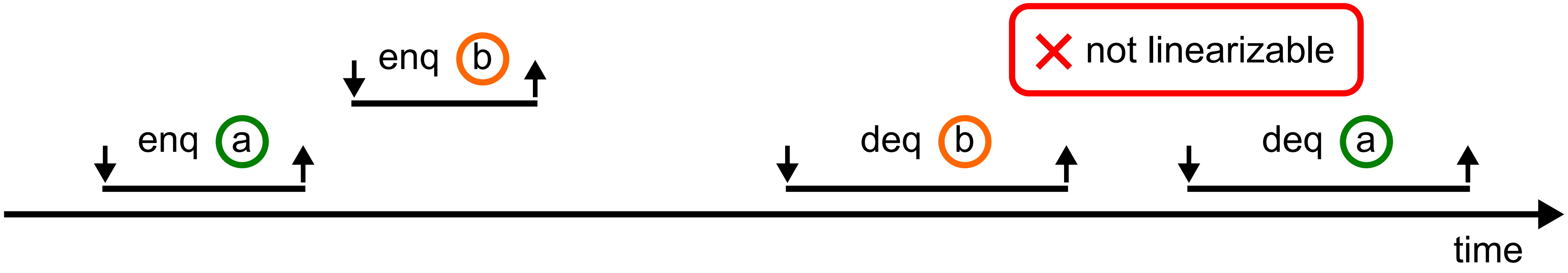

enq b
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✗ not linearizable
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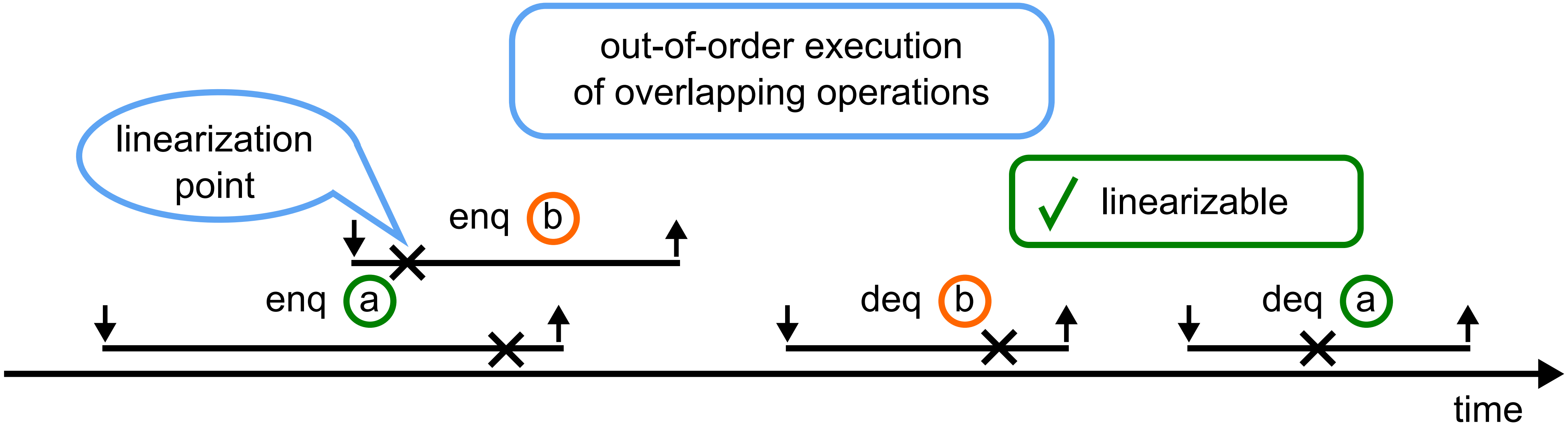
out-of-order execution
of overlapping operations
linearization
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enq b
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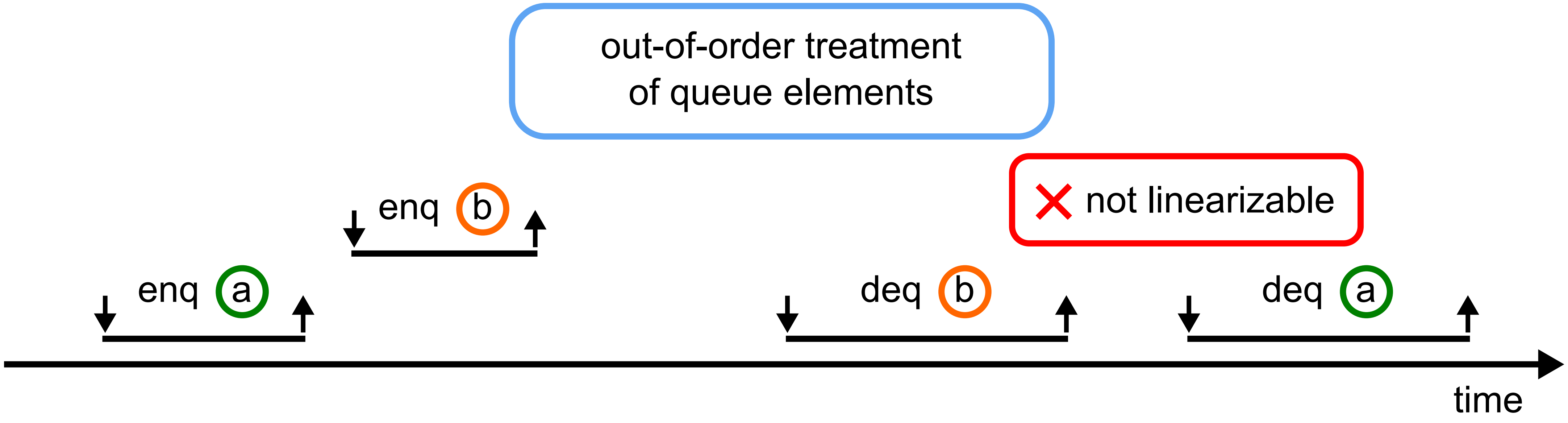
deq a
time


out-of-order treatment
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Key Idea

1.) Record concurrent histories of various FIFO queue implementations.

2.) Analyze these concurrent histories using only the invocation times of operations.

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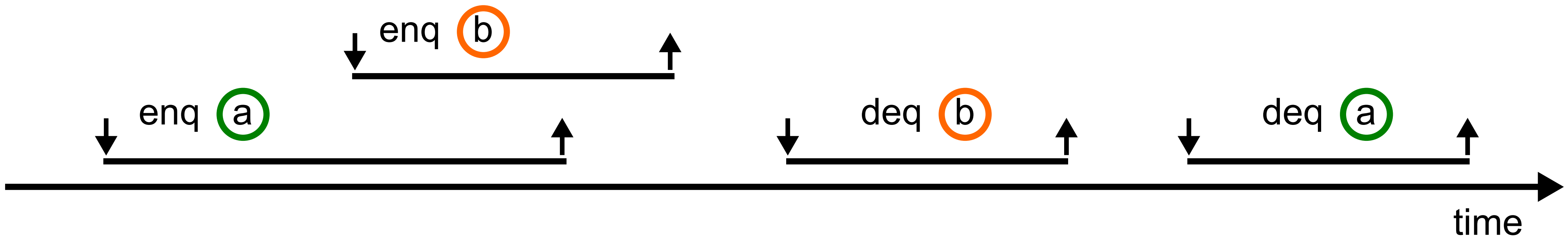
2.) Analyze these concurrent histories using only the invocation times of operations.

- Ideally operations would take zero time
- Independent of the execution time of operations

Element-Fairness



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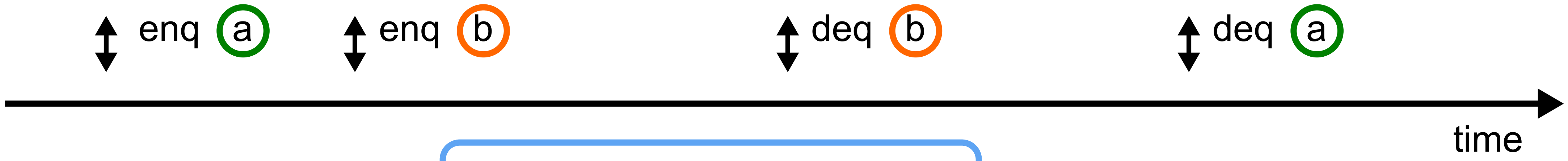
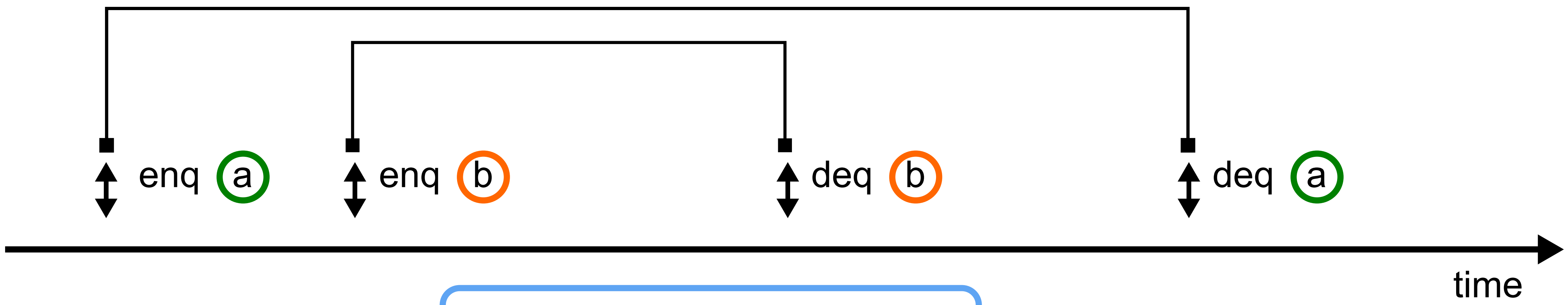


zero-time linearization

Element-Fairness

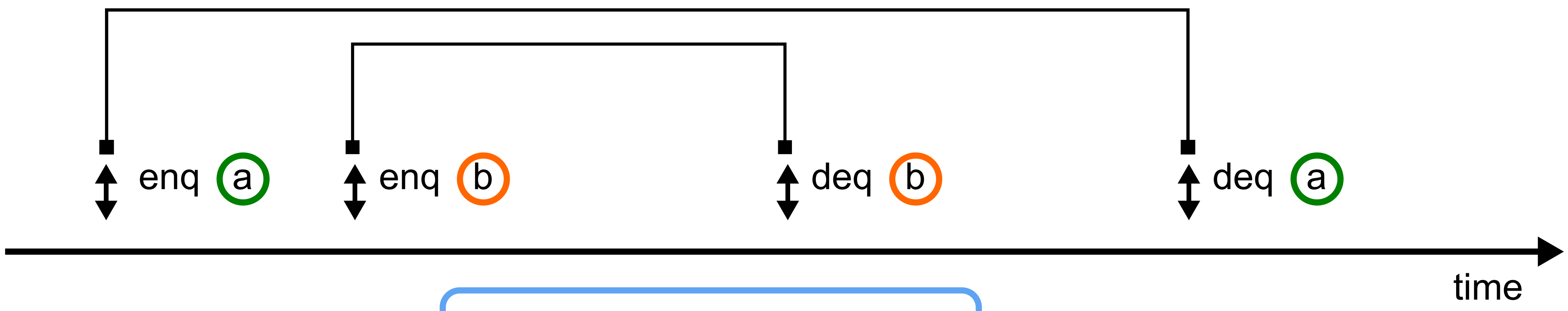
element b overtakes element a



zero-time linearization

Element-Fairness

element (b) overtakes element (a)



zero-time linearization

Definition

element-fairness =
number of overtakings in the zero-time linearization

Experiments

all threads do in parallel

```
for 10.000 iterations
{
    enqueue unique element

    dequeue element

}
```

Experiments

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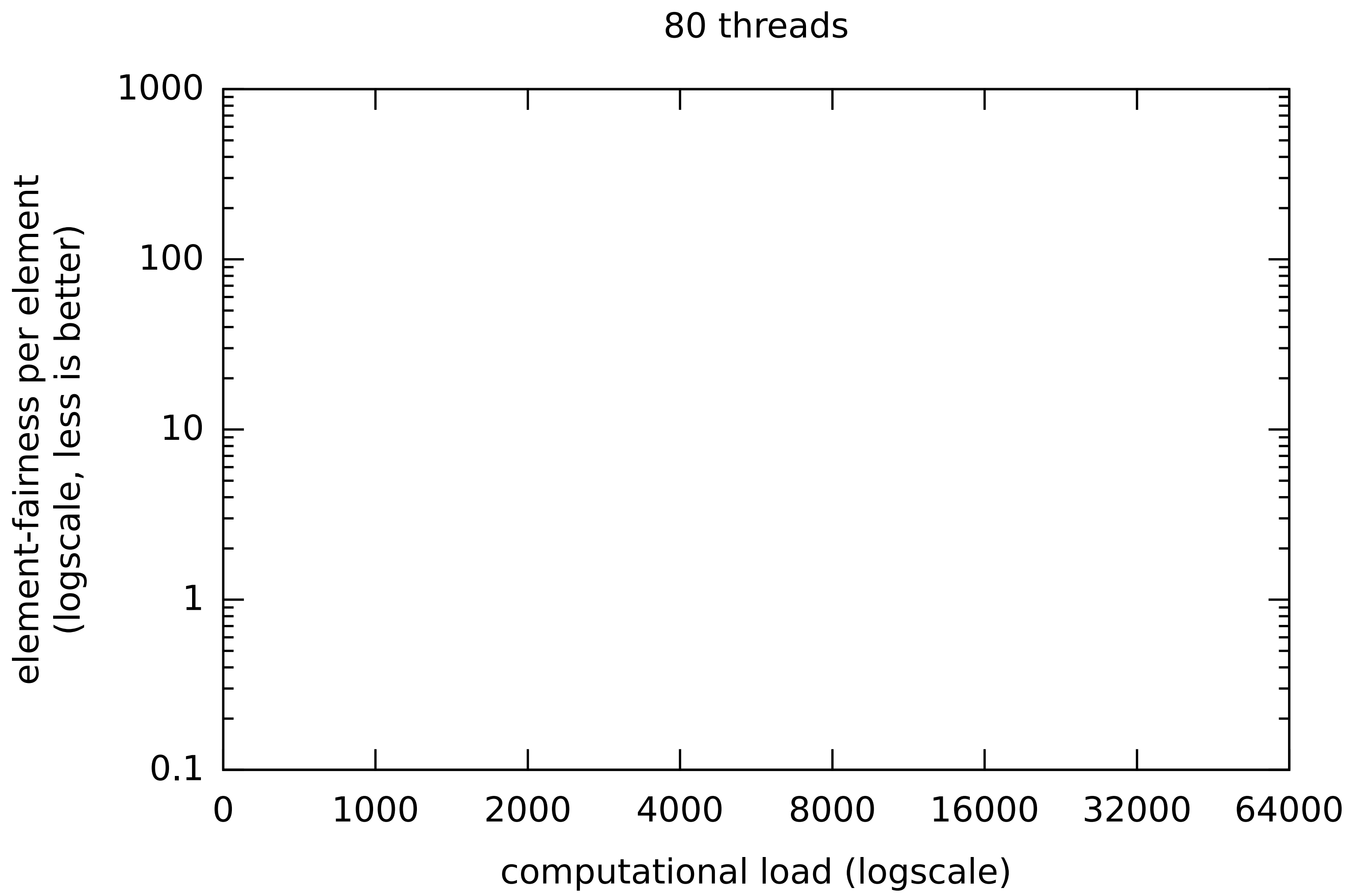
- No dequeues in the first 200 iterations to avoid empty checks
- No enqueues in the last 200 iterations to empty the queue.

Element-Fairness per Element



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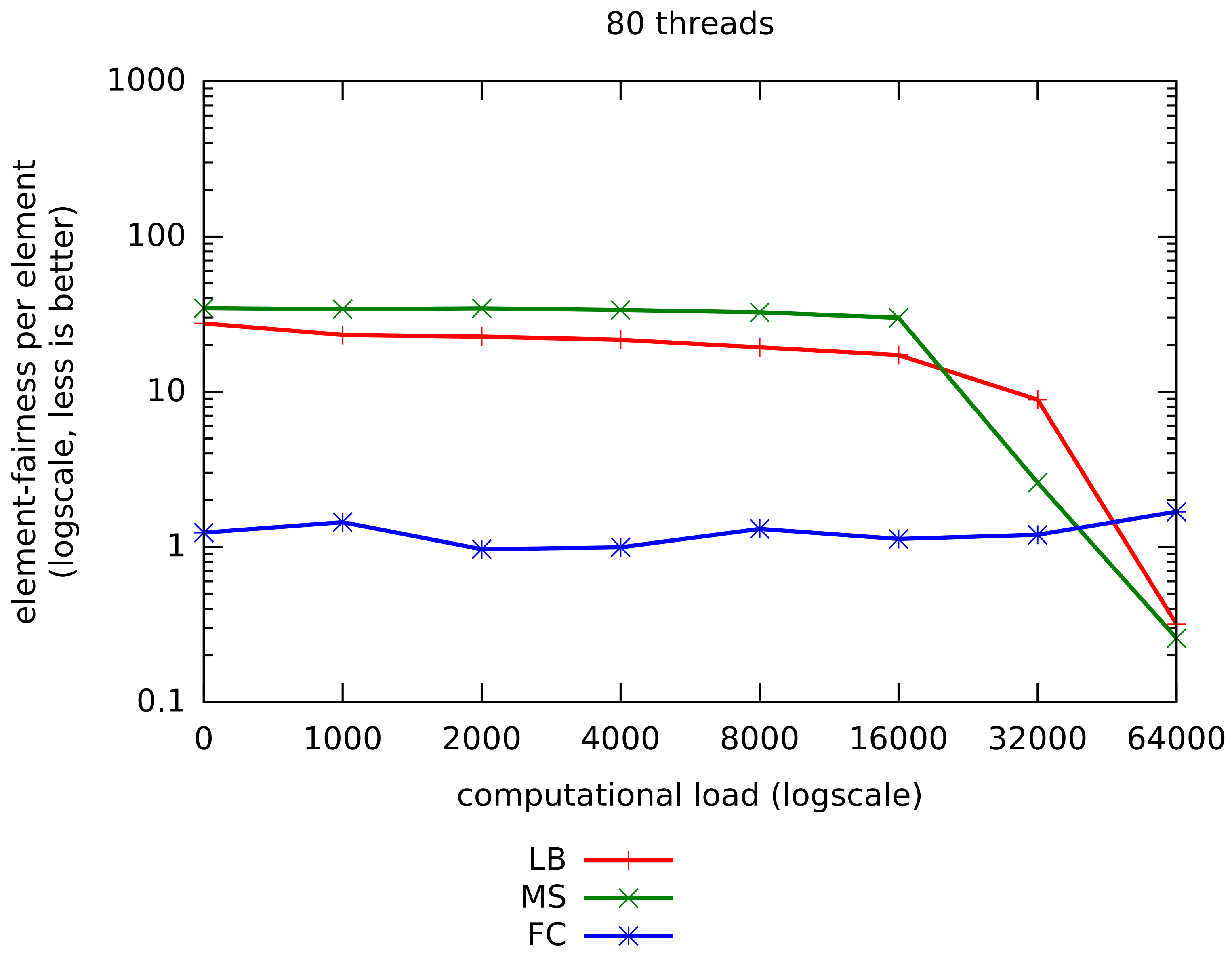

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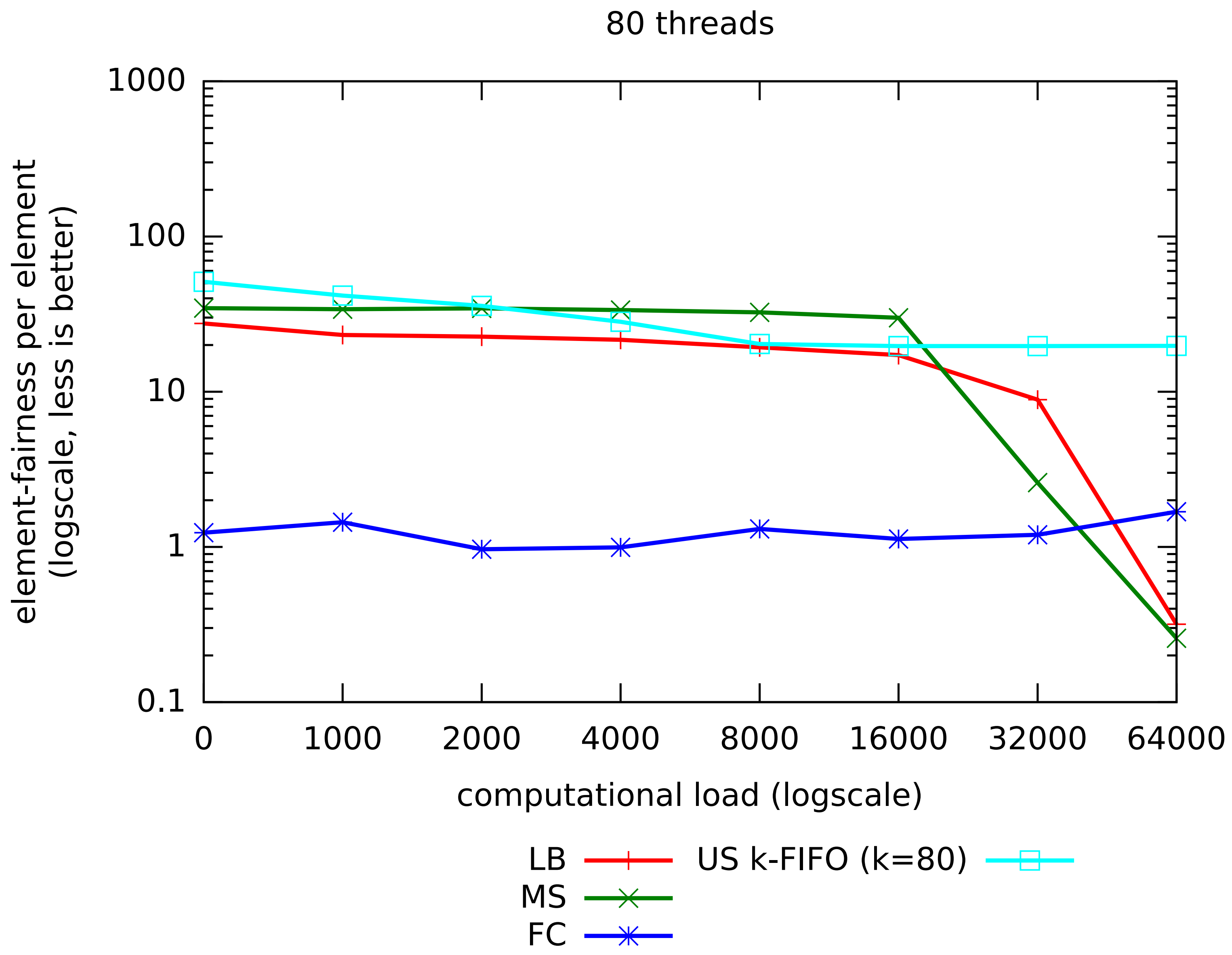

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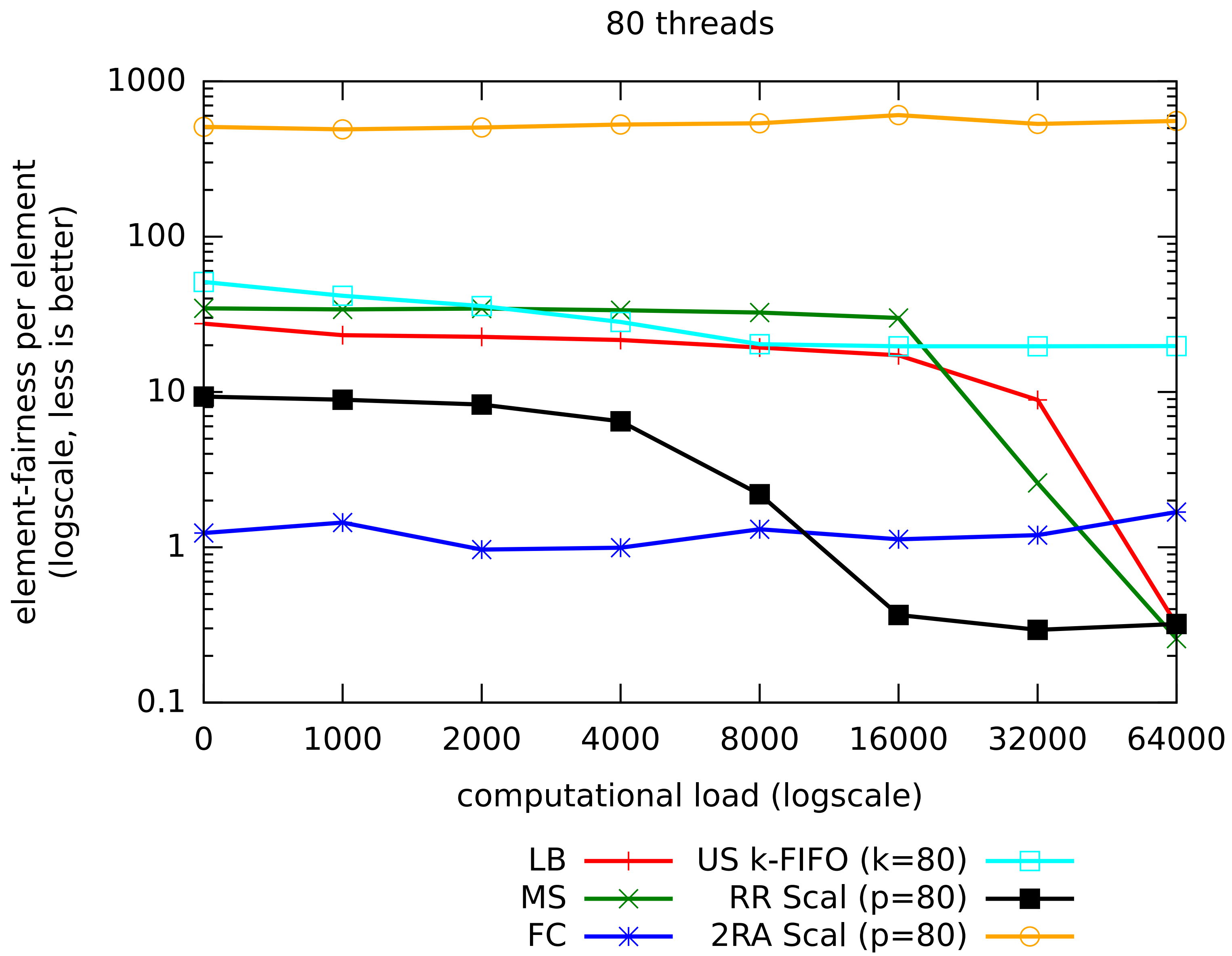

Operation-Fairness

- Measure the out-of order execution of single operations

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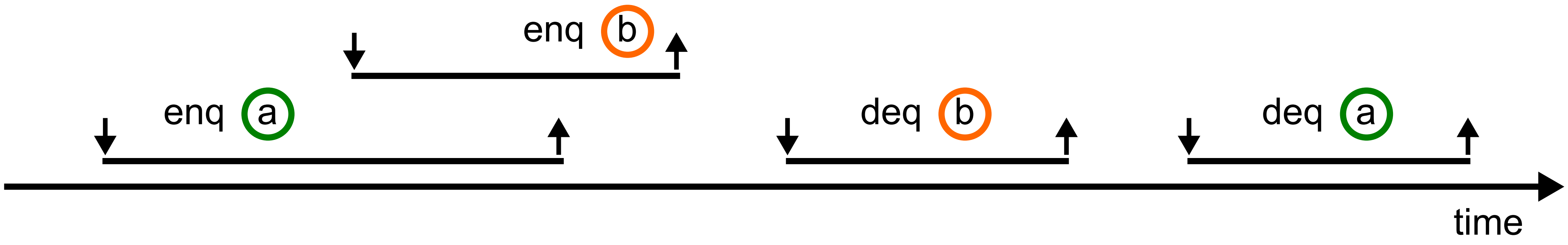

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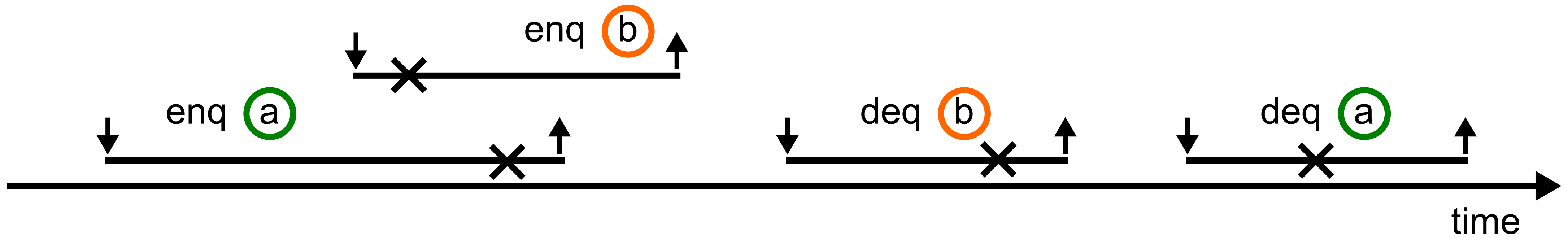

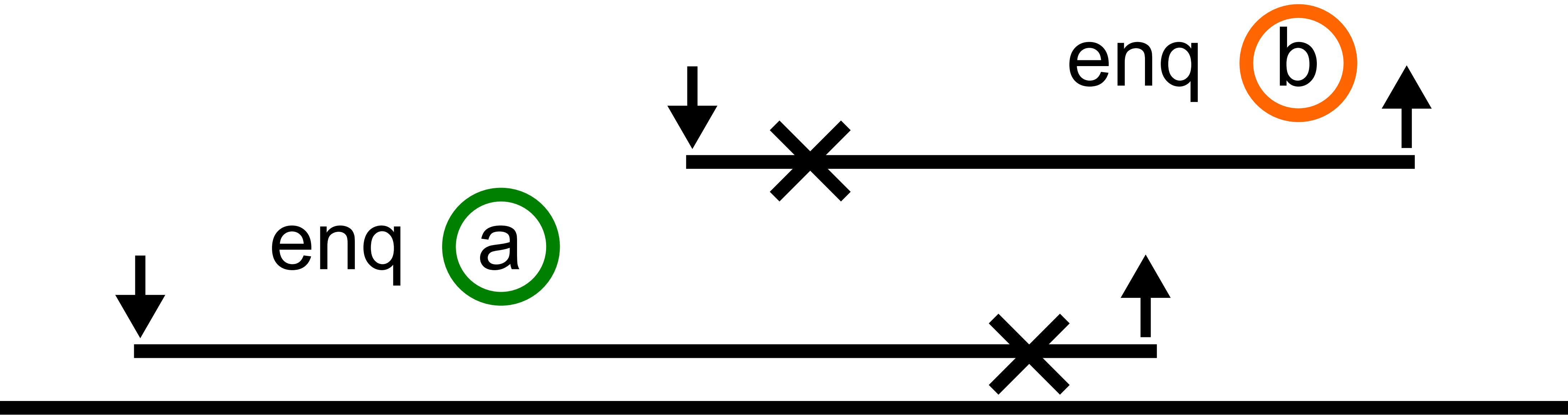
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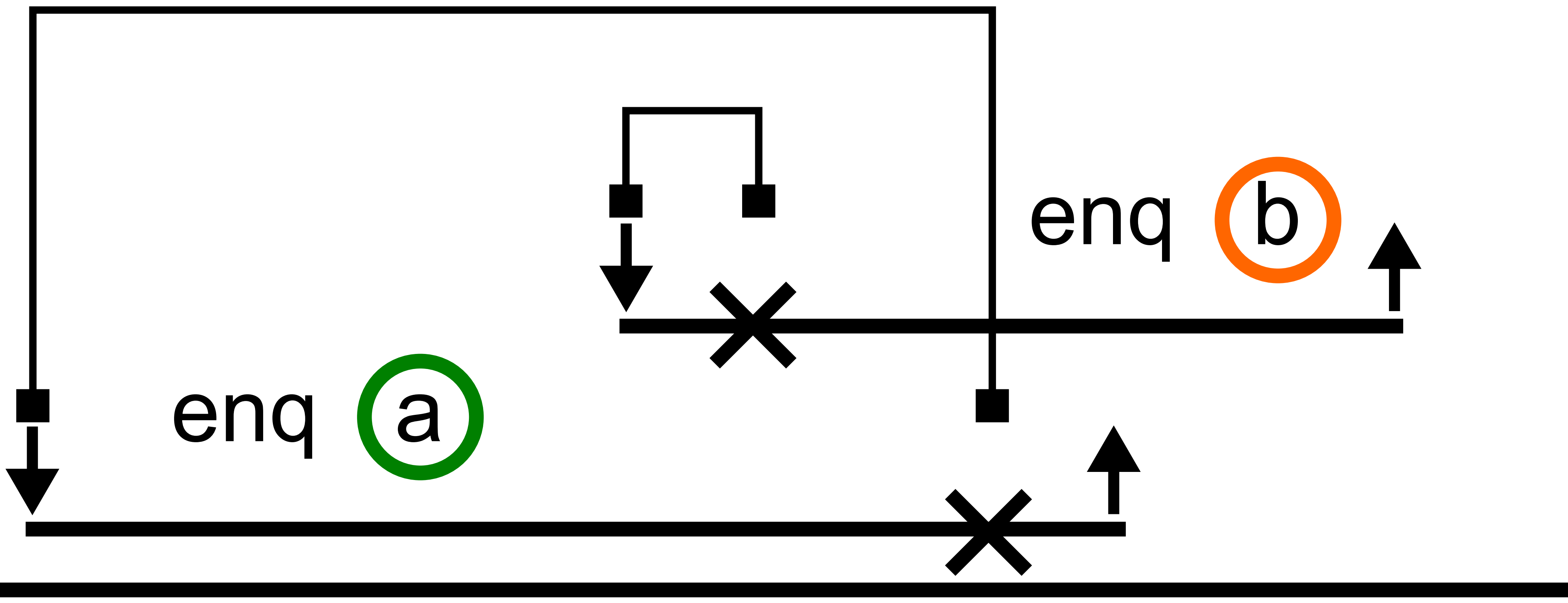
enq a

operation enq ⓑ overtakes operation enq ⓐ



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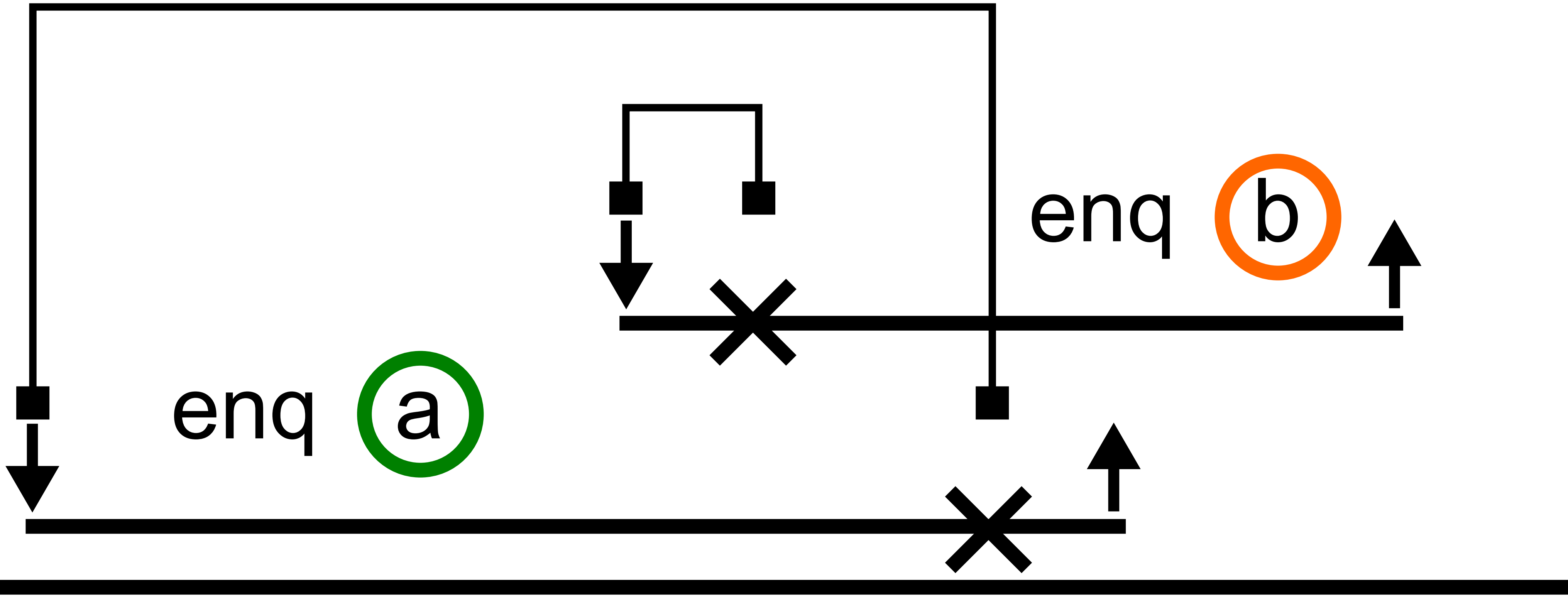

Definition

operation-fairness =
number of overtakings in a concurrent history

Operation-Age and Operation-Lateness

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age (op) =
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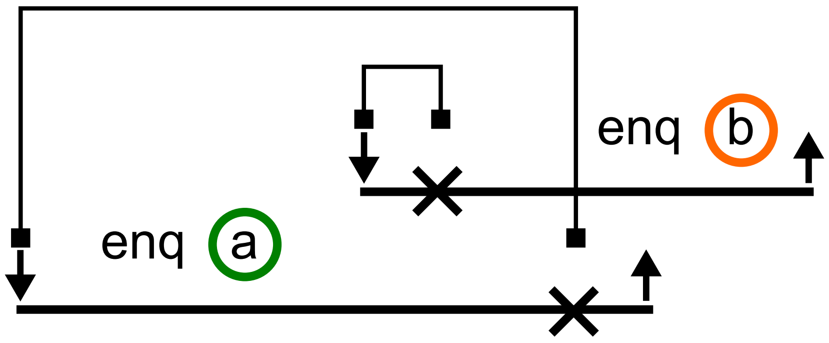

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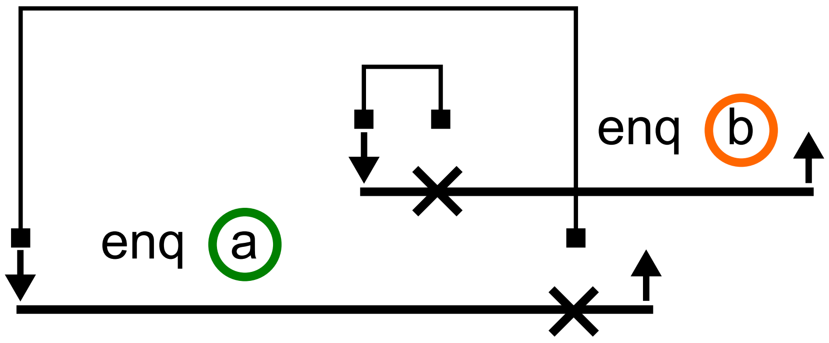
Definition

lateness (op) =
number of operations which overtake op



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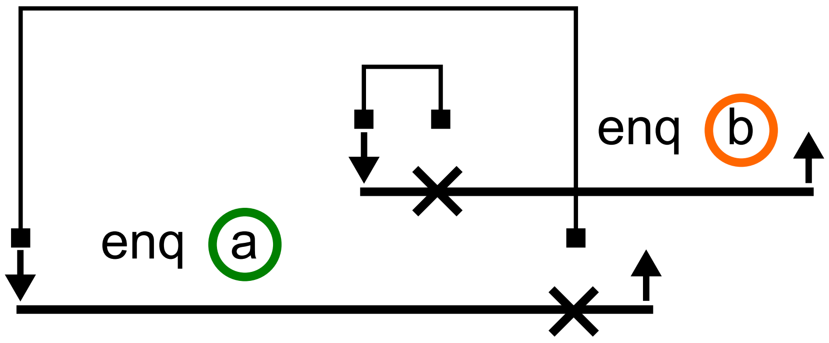

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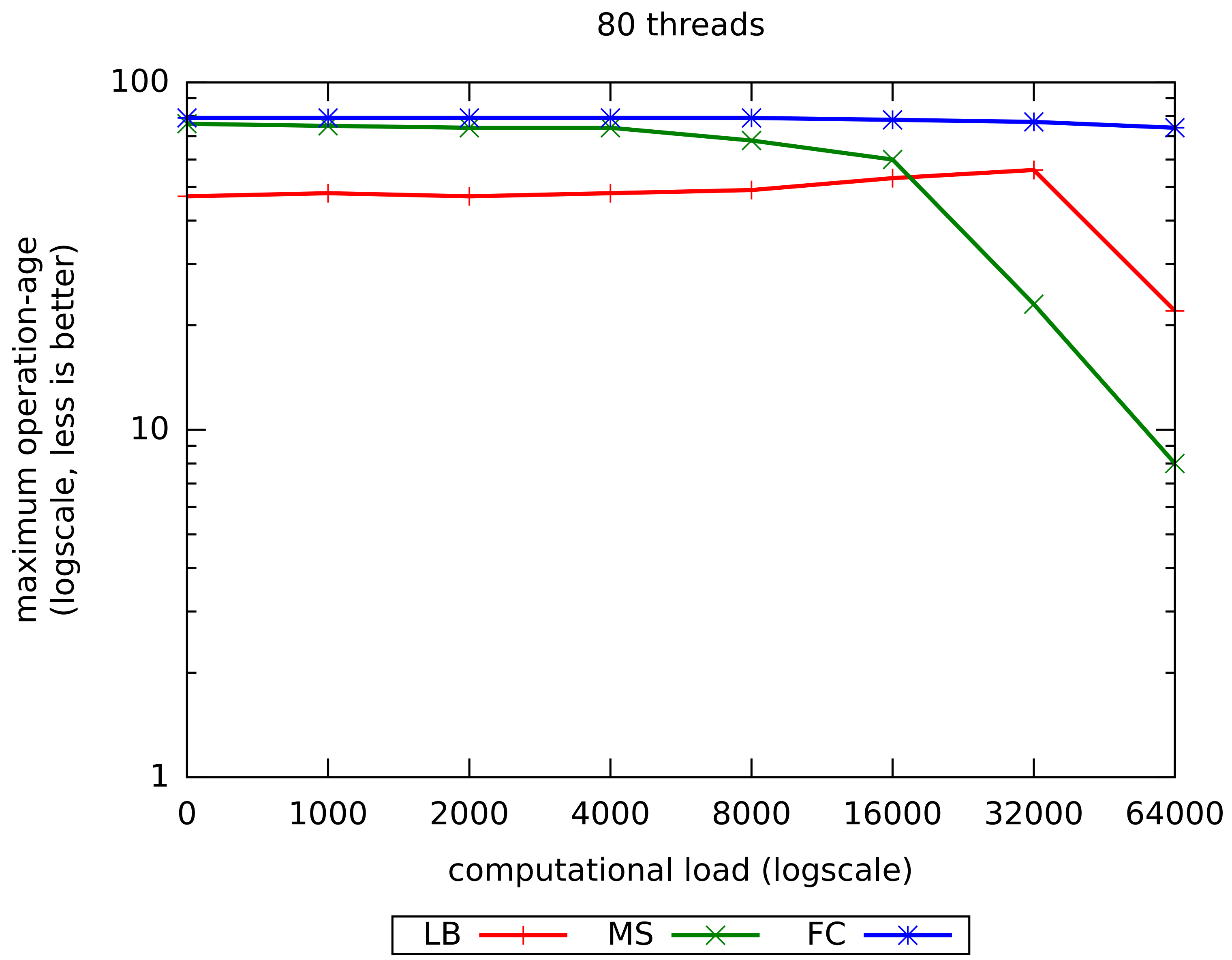
```

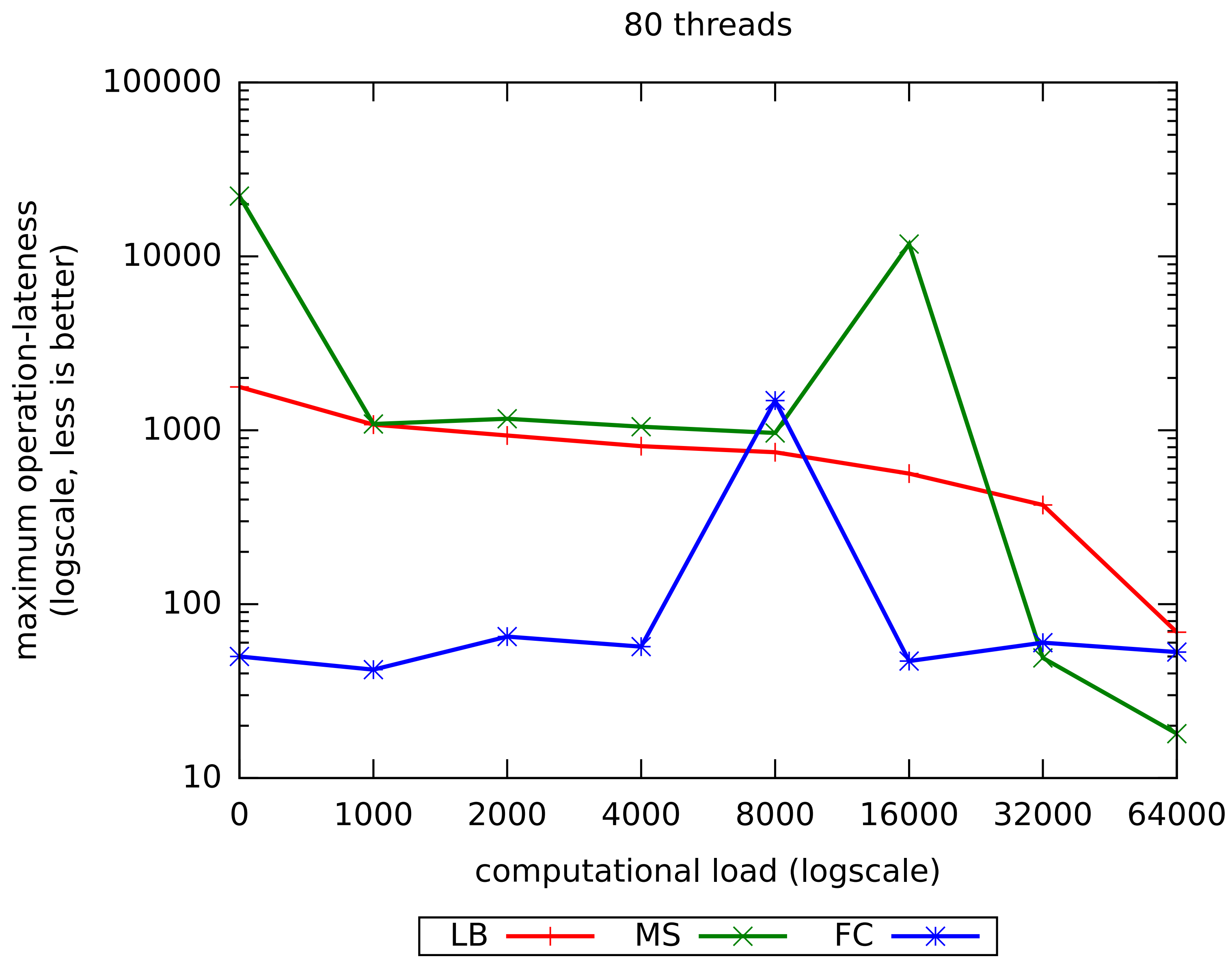
```
one thread does

dequeue all elements sequentially
```

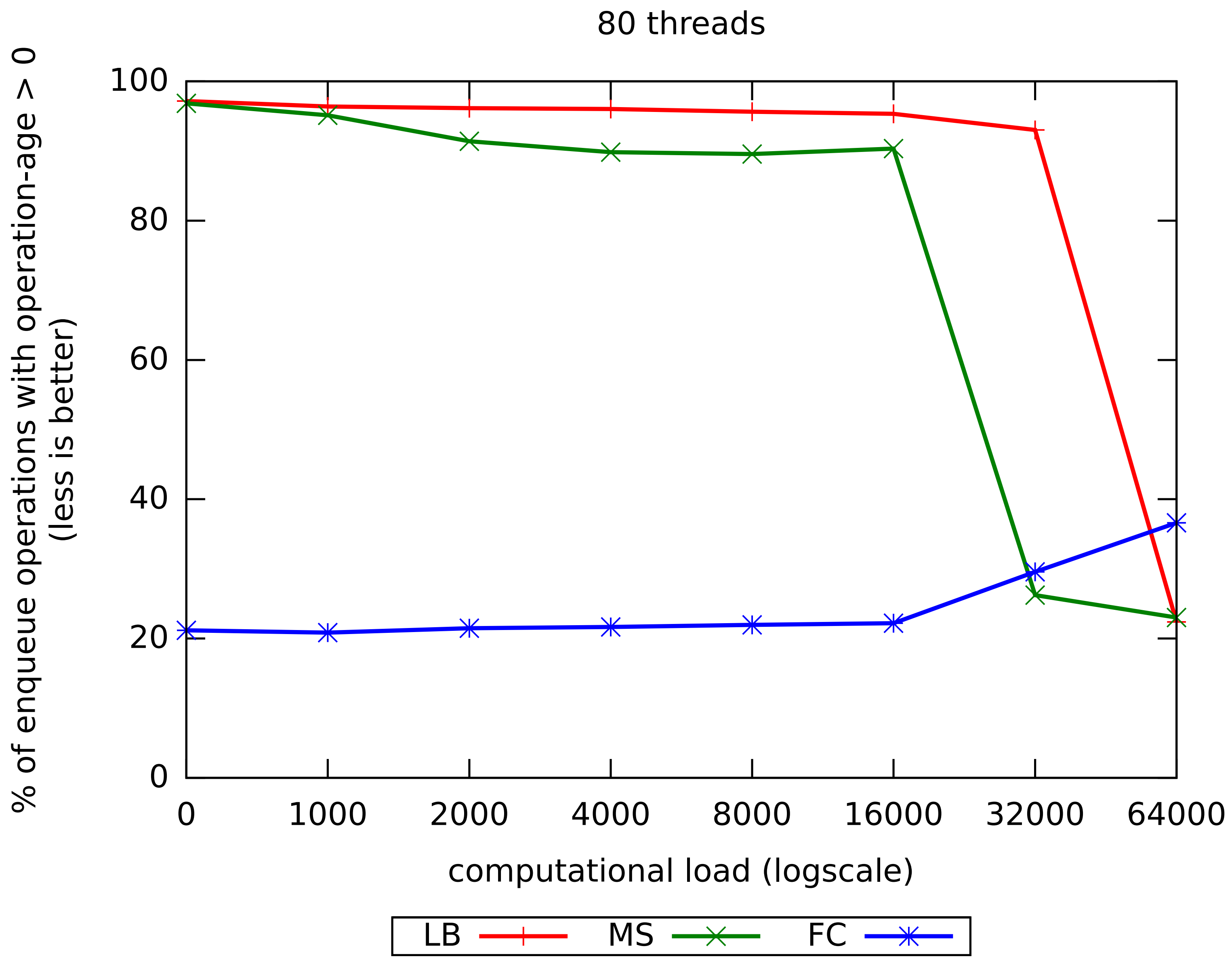
Maximum Operation-Age



Maximum Operation-Lateness



Number of Overtaking Operations



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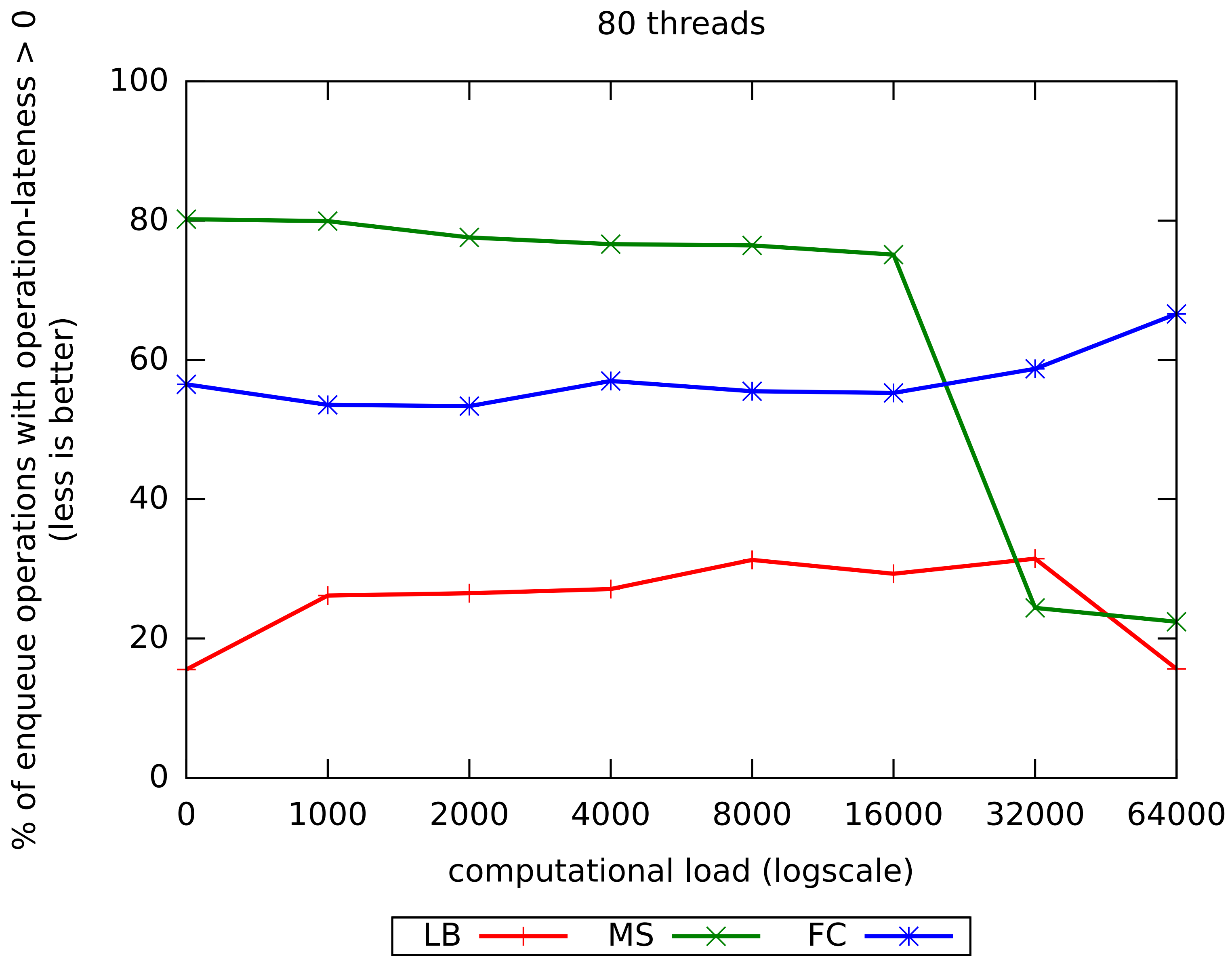

Conclusion

- We introduced metrics to compare the behavior of various FIFO queue implementations.
    - Relaxed implementation can appear more FIFO than strict implementations.
- Future work
    - Measure operation-fairness of relaxed FIFO queue implementations.
    - Use element-fairness to analyze implementation of other data structures, e.g. stacks.

Thank You

For more information about the queue implementations see
http://scal.cs.uni-salzburg.at/

Additional measurement results can be seen on
http://scal.cs.uni-salzburg.at/races12/