Remote Core Locking

Migrating Critical-Section Execution to Improve the Performance of Multithreaded Applications

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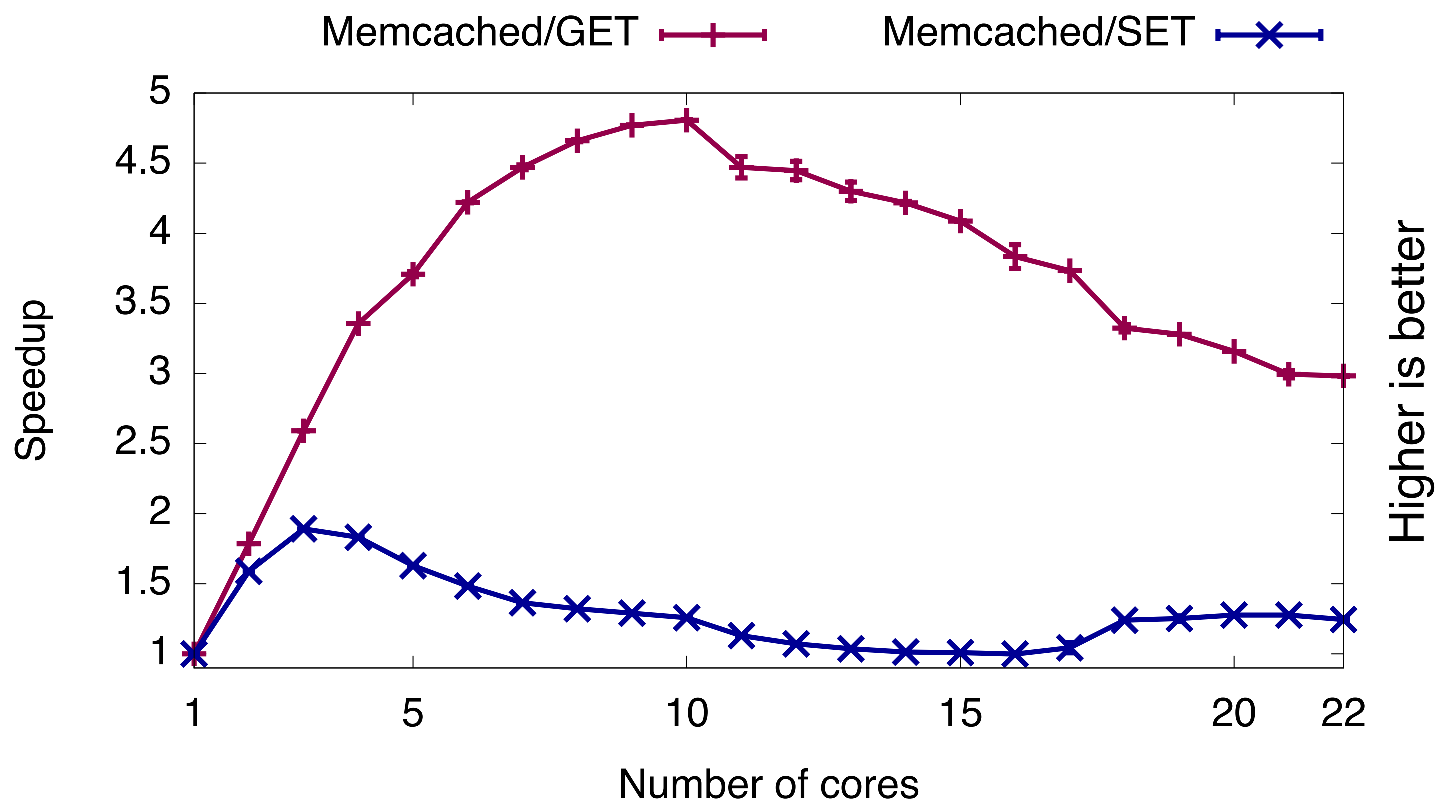
Problem: scalability

- Many legacy applications don't scale well on multicore architectures
- For instance, Memcached (GET/SET requests):



Experiments run on a 48-core, "magny-cours" x86 AMD machine

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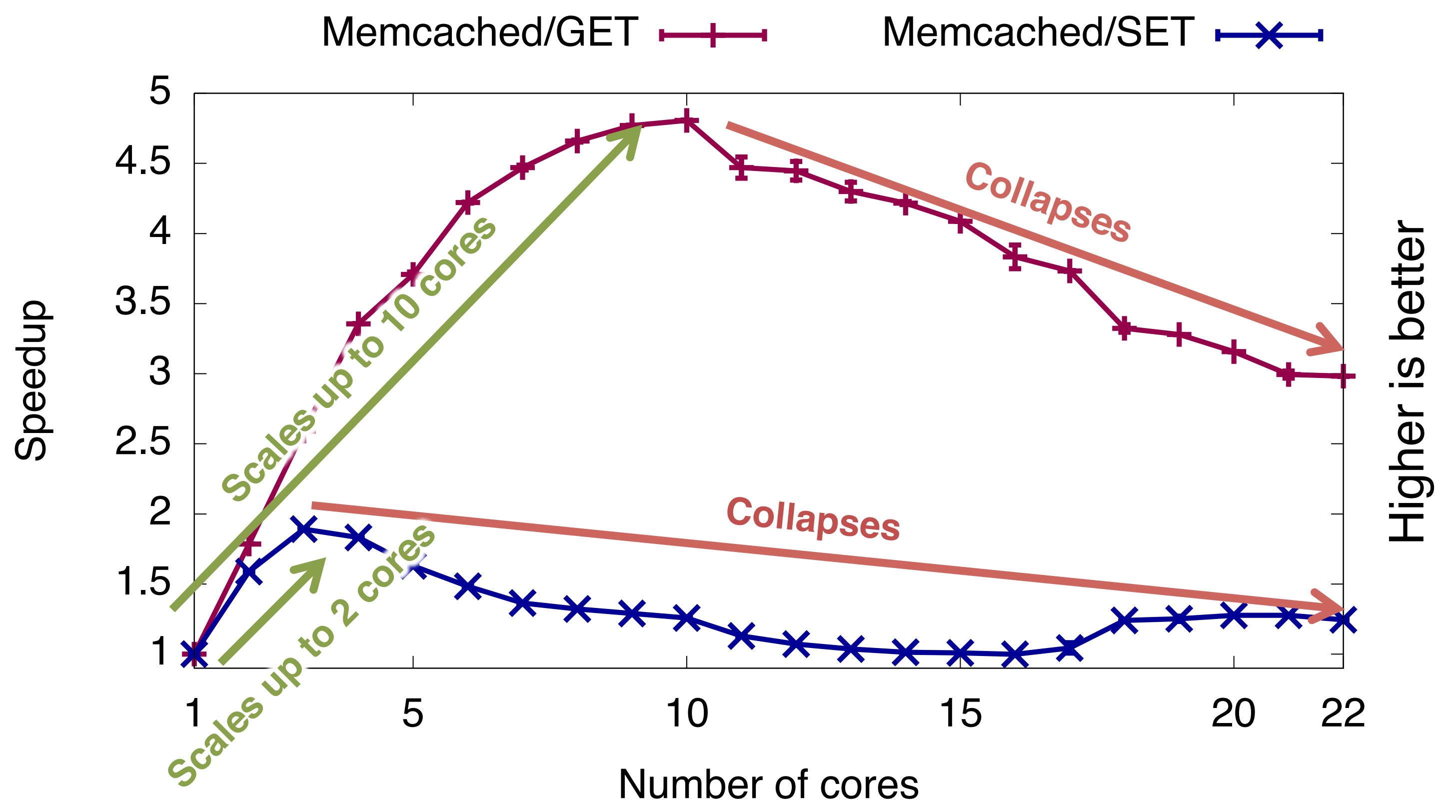

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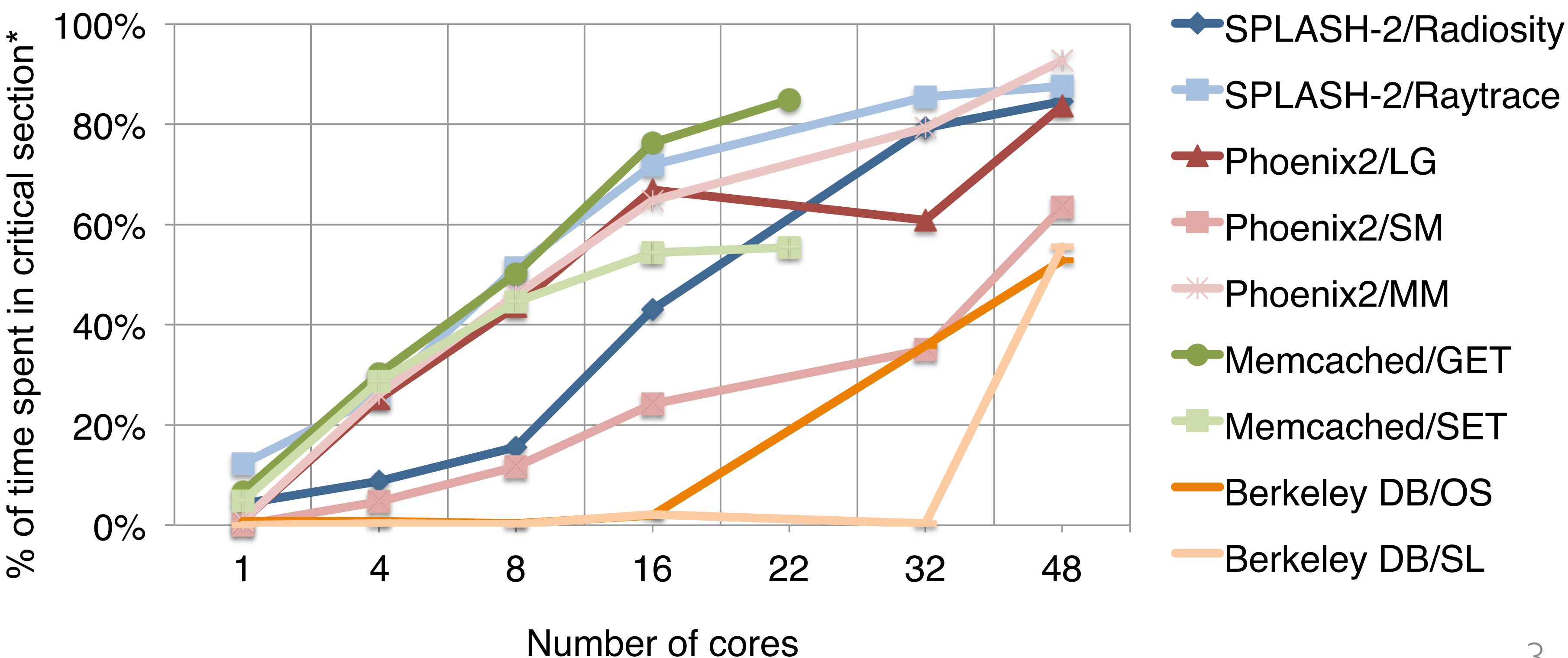
Why?

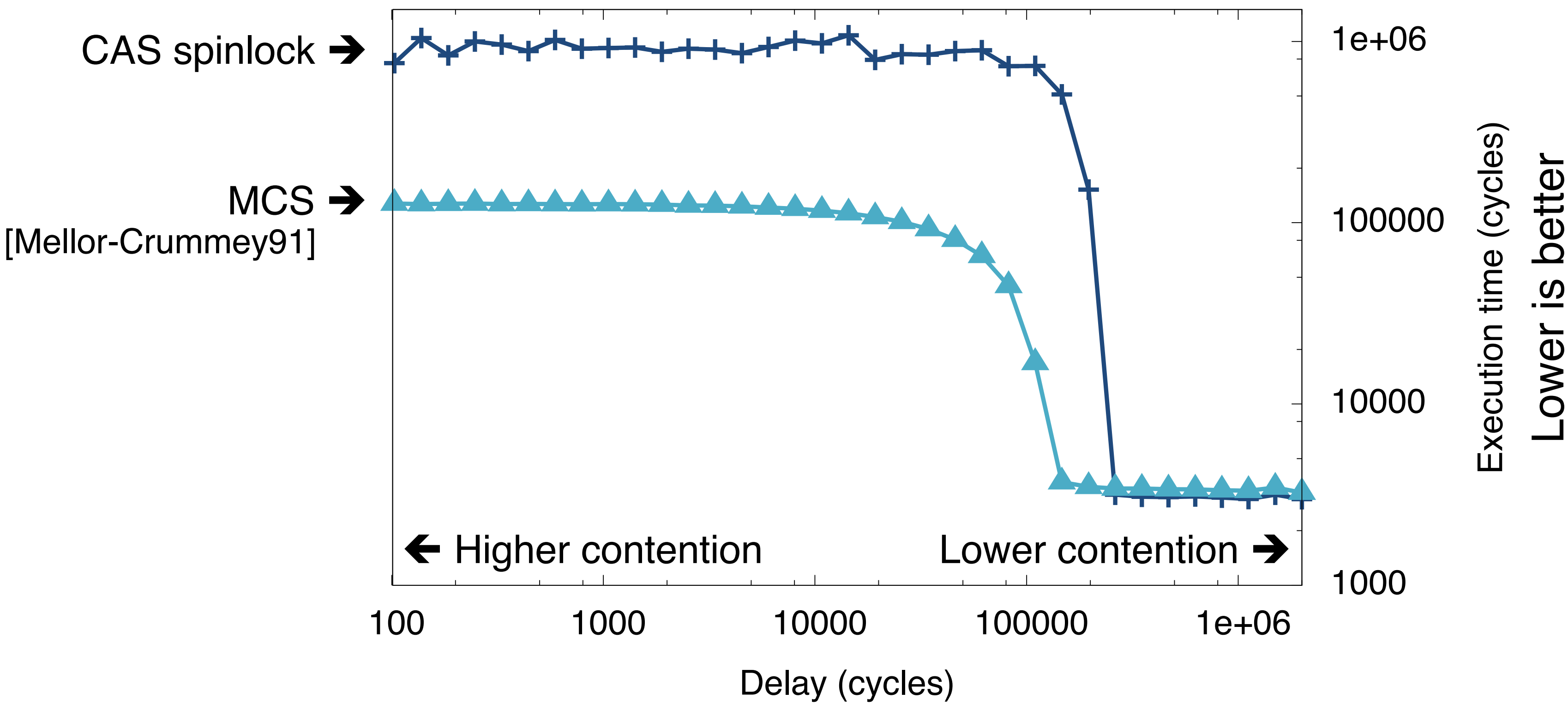
- Critical sections = bottleneck on multicore architectures
- High contention ⇒ lock acquisition is costly
  - More cores ⇒ more contention



* Including lock acquisition time

Solution: designing better locks

- Better resistance to contention
- No need to redesign the application
- Custom microbenchmark to compare locks:



Critical sections access 5 cache lines each

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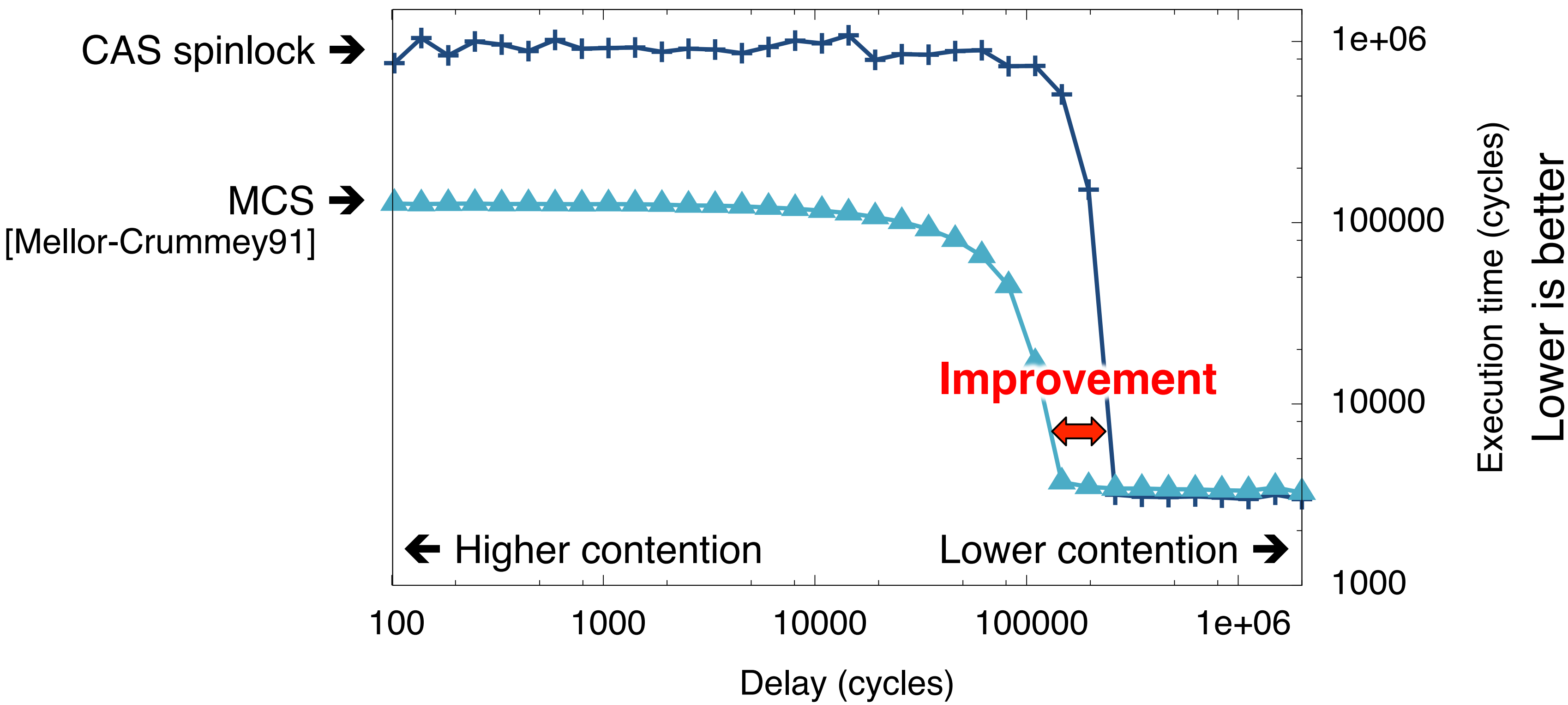

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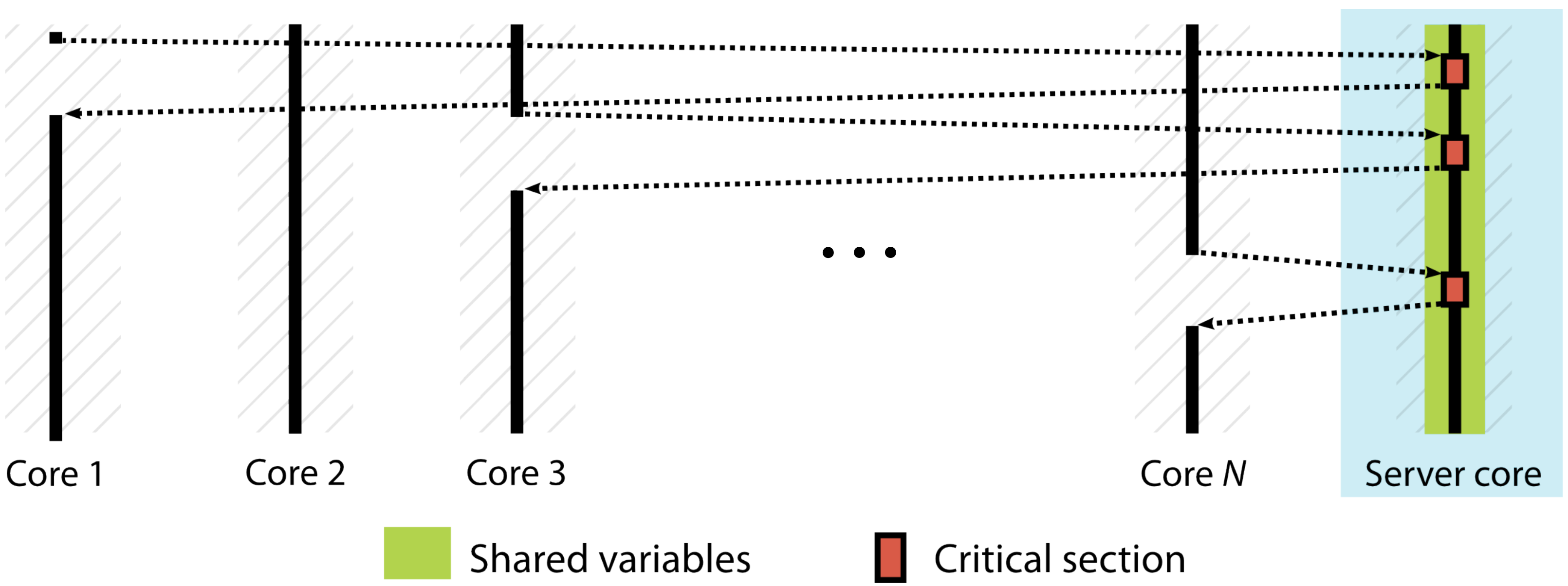
Remote Core Locking

Objective: remove atomic instructions and reduce cache misses

- Execute contended critical sections on a dedicated server core
- Very fast transfer of control, no sync on global variable
  - Faster than lock acquisitions when contention is high
- Shared data remains on server core ⇒ fewer cache misses



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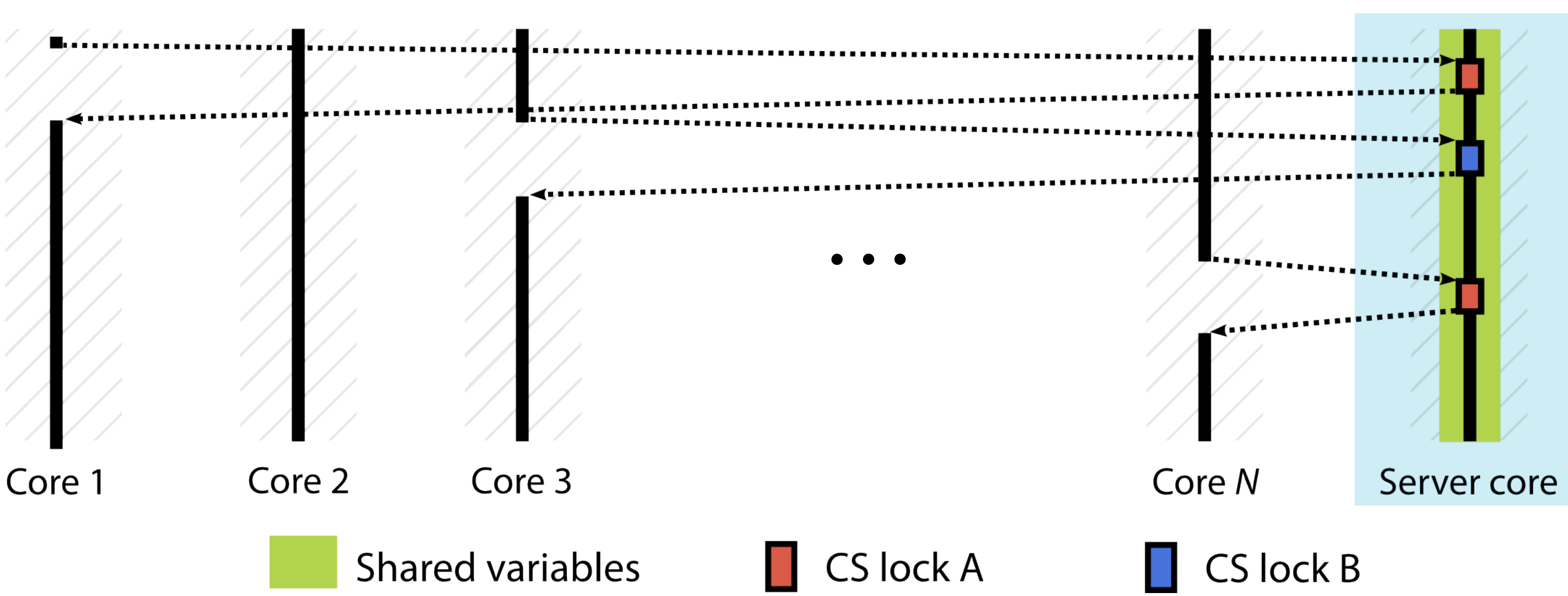

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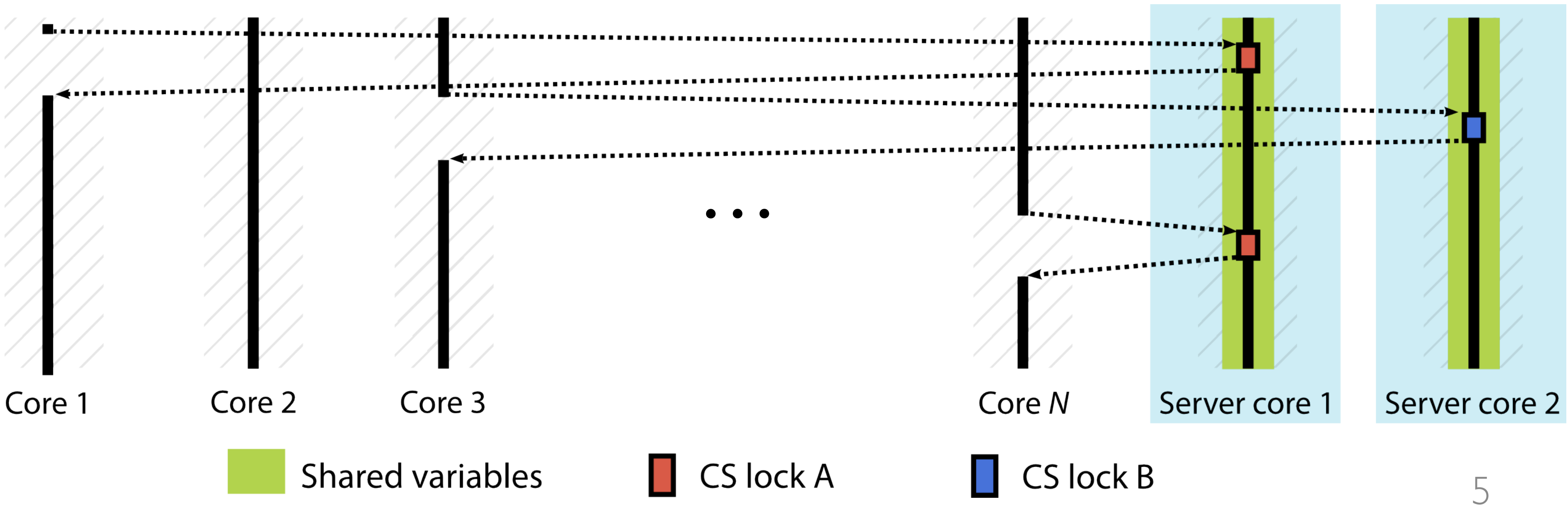
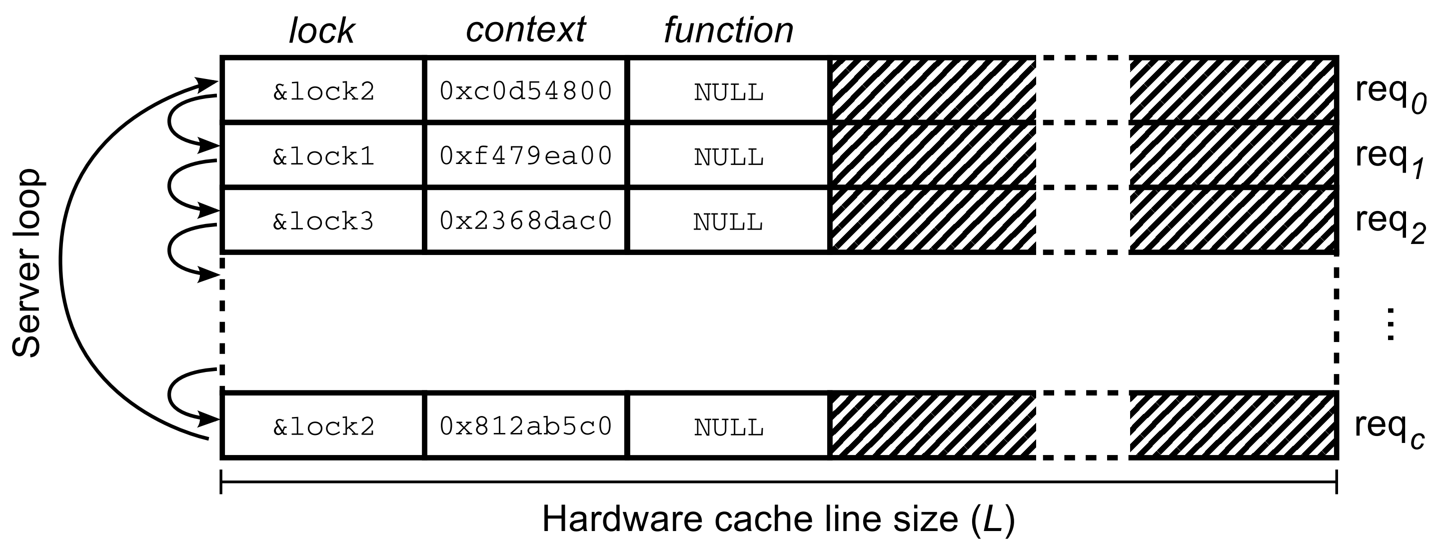


Implementation: general idea

- Implementation based on cache line-sized mailboxes
- Three fields: lock, context, function



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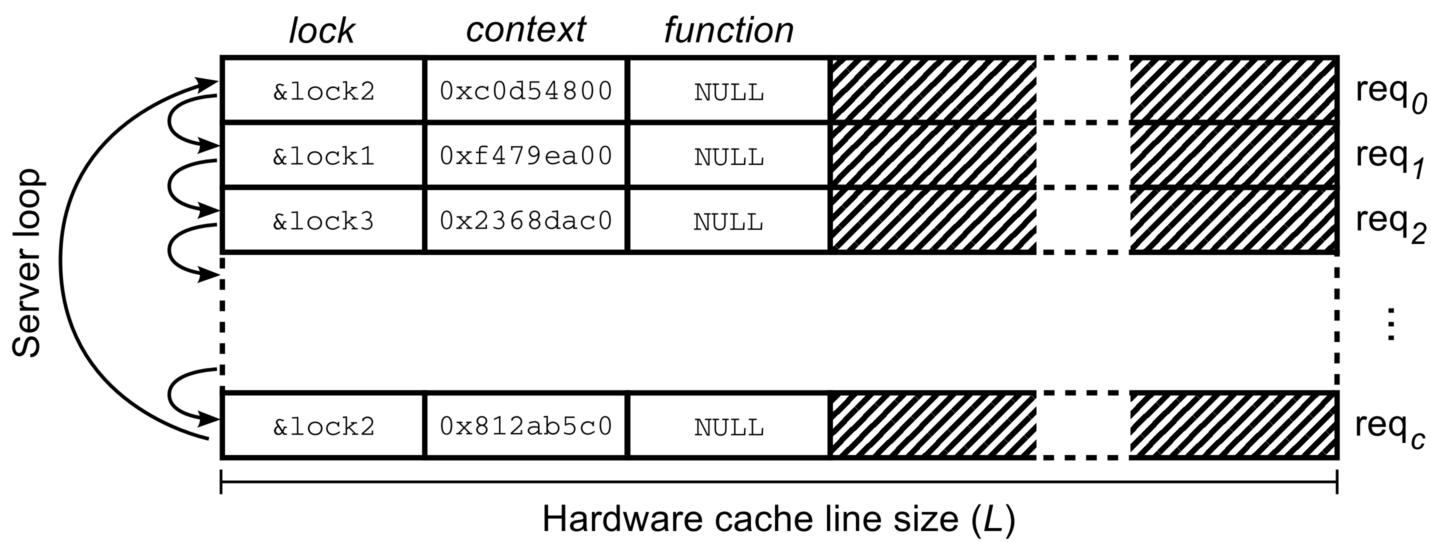

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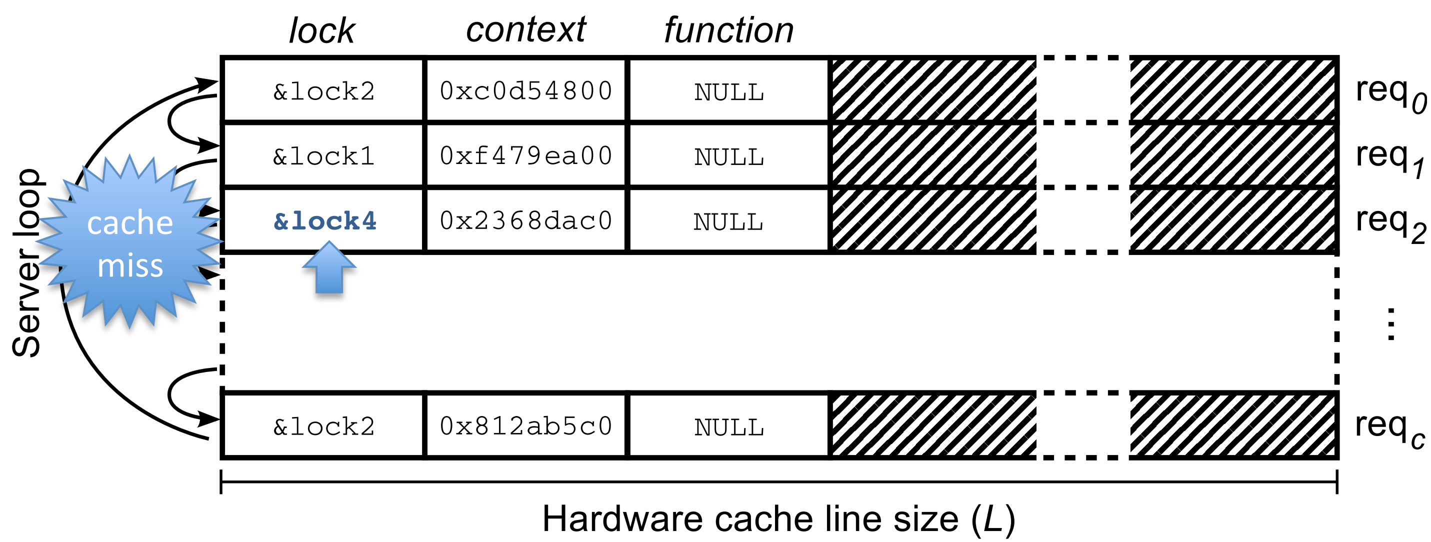

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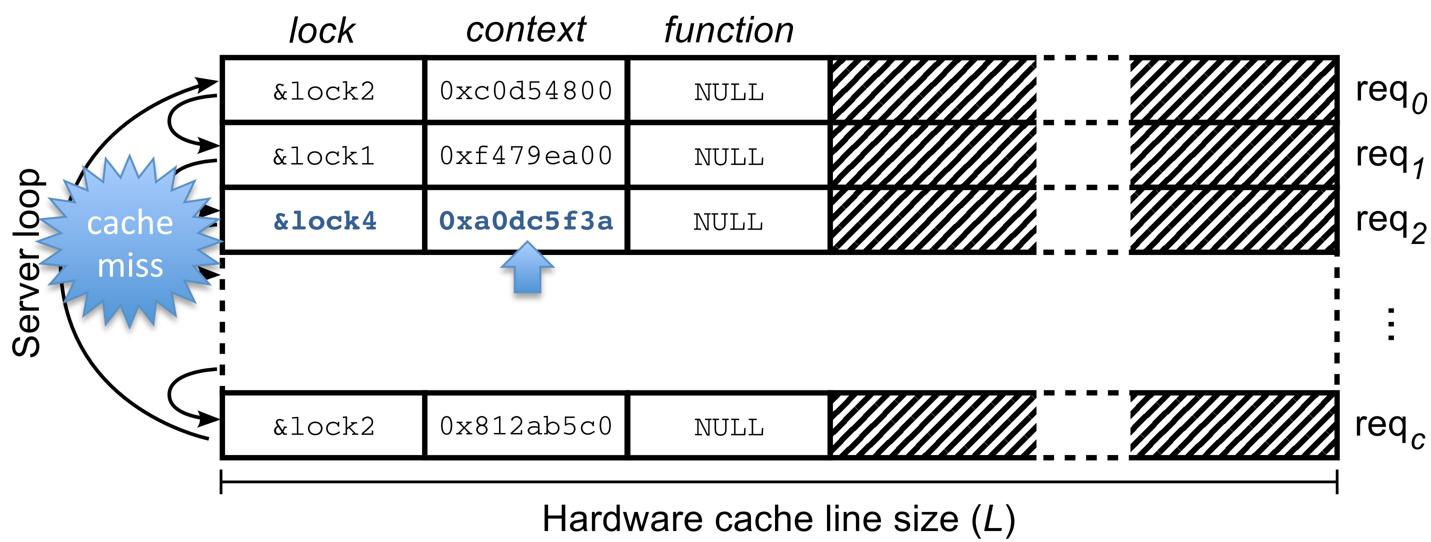

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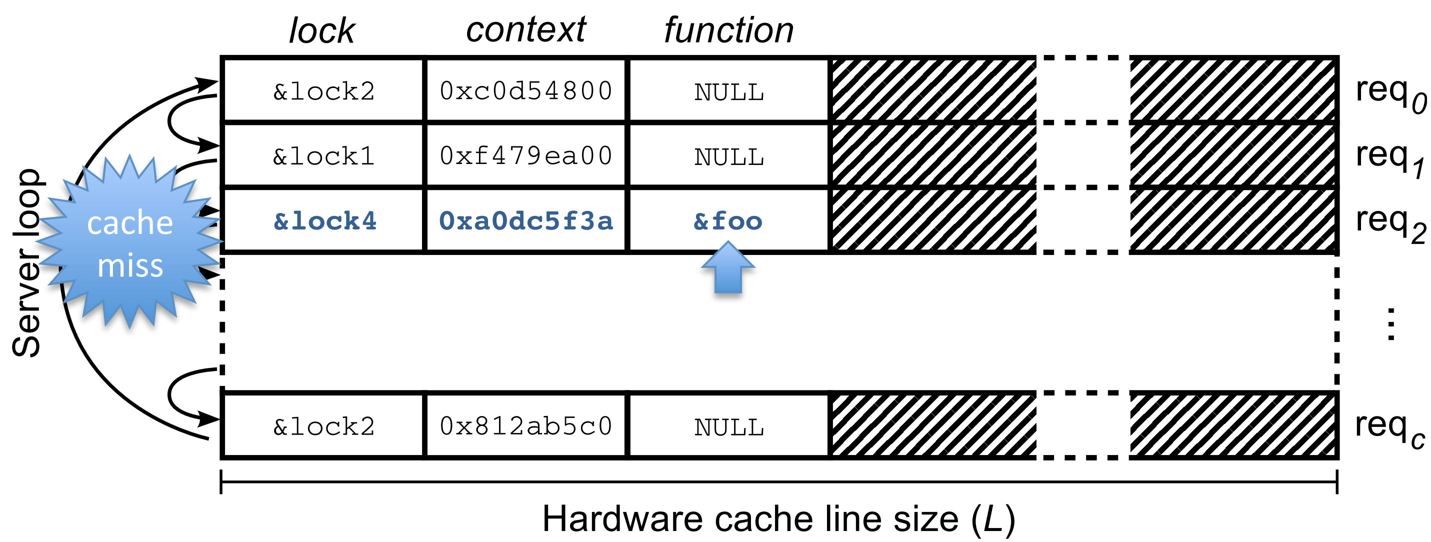

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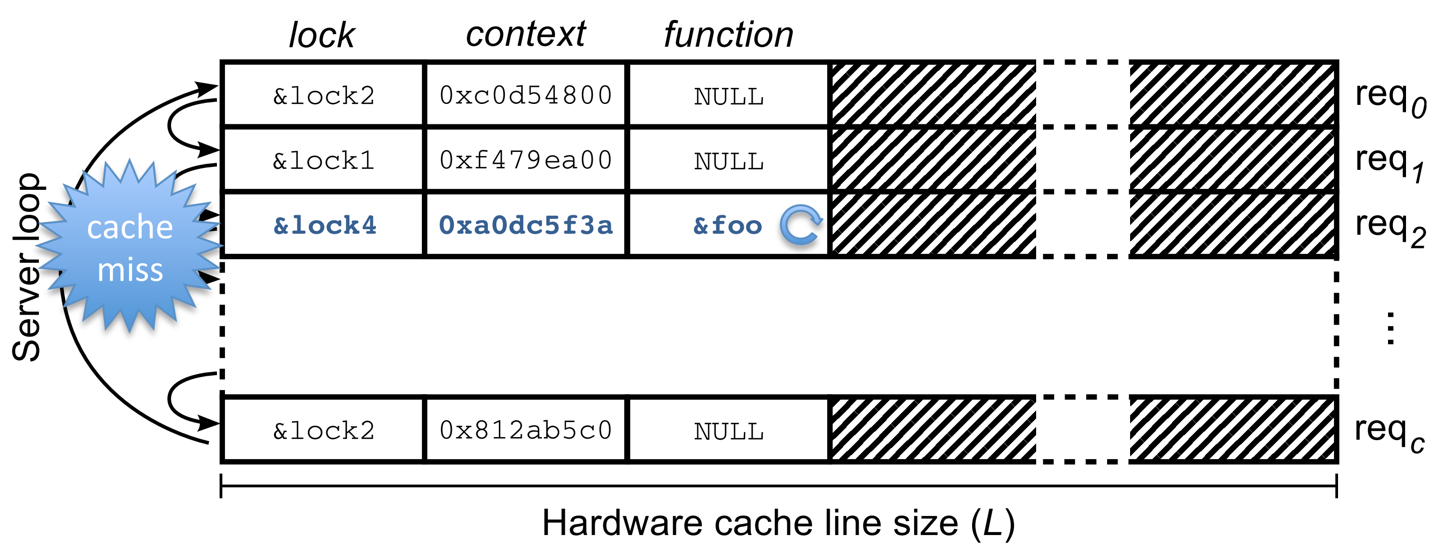

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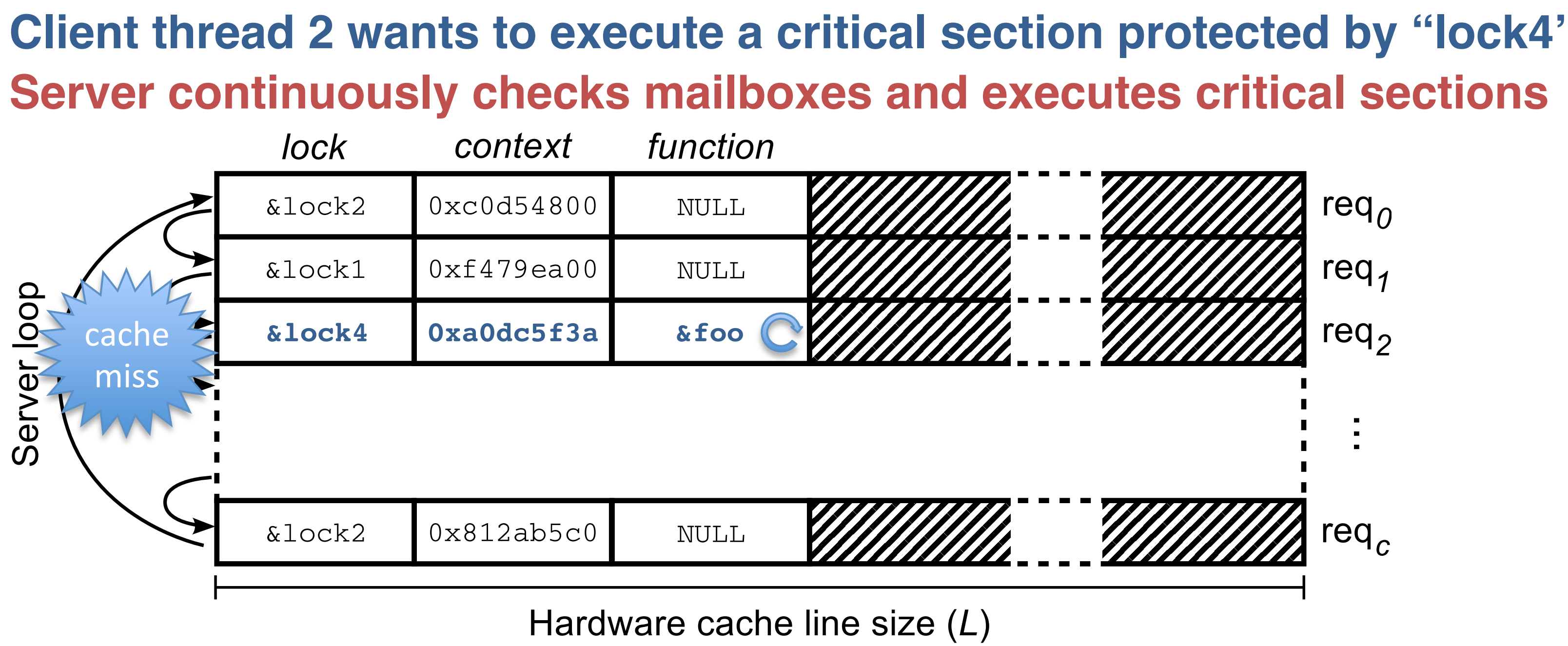

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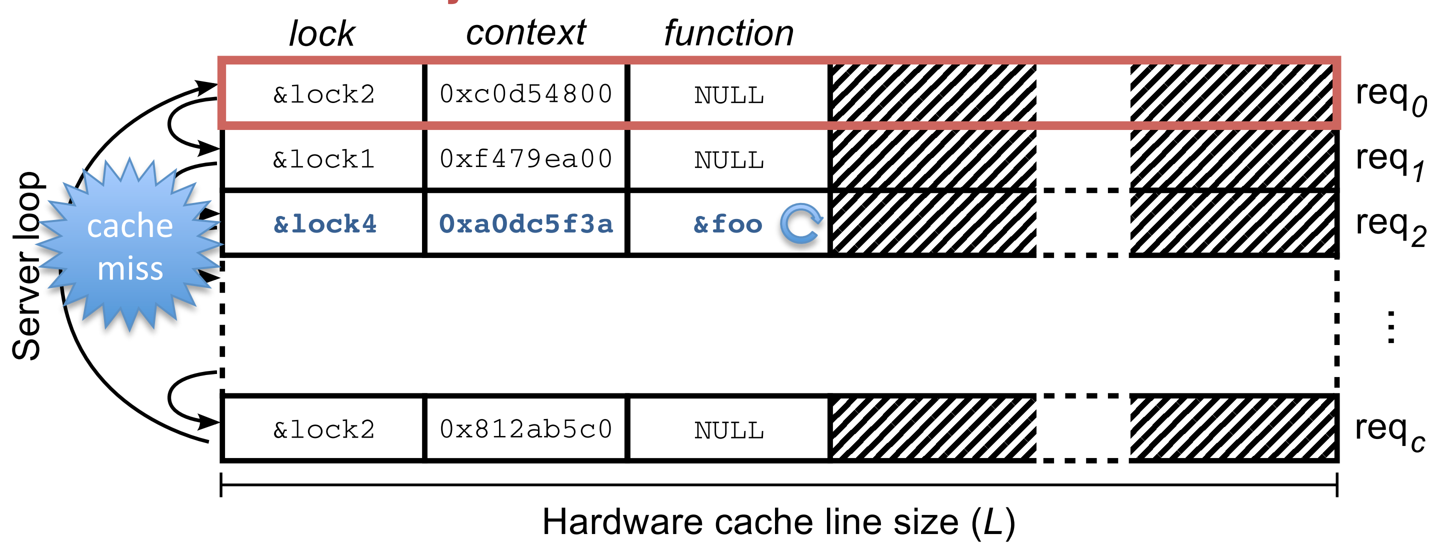

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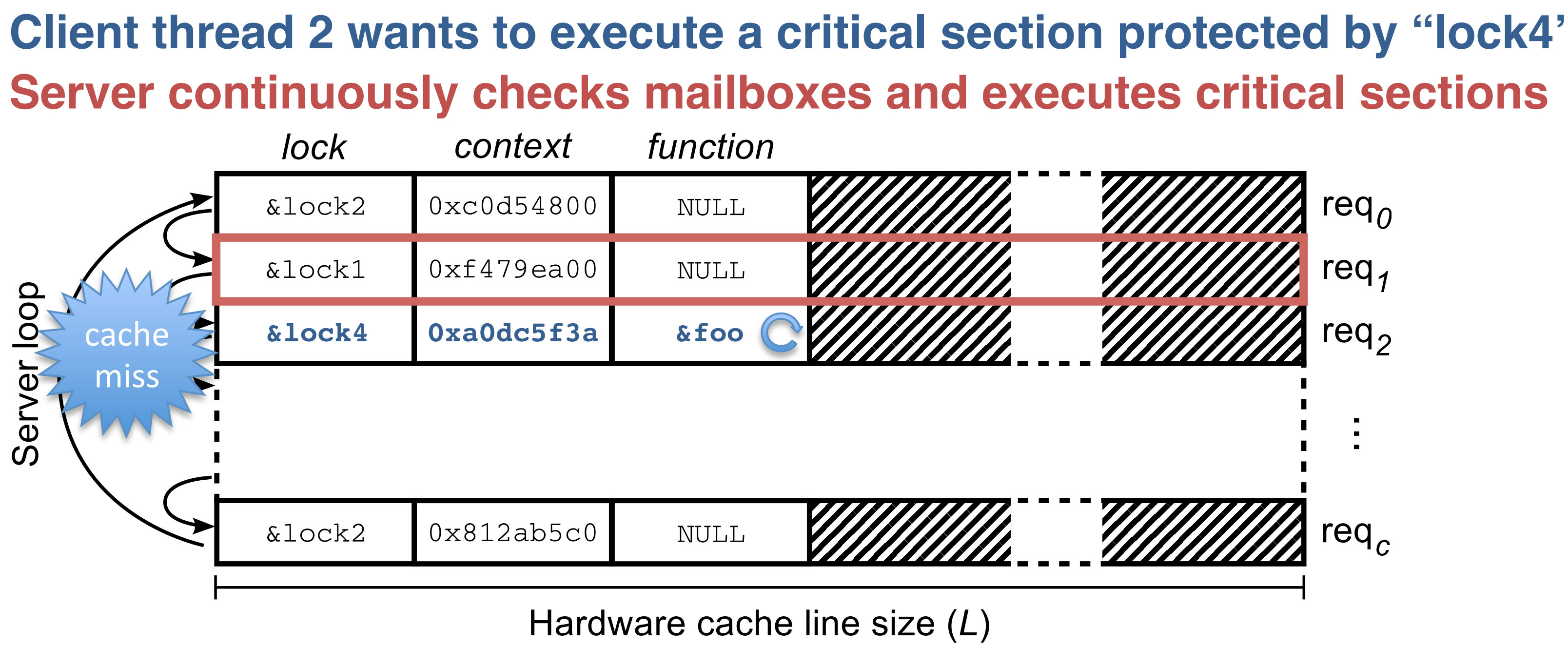

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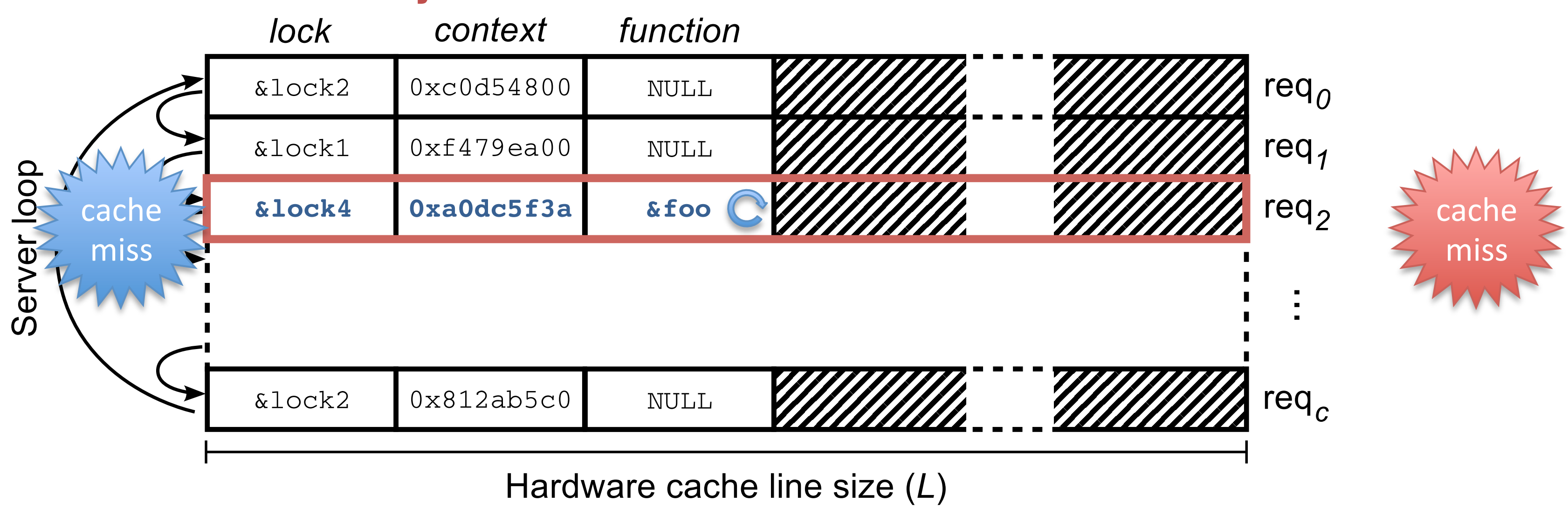

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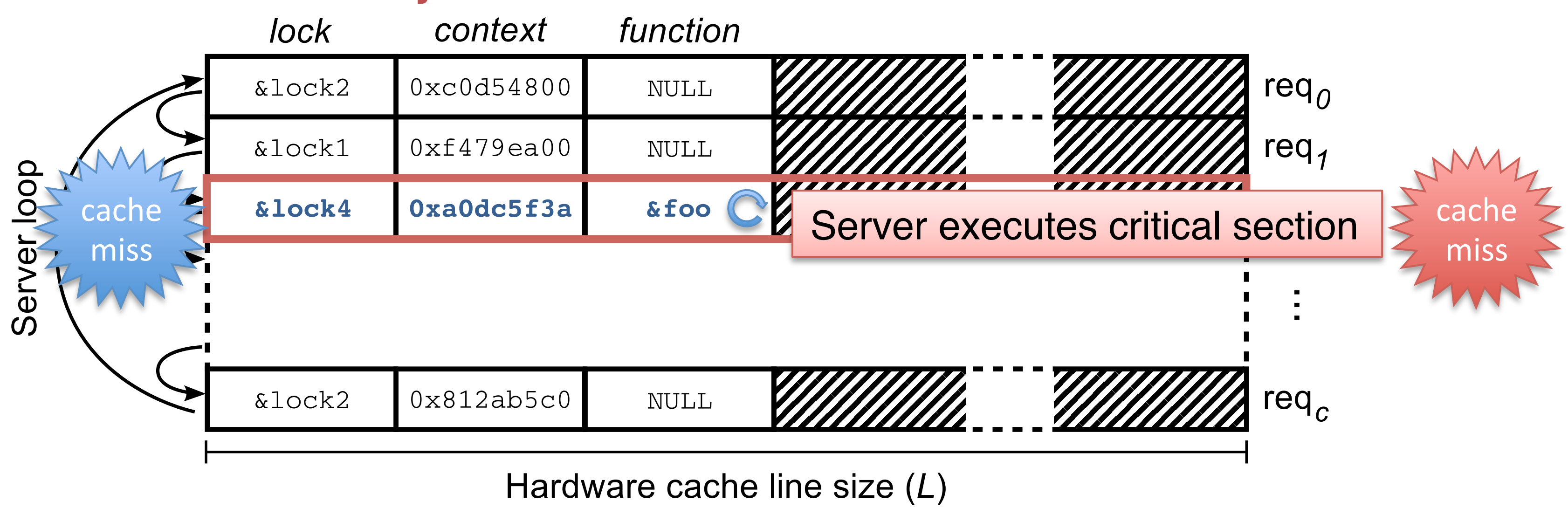

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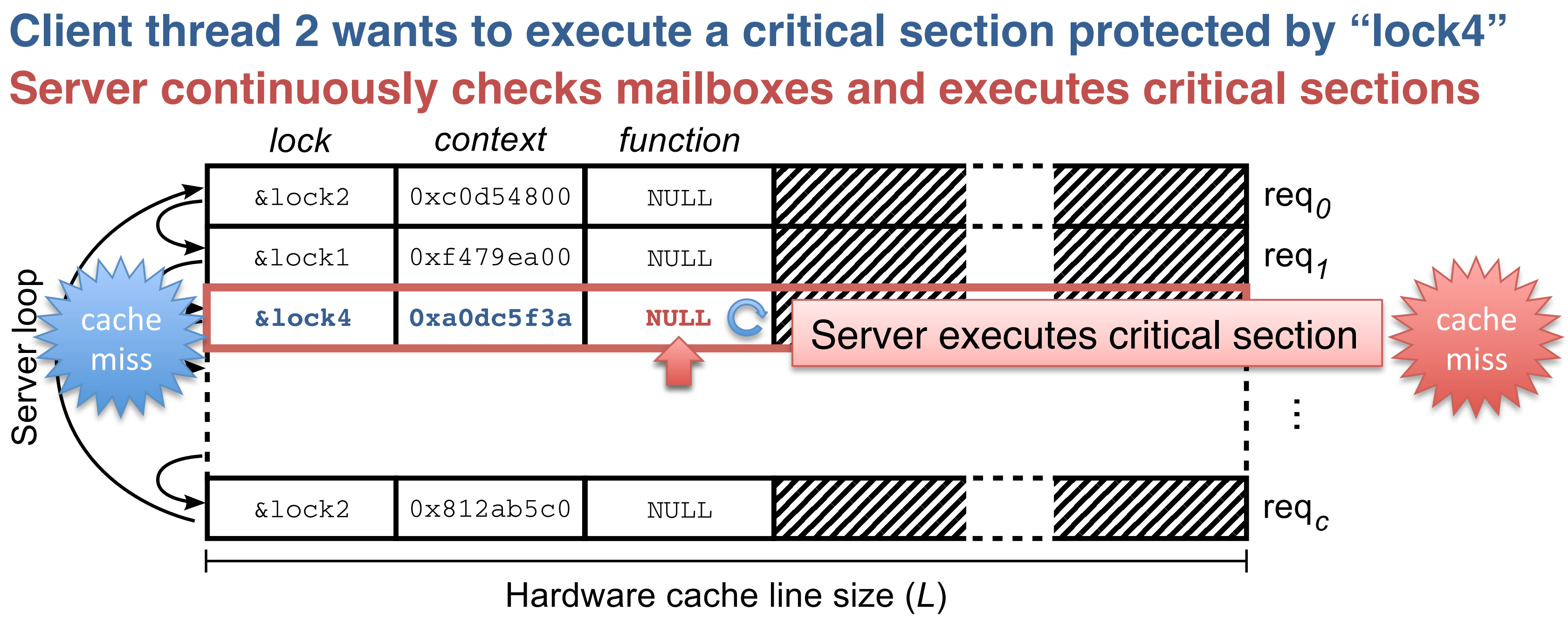

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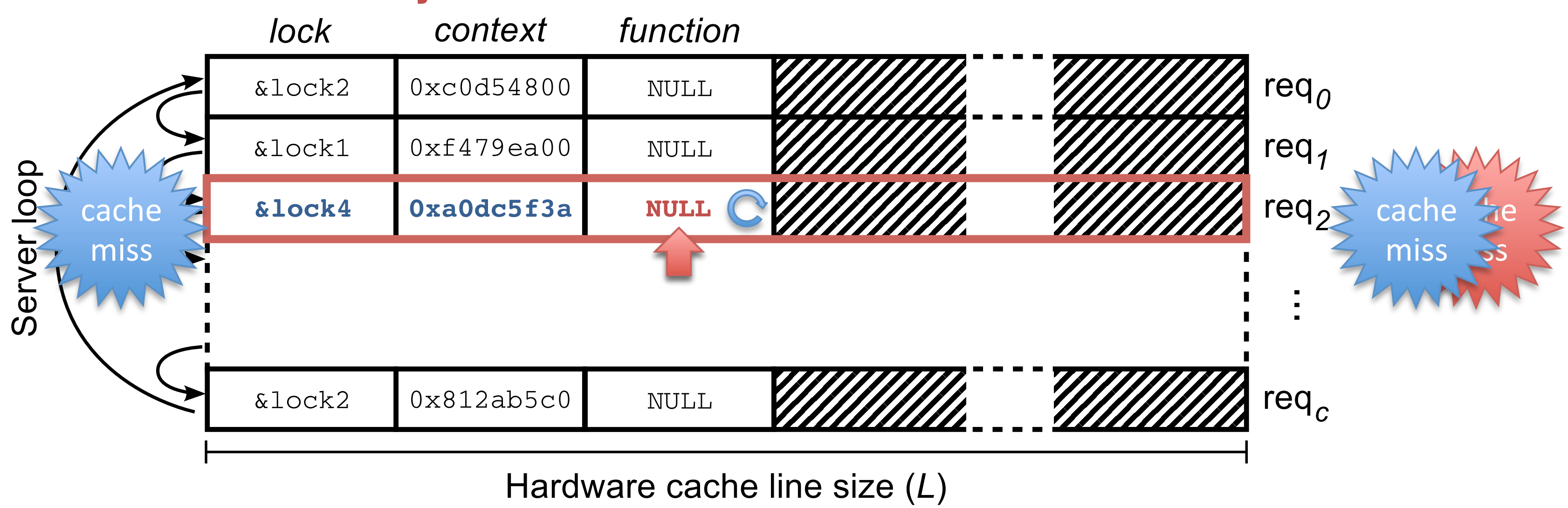

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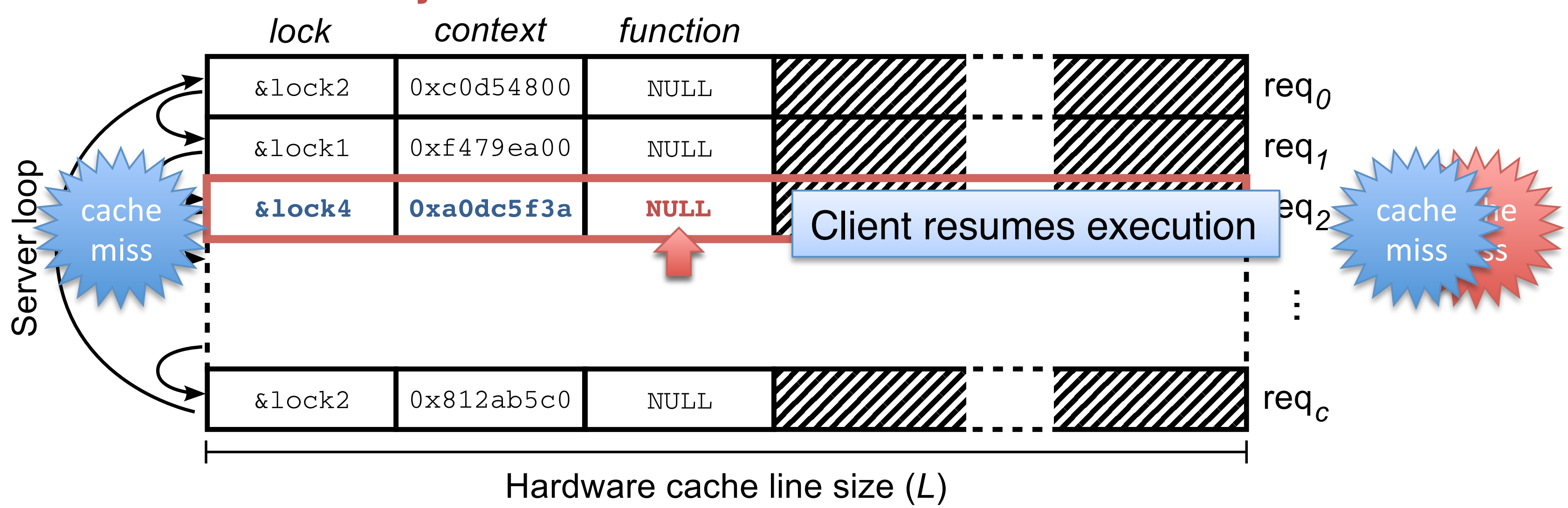

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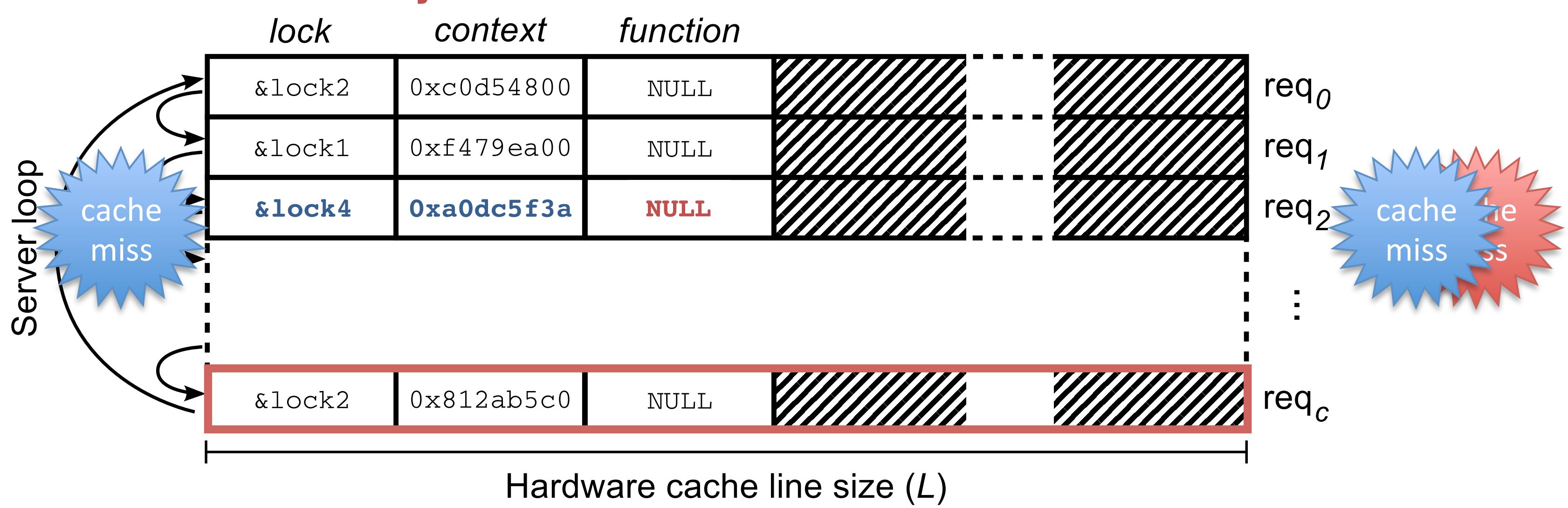

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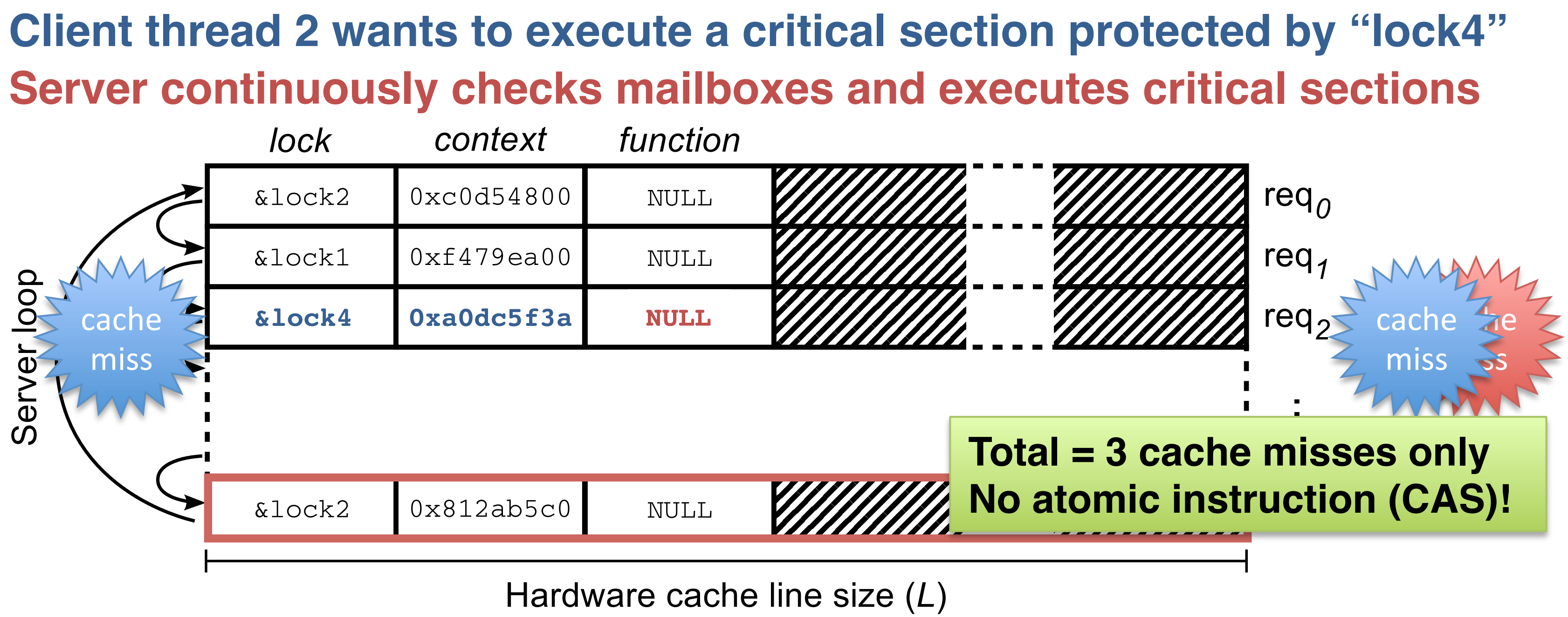

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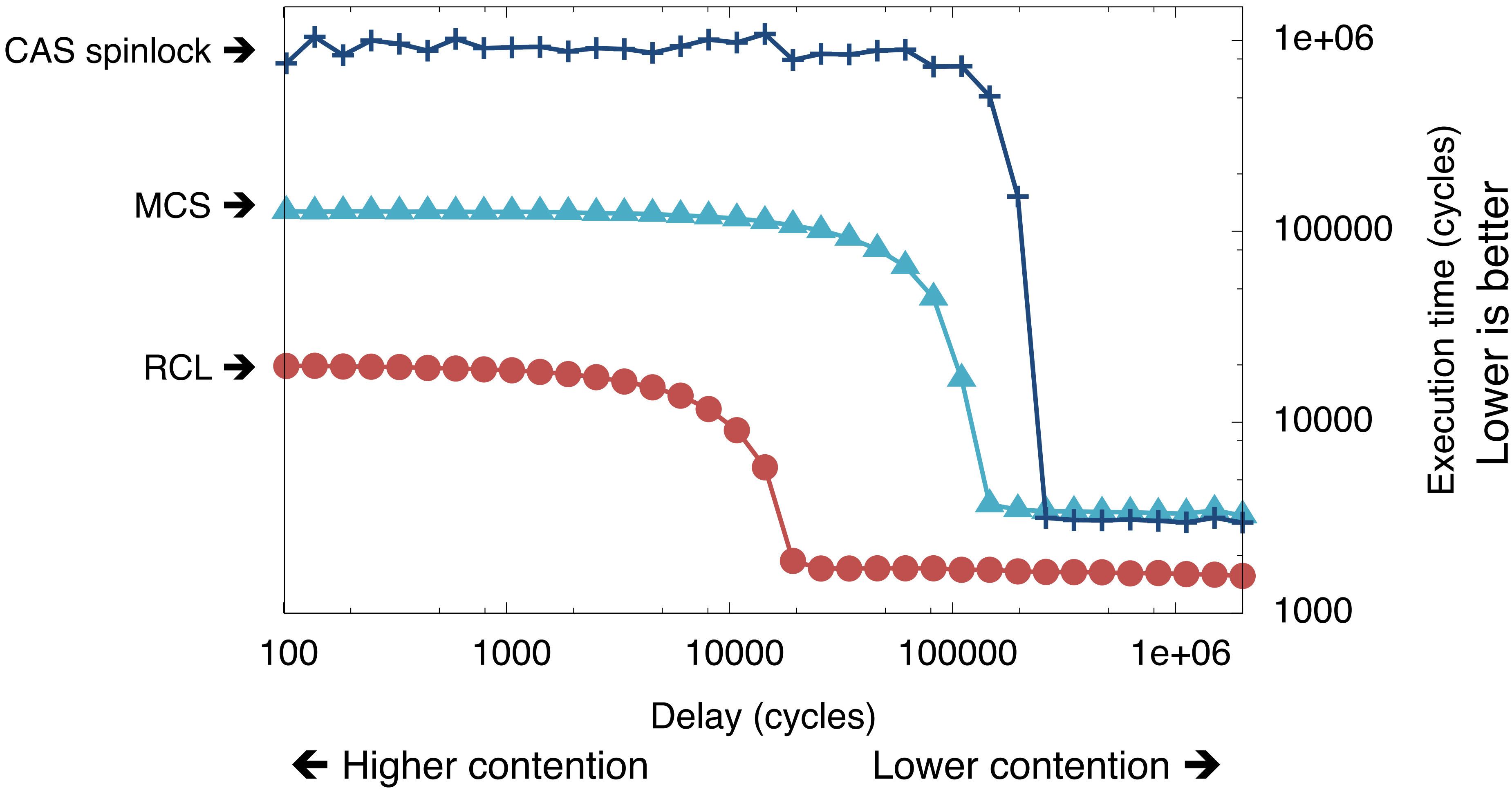
Performance



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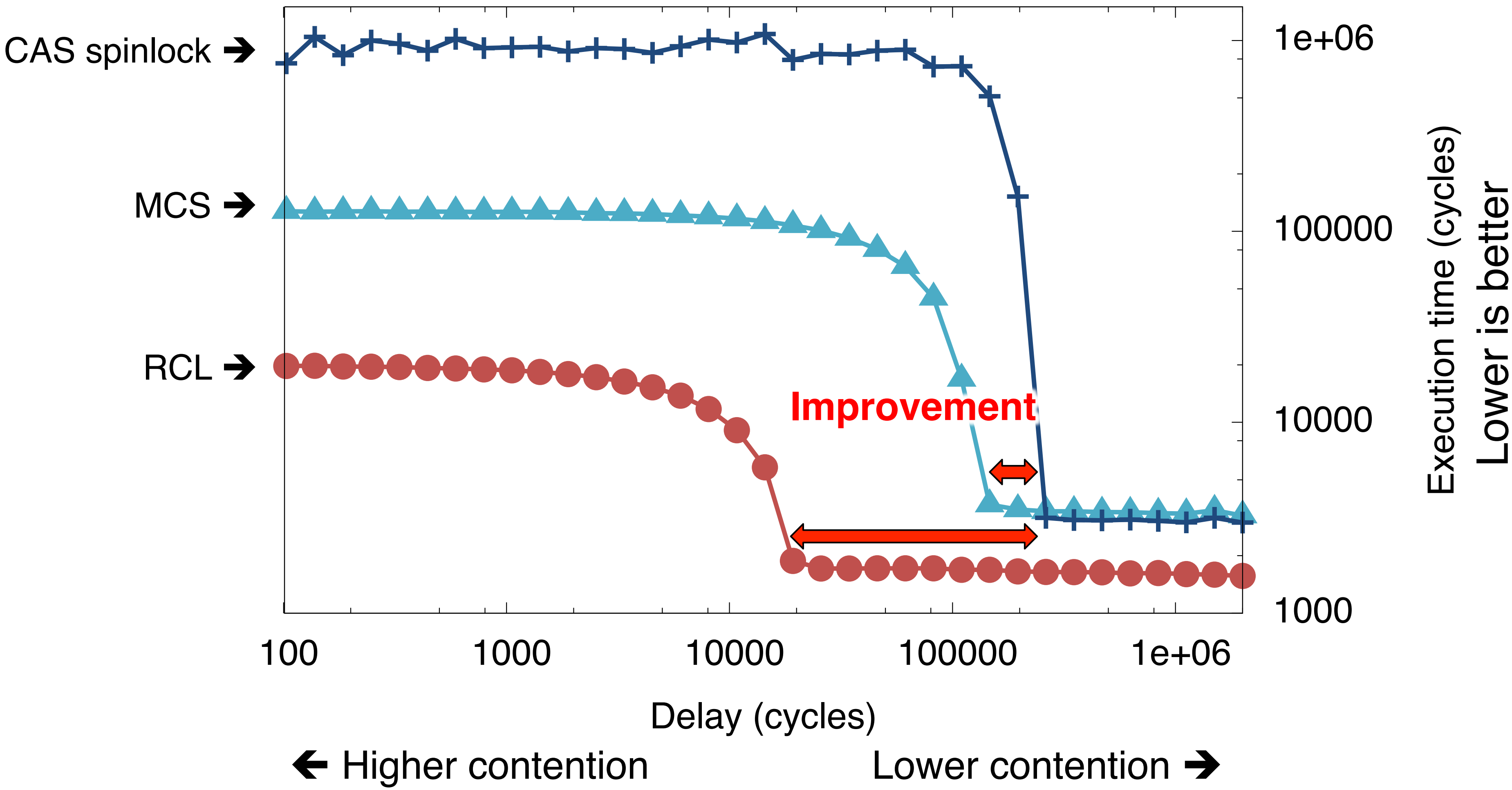

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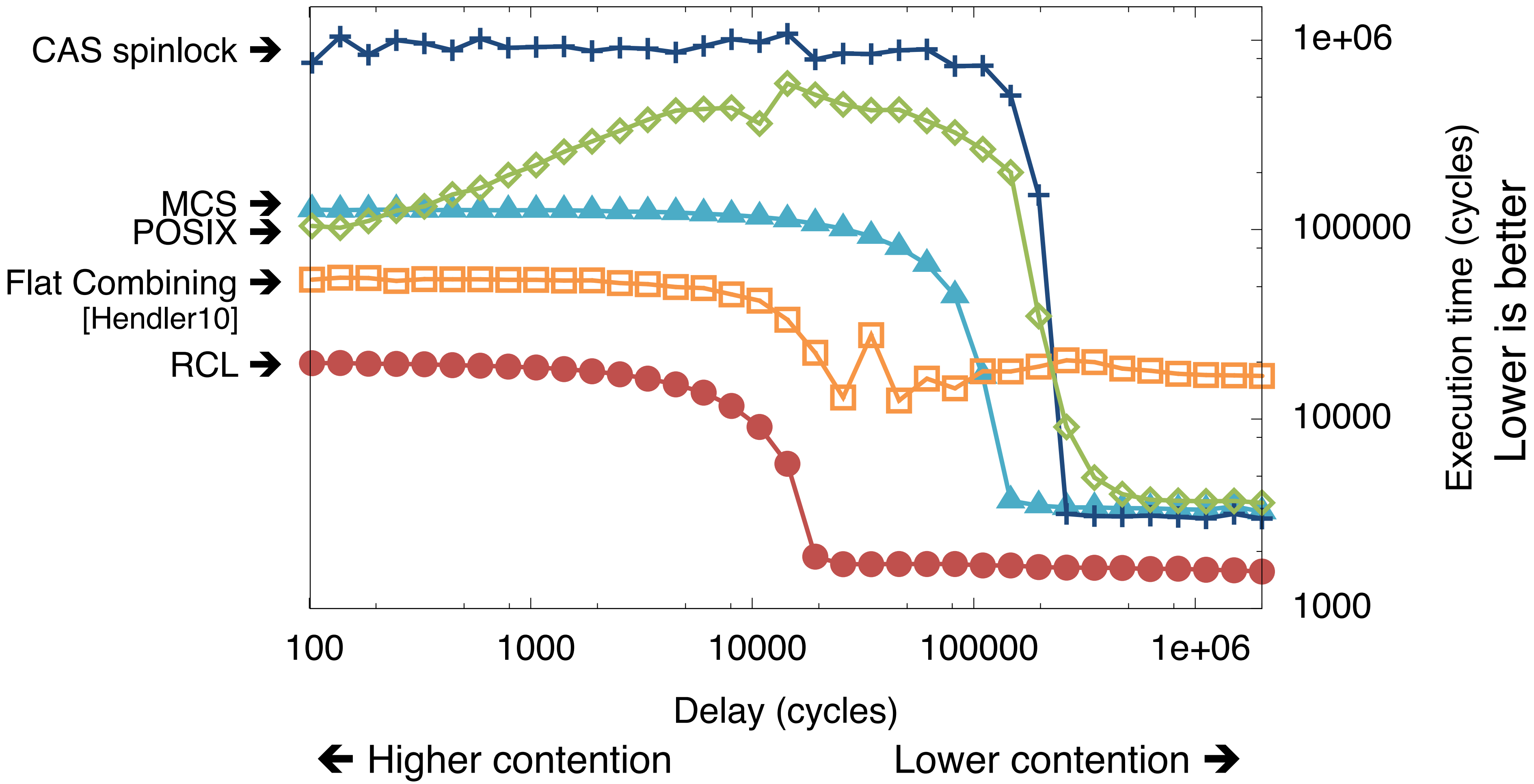

Using RCL in legacy applications (1)

RCL Runtime :

- Handles blocking in critical sections (I/O, page faults…)
  - Pool of servicing threads on server
  - Able to service other (independent) critical sections when blocked
- Makes it possible to use condition variables (cond/wait)
  - Used by ~50% of applications that use POSIX locks in Debian 6.0.3

Using RCL in legacy applications (2)

Reengineering:

- Critical sections must be encapsulated into functions
  - Local variables sent as parameters (context)

Using RCL in legacy applications (2)

Reengineering:

```
void func(void) {
  int a, b, x;
  …
  a = …;
  …
  pthread_mutex_lock();
  a = f(a);
  f(b);
  pthread_mutex_unlock();
  …
}
```

```
struct context { int a, b };

void func(void) {
    struct context c;
    int x;
    …
    c.a = …;
    …
    execute_rcl(__cs, &c);
    …
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void __cs(struct context *c) {
    c->a = f(c->a)
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Using RCL in legacy applications (2)

Reengineering:

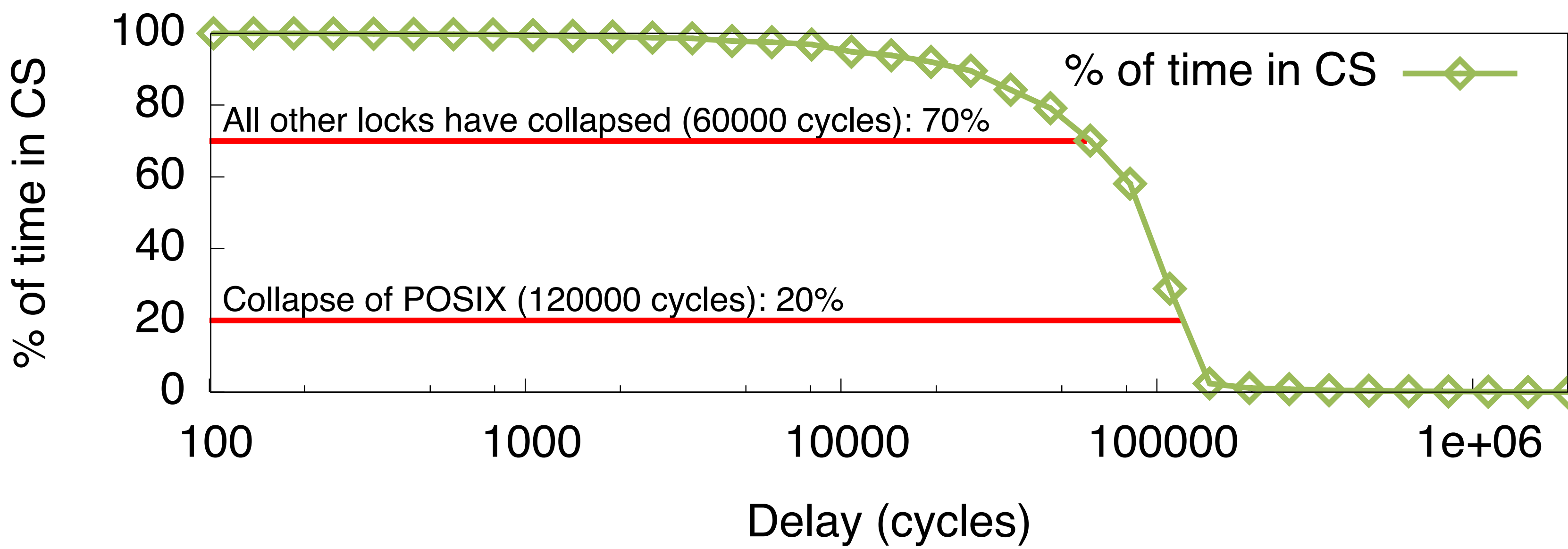
- Critical sections must be encapsulated into functions
  - Local variables sent as parameters (context)

- Tool to reengineer applications automatically
  - Possible to pick which locks use RCL
  - To avoid false serialization:
    Possible to pick which server(s) handle which lock(s).

Using RCL in legacy applications (3)

Profiling:

- Custom profiler to find good candidates
- Metric: time spent in critical sections
- Running the profiler on the microbenchmark shows that:
  - If time spent in CS > 20%, RCL is more efficient than POSIX locks
  - If time spent in CS > 70%, RCL is more efficient than all other locks

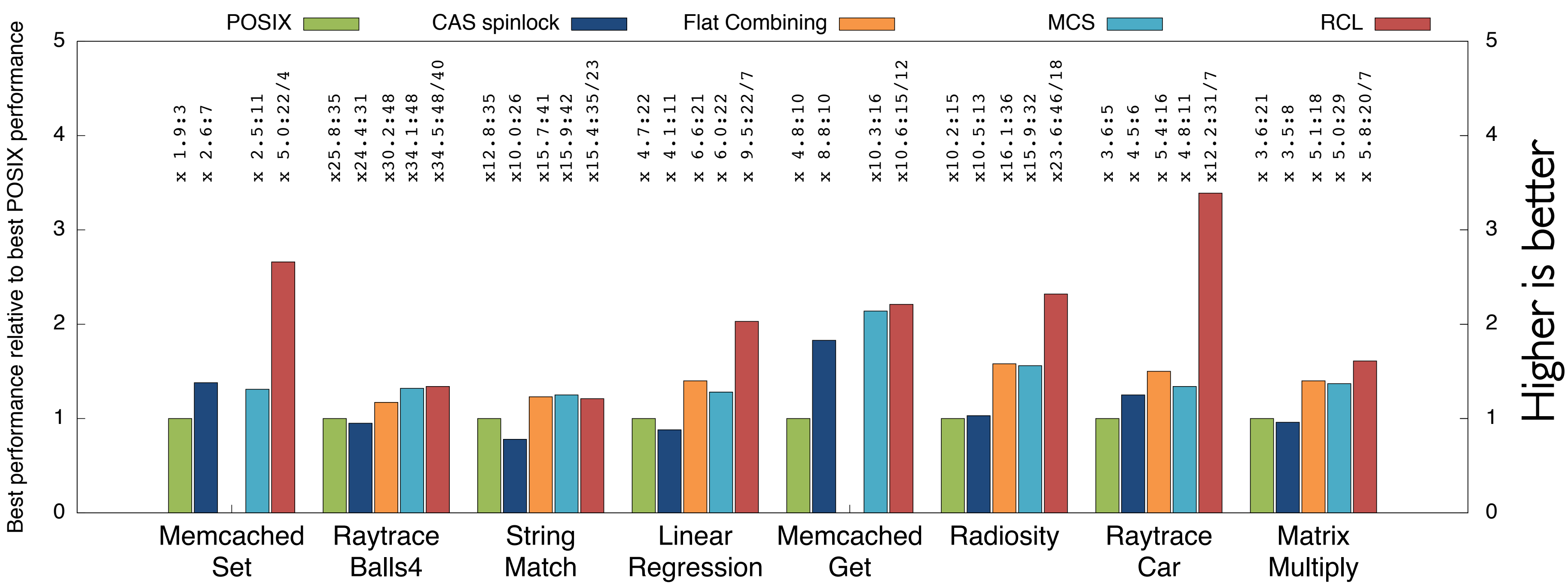


Experiments

- Benchmarks (highly contended ⇒ 70% time spent in CS):
  - **SPLASH-2 benchmark suite**
    - 3 applications out of 10 are highly contended
  - **Phoenix2 benchmark suite**
    - 3 applications out of 7 are highly contended
  - **Memcached**
    - Highly contended with the GET workload
  - **Berkeley DB / TPC-C**
    - Highly contended with 2 workloads (Order Status, Stock Level)

Evaluation results (1)

- Better performance and scalability when time in CS > 70%
  - Performance improvement correlated with time in CS
- Only one or two locks replaced each time



% in CS: 55% (many DCMs) 40% 63% 83% 84% 84% 88% 93%

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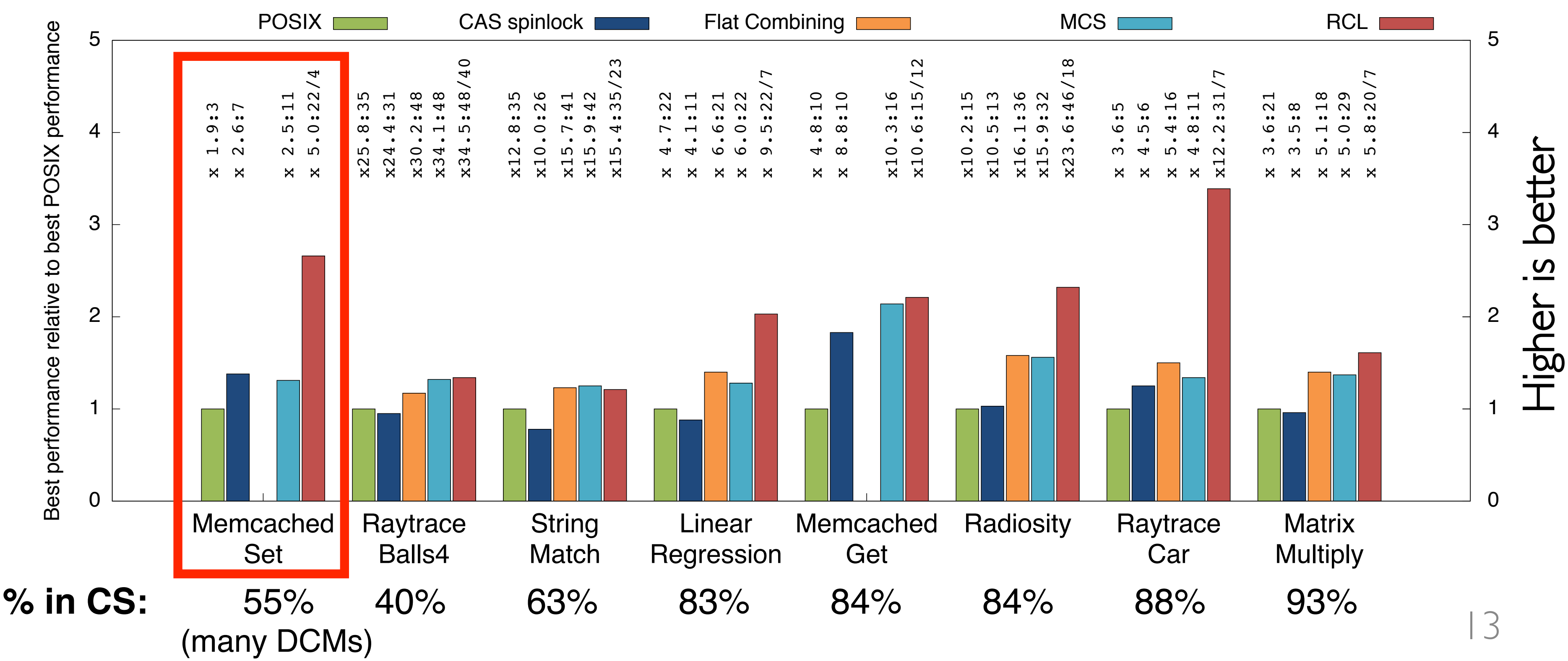

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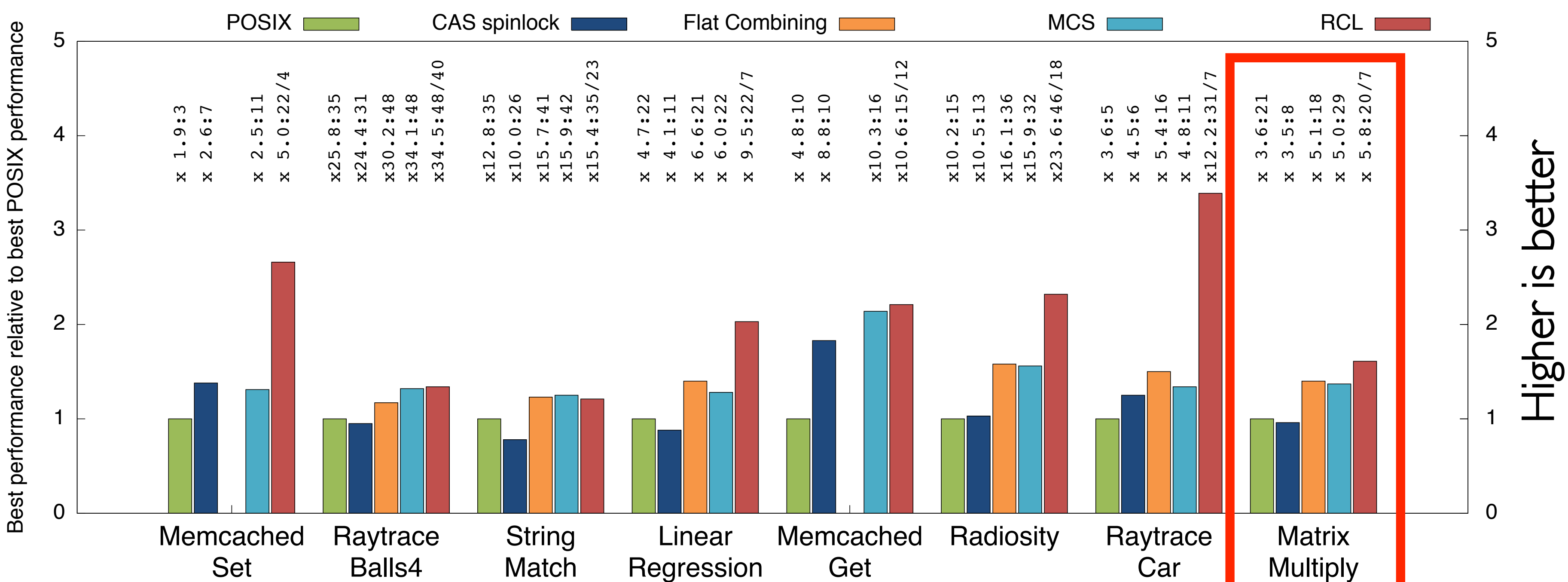

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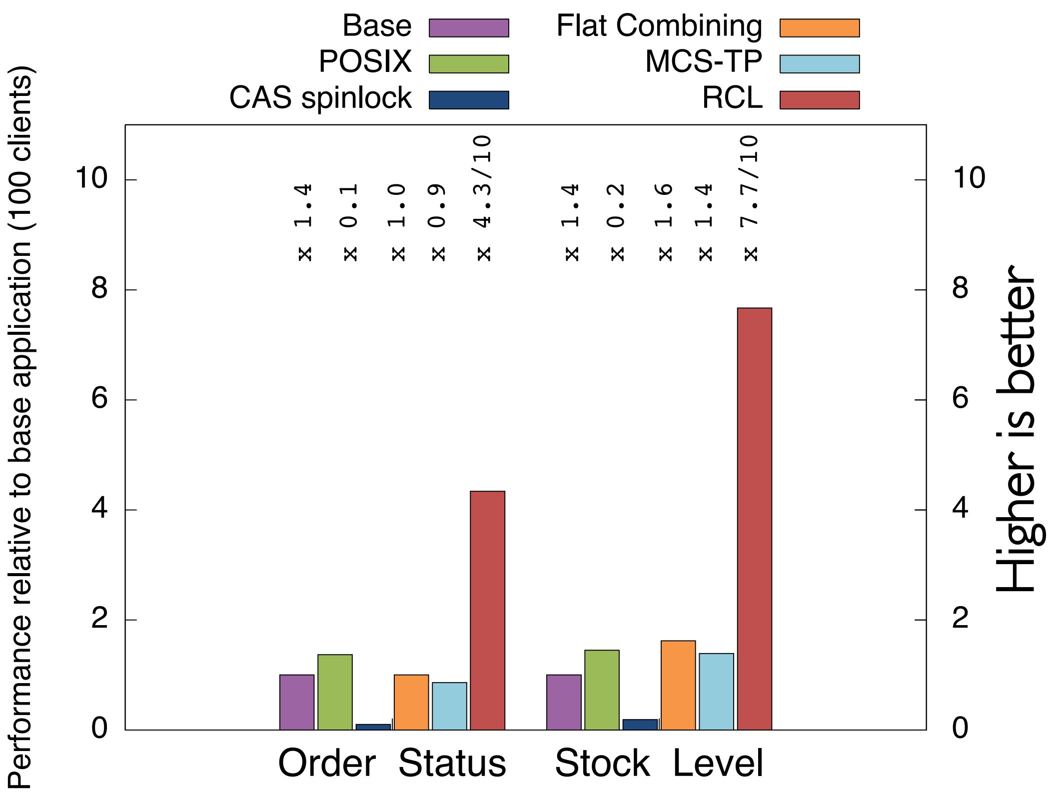
Evaluation results (2)

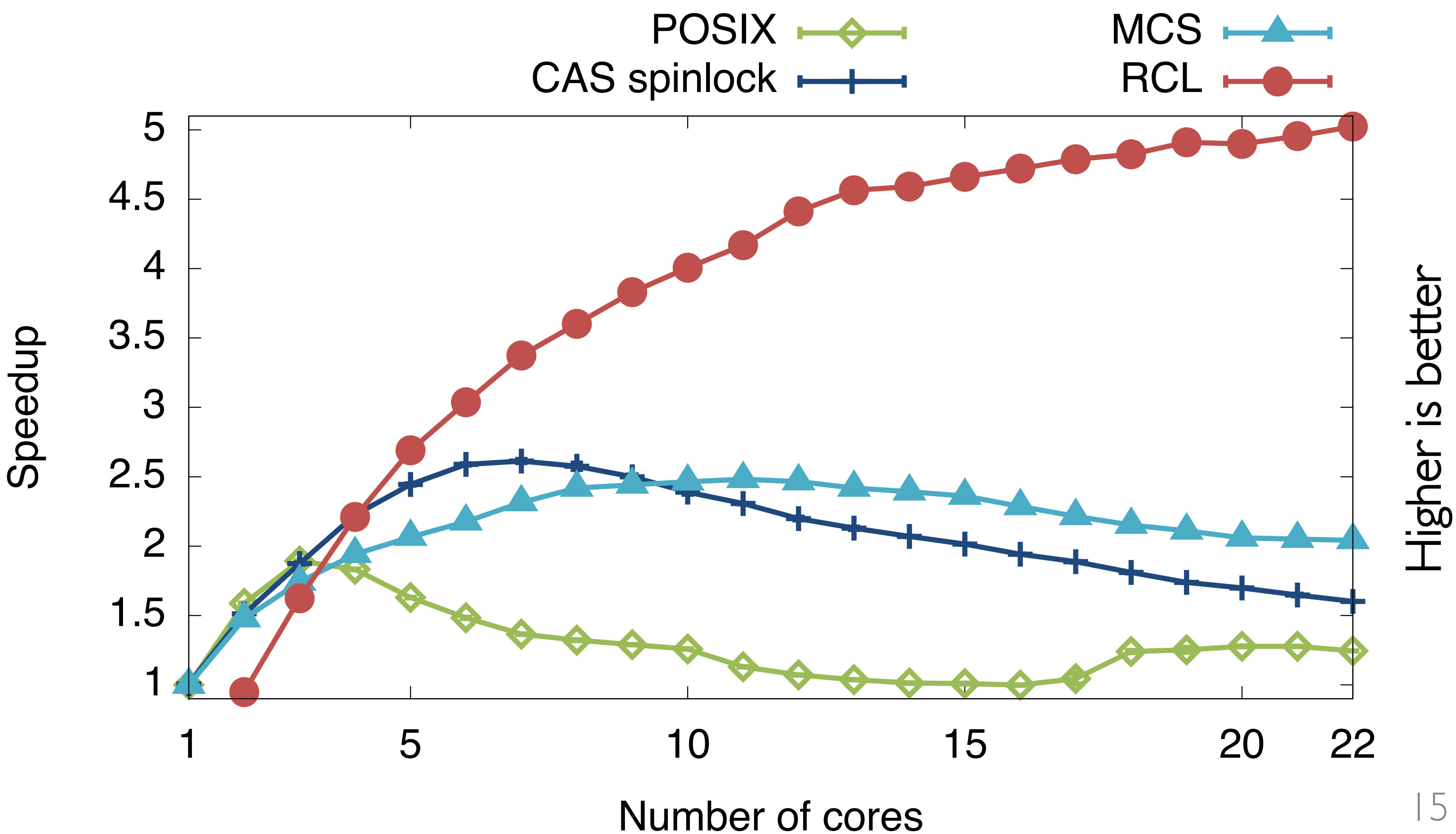
- Berkeley DB with TPC-C (100 clients)
- Large gains, % in CS underestimated



% in CS: 53% 56%

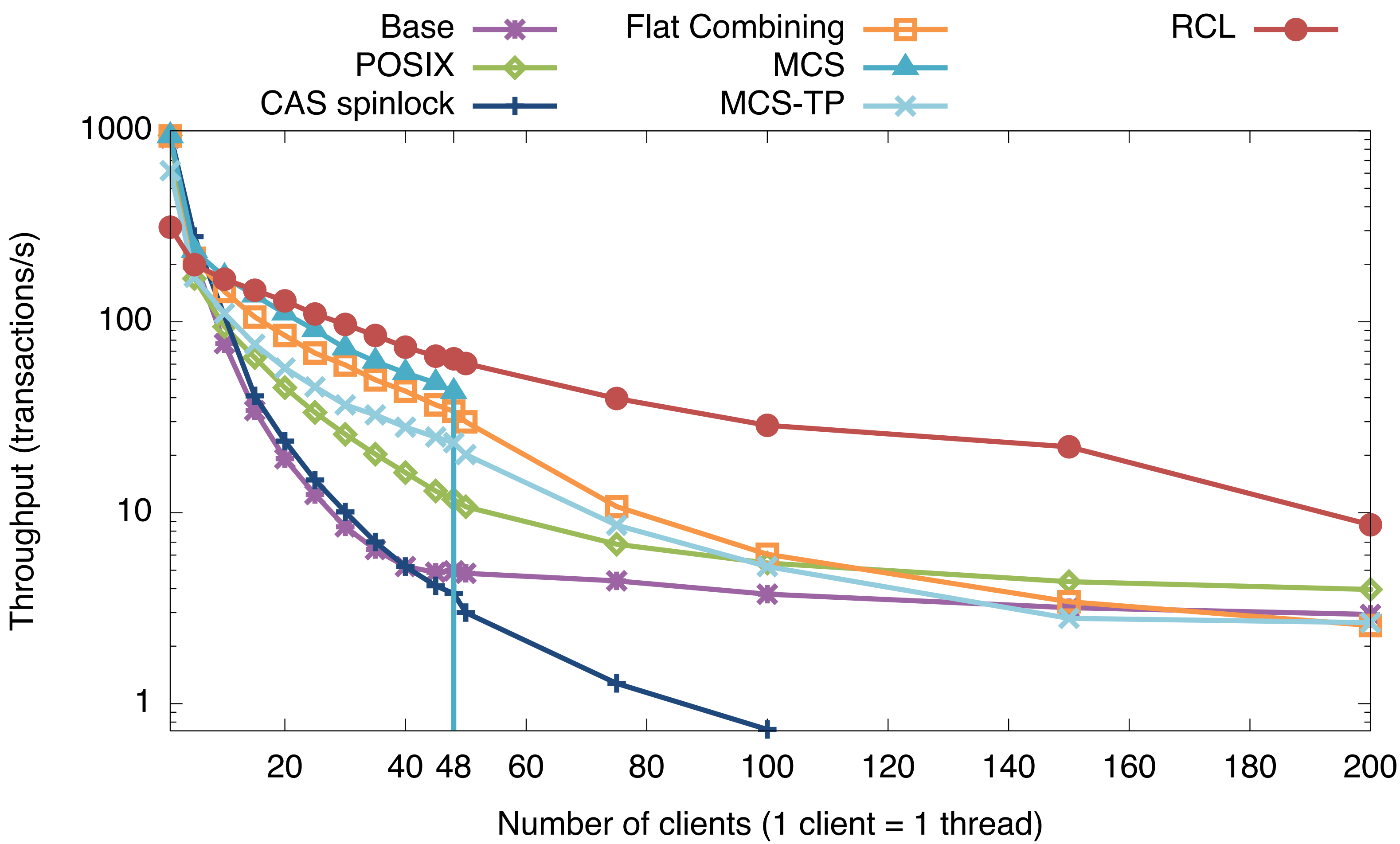
RCL Scalability (1)

- Memcached, SET requests:



RCL Scalability (2)

- Berkeley DB / TPC-C, Stock Level requests:



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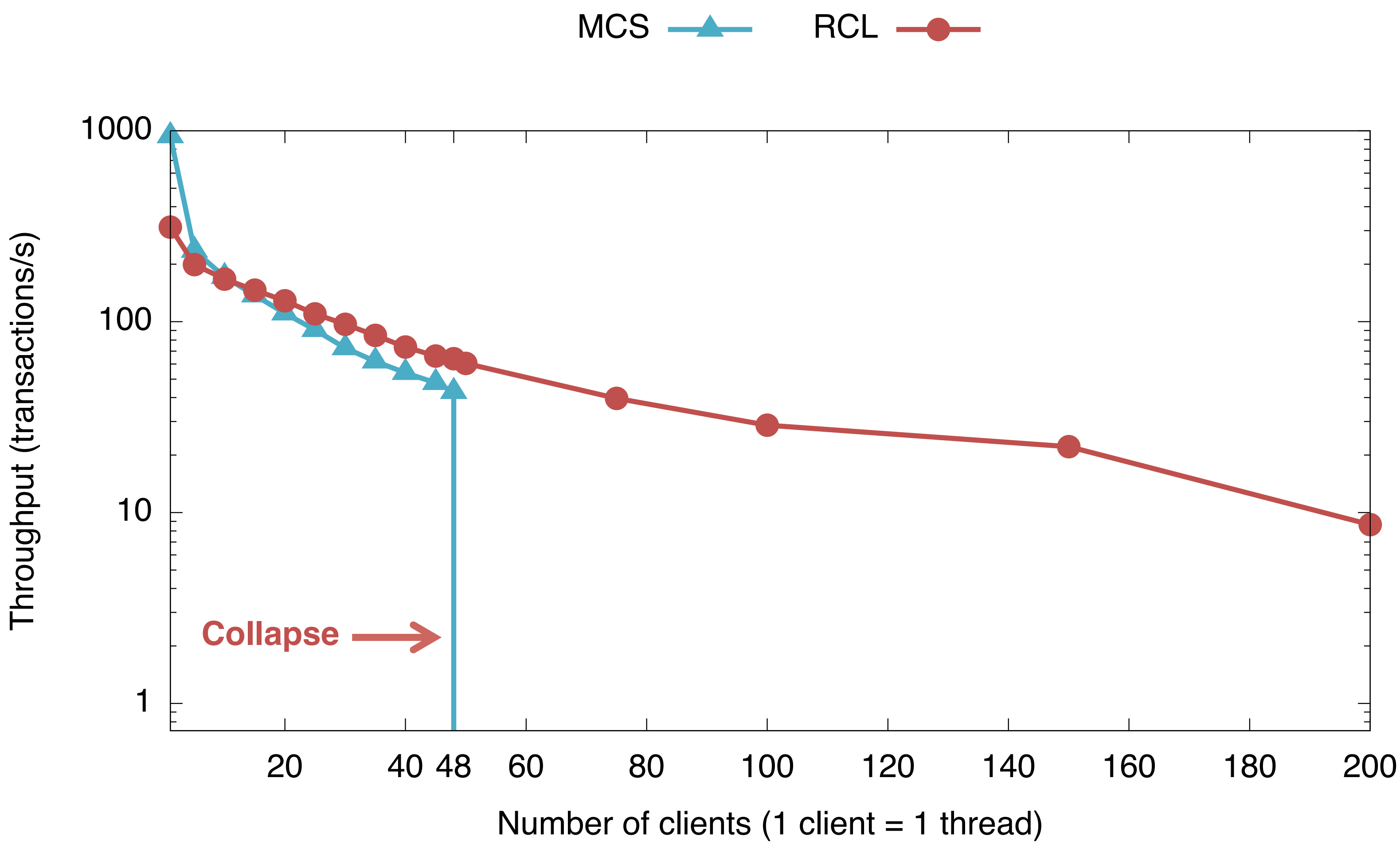

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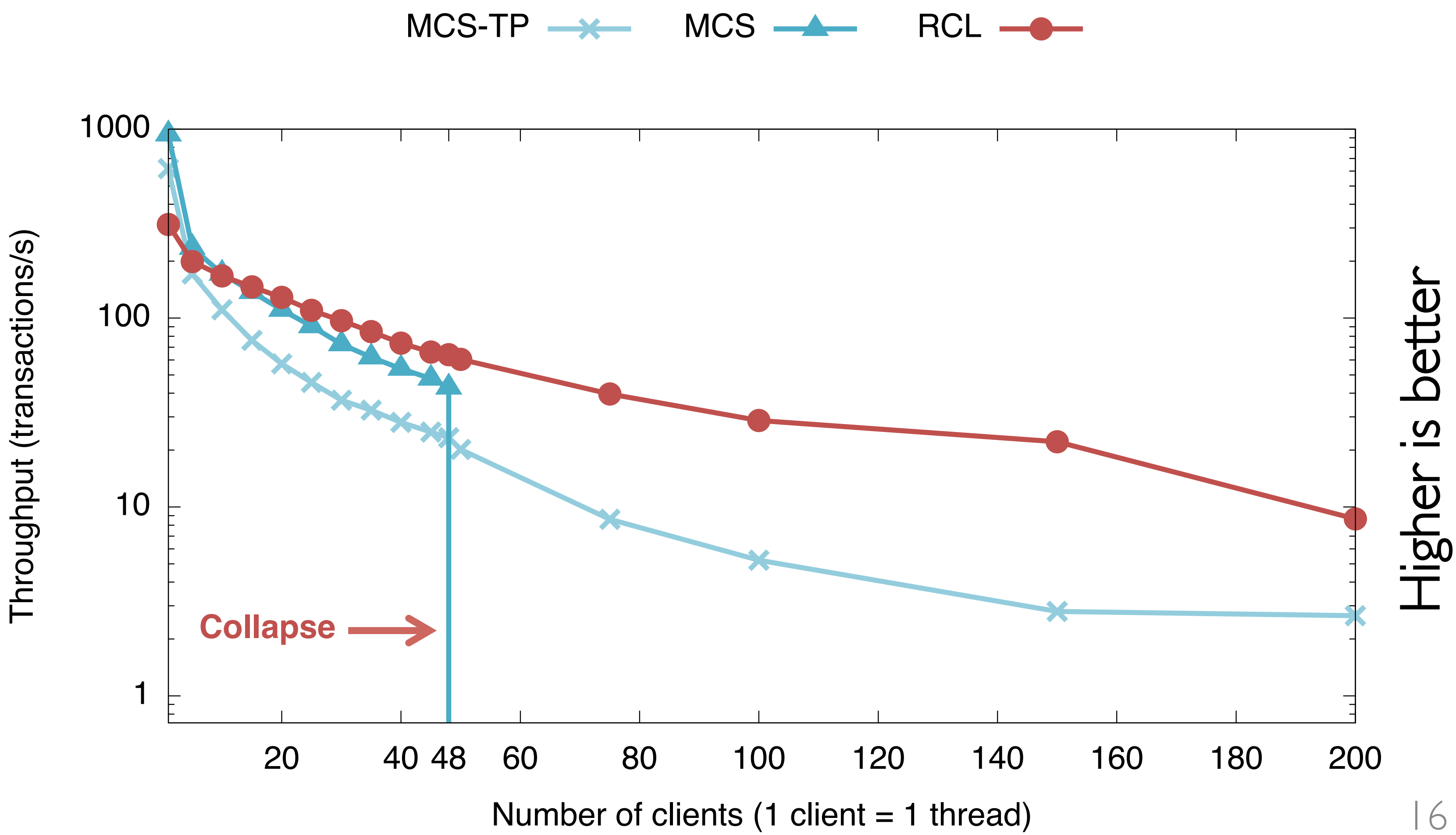

Conclusion

- RCL reduces lock acquisition time and improves data locality
- Profiler to detect when RCL can be useful
- Tool to ease the transformation of legacy code
- Future work: adaptive RCL runtime
  - Dynamically switch between locking strategies
  - Load balancing between servers