scal.cs.uni-salzburg.at

multicore-scalable concurrent data structures

scalloc.cs.uni-salzburg.at

multicore-scalable concurrent allocator

selfie.cs.uni-salzburg.at

self-referential systems software for teaching

Scal, Scalloc, and Selfie

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UPMARC Multicore Computing Summer School, Uppsala University, June 2016

Joint Work

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Concurrent Data Structures: scal.cs.uni-salzburg.at [POPL13, CF13, POPL15, NETYS15]

- Scal is an open-source benchmarking framework that provides

  1. software infrastructure for executing concurrent data structure algorithms,

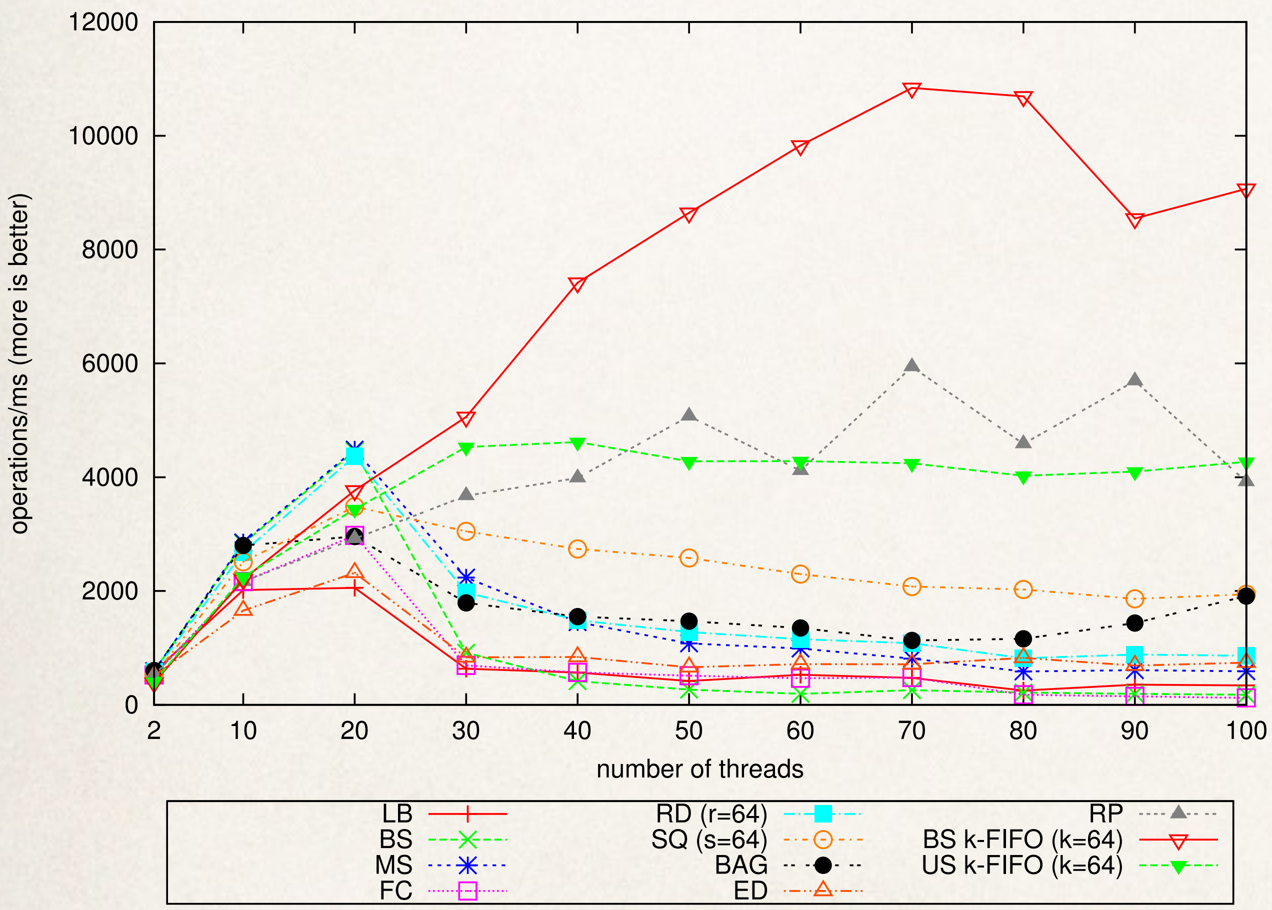
  2. workloads for benchmarking their performance and scalability, and

  3. implementations of a large set of concurrent data structures.

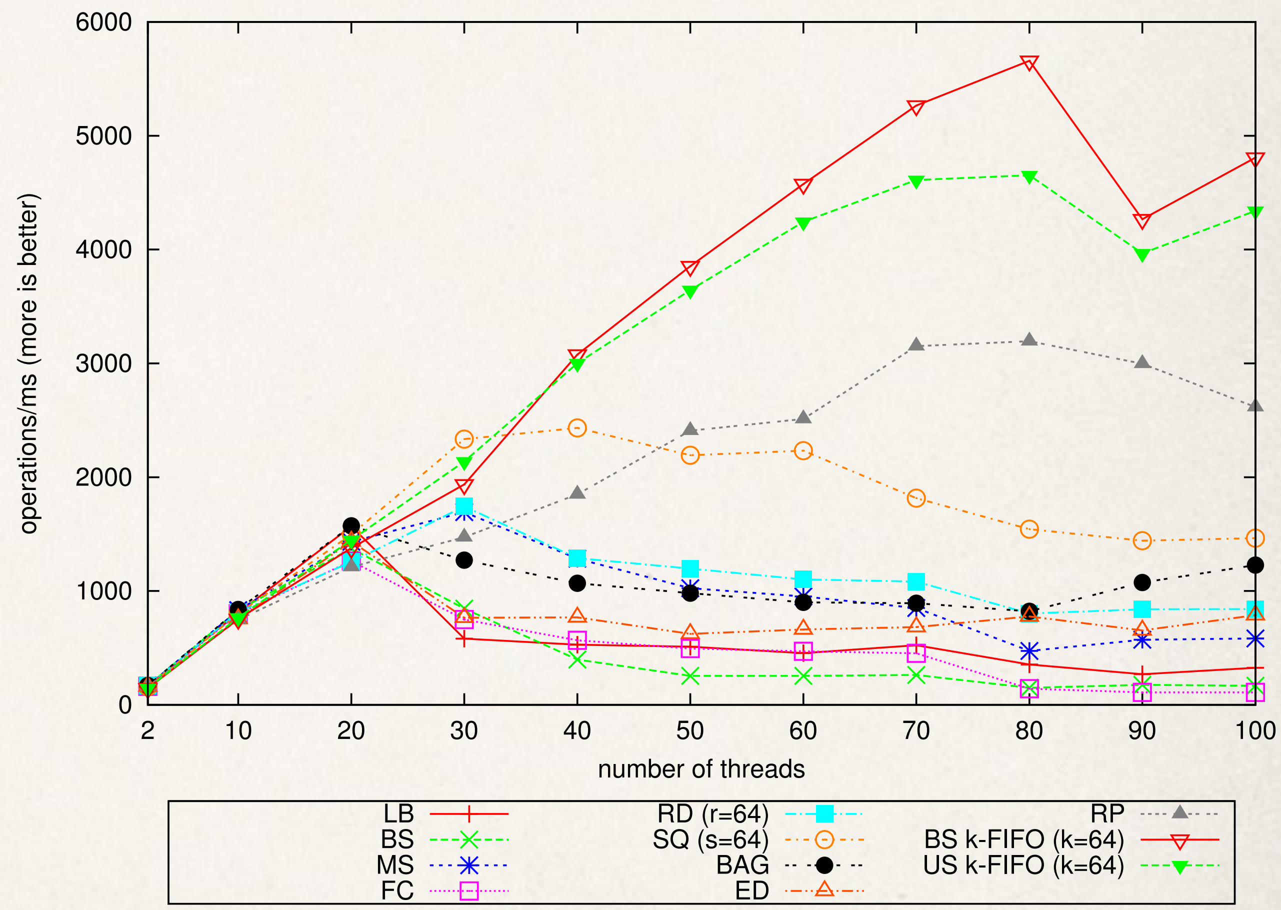
Scal: A Benchmarking Suite for Concurrent Data Structures [NETYS15]

Name	Semantics	Year	Ref
Lock-based Singly-linked	strict queue	1968	[1]
Michael Scott (MS) Queue	strict queue	1996	[2]
Flat Combining Queue	strict queue	2010	[3]
Wait-free Queue	strict queue	2012	[4]
Linked Cyclic Ring Queue	strict queue	2013	[5]
Timestamped (TS) Queue	strict queue	2015	[6]
Cooperative TS Queue	strict queue	2015	[7]
Segment Queue	k-relaxed queue	2010	[8]
Random Dequeue (RD)	k-relaxed queue	2010	[8]
Bounded Size k-FIFO	k-relaxed queue, pool	2013	[9]
Unbounded Size k-FIFO	k-relaxed queue, pool	2013	[9]
b-RR Distributed Queue	k-relaxed queue, pool	2013	[10]
Least-Recently-Used (LRU)	k-relaxed queue, pool	2013	[10]
Locally Linearizable DQ	locally linearizable	2015	[11]
Locally Linearizable k-FIFO	locally linearizable	2015	[11]
Relaxed TS Queue	quiescently consistent	2015	[7]
Lock-based Singly-linked	strict stack	1968	[1]
Treiber Stack	strict stack	1986	[12]
Elimination-backoff Stack	strict stack	2004	[13]
Timestamped (TS) Stack	strict stack	2015	[6]
k-Stack	k-relaxed stack	2013	[14]
b-RR Distributed Stack (DS)	k-relaxed stack, pool	2013	[10]
Least-Recently-Used (LRU)	k-relaxed stack, pool	2013	[10]
Locally Linearizable DS	locally linearizable	2015	[11]
Locally Linearizable k-Stack	locally linearizable	2015	[11]
Timestamped (TS) Deque	strict deque	2015	[7]
d-RA DQ and DS	strict pool	2013	[10]

k-FIFO Queues [PaCT13]

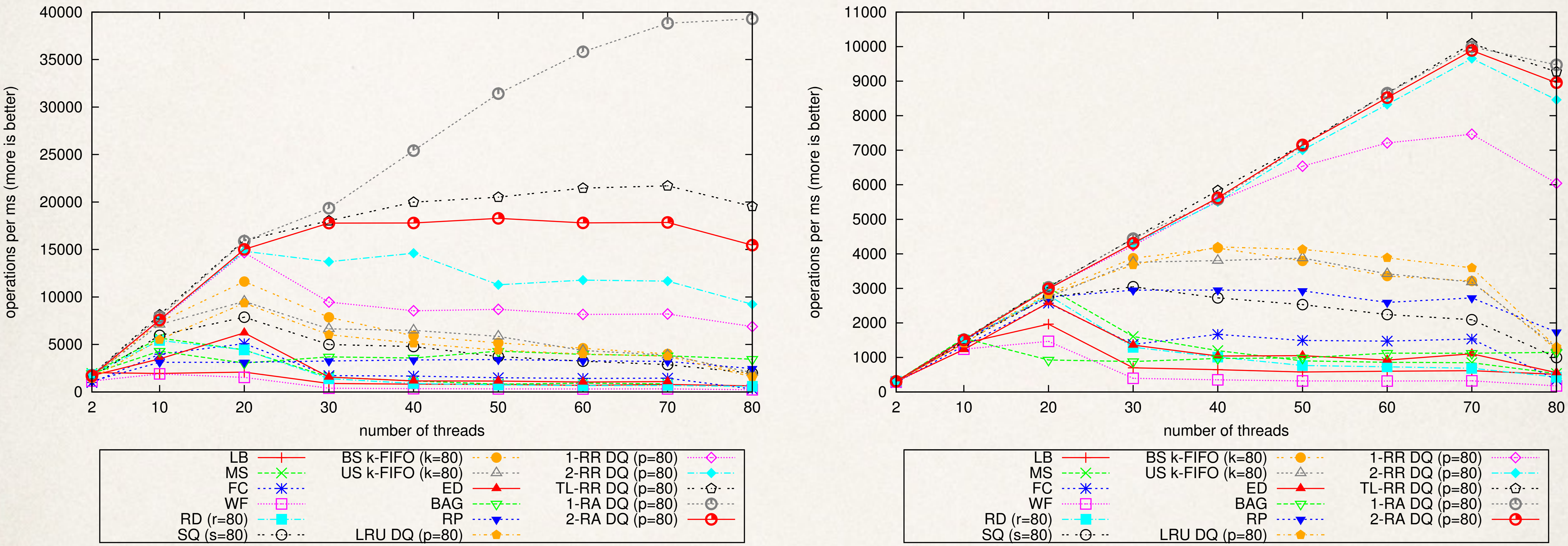


(a) Very high contention ($c = 1000$, $i = 0$)



(b) High contention ($c = 4000$, $i = 0$)

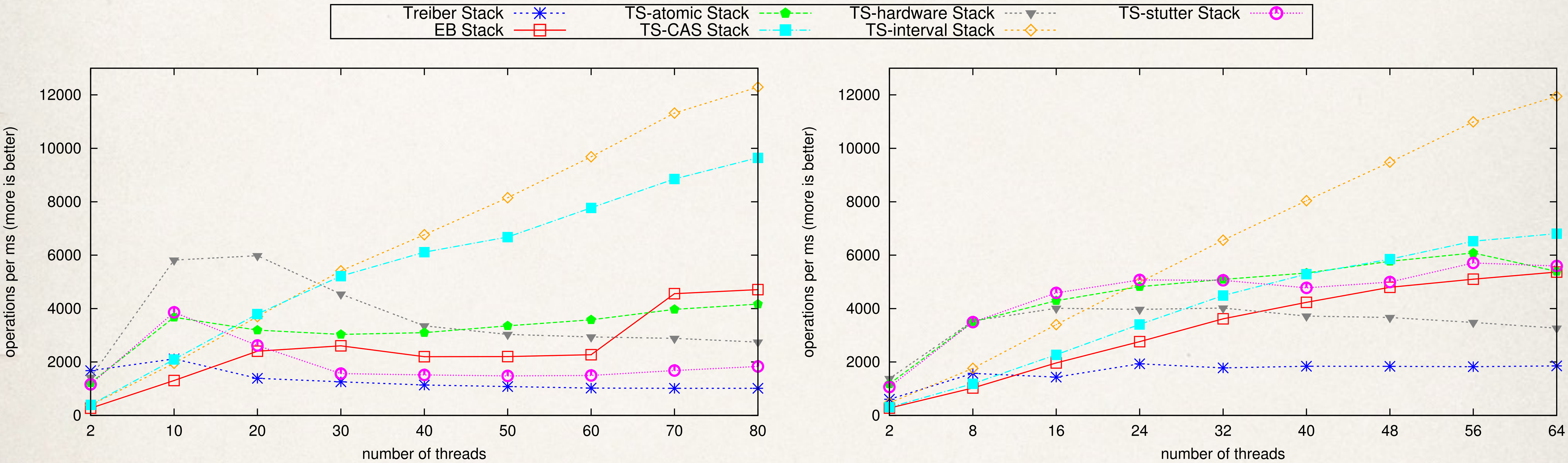
Distributed Queues [CF13]



(a) High contention producer-consumer microbenchmark ($c = 250$) (b) Low contention producer-consumer microbenchmark ($c = 2000$)

Figure 1: Performance and scalability of producer-consumer microbenchmarks with an increasing number of threads on a 40-core (2 hyper-threads per core) server machine

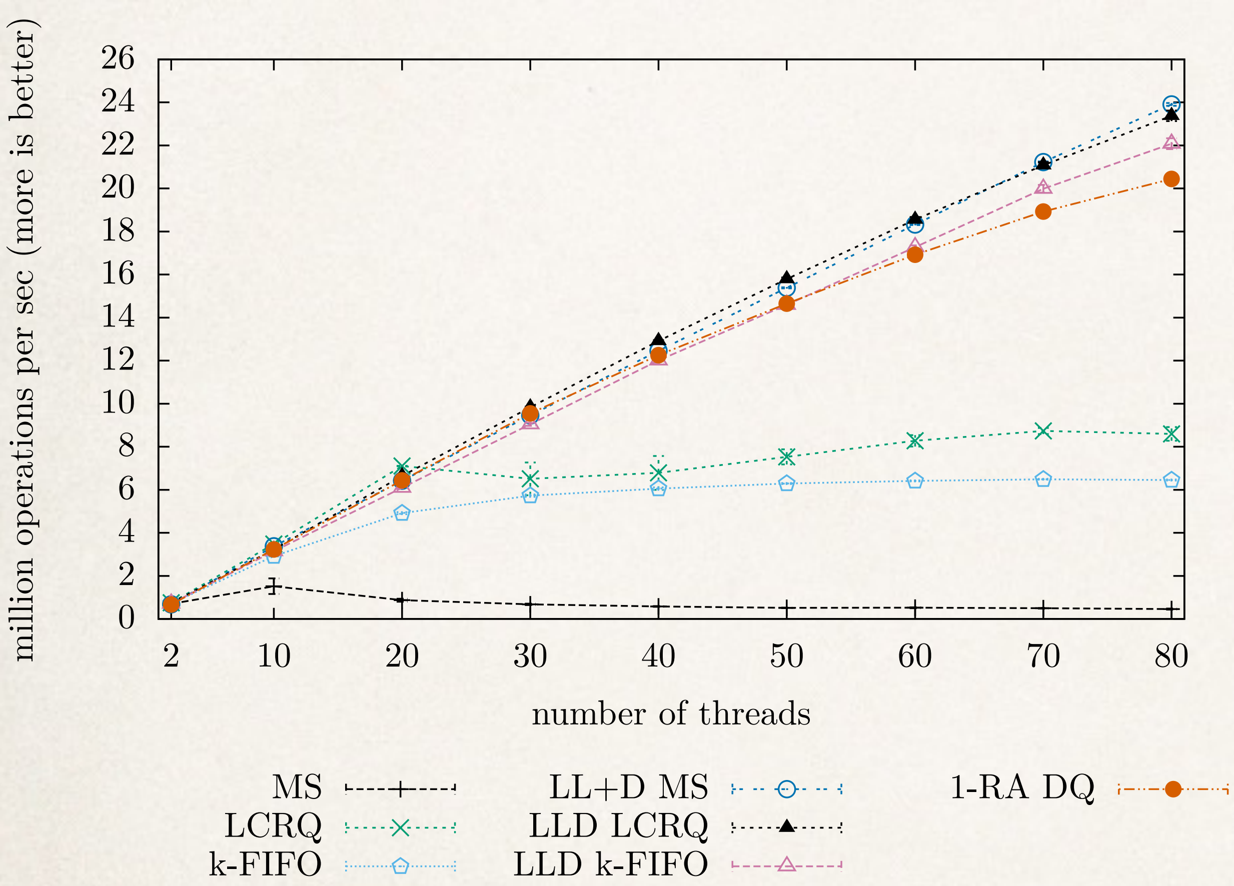
Timestamped (TS) Stack [POPL15]



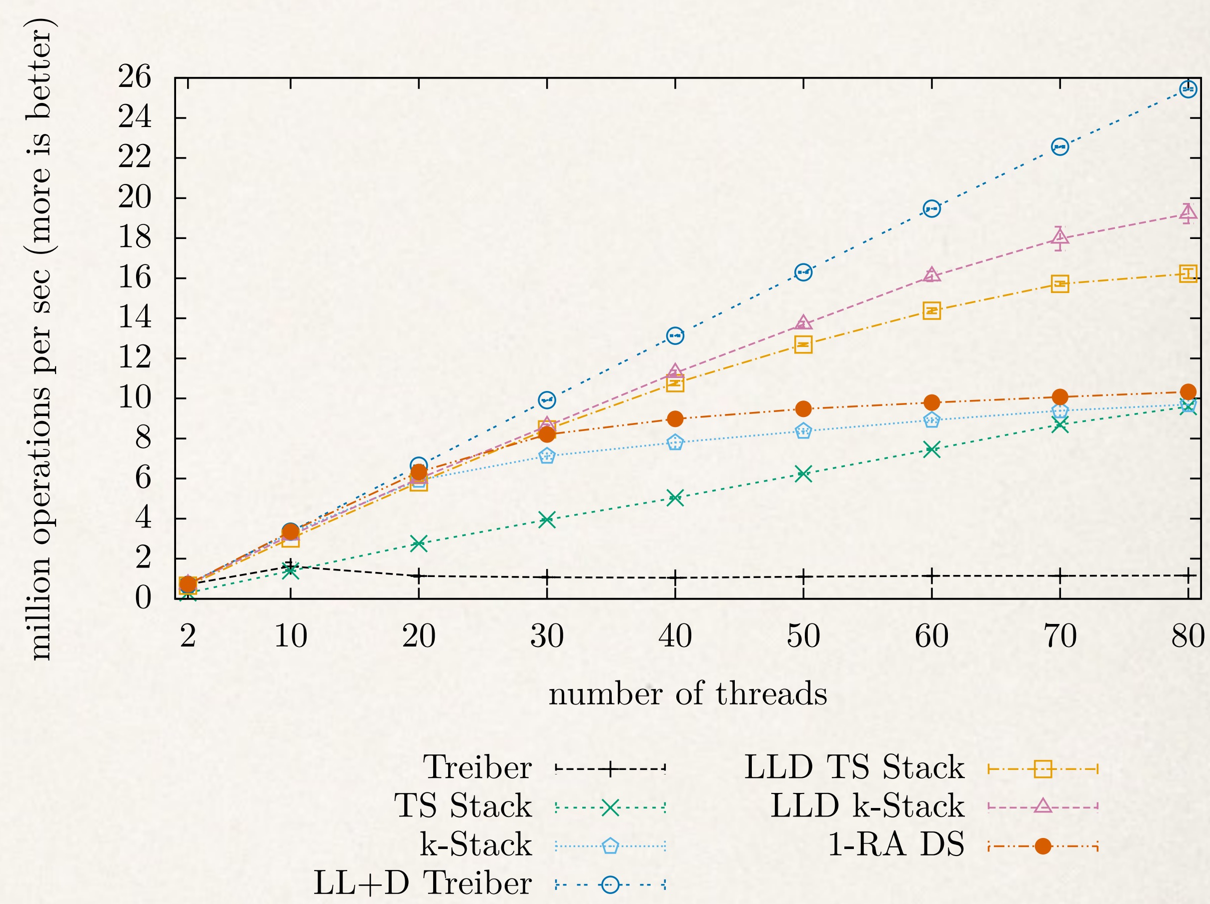
(a) Producer-consumer benchmark, 40-core machine.

(b) Producer-consumer benchmark, 64-core machine.

Local Linearizability [CONCUR16]



"queue-like" data structures



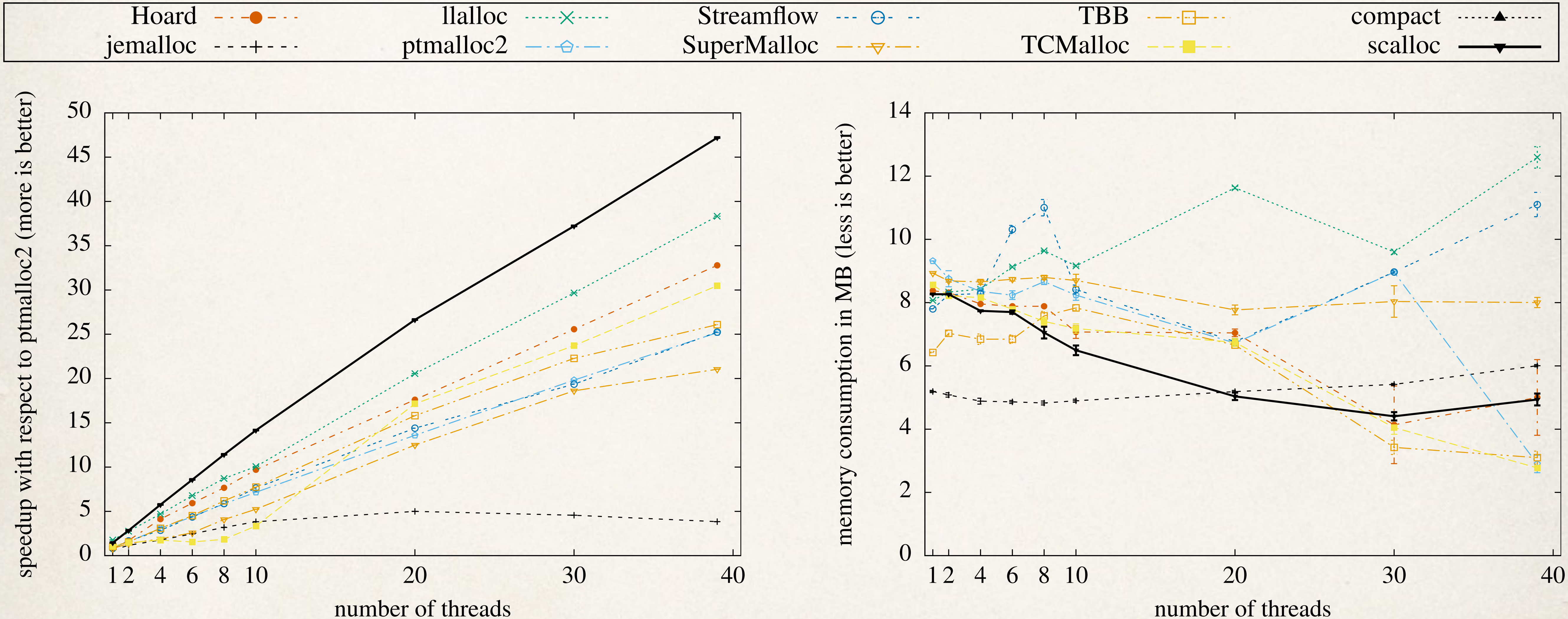
"stack-like" data structures

Figure 5 Performance and scalability of producer-consumer microbenchmarks with an increasing number of threads on a 40-core (2 hyperthreads per core) machine

Scalloc: Concurrent Memory Allocator scalloc.cs.uni-salzburg.at [OOPSLA15]

- fast, multicore-scalable, low-memory-overhead allocator
- three key ideas:
    1. backend: single global concurrent data structure for reclaiming memory effectively and efficiently
    2. virtual spans: single algorithm for small and big objects
    3. frontend: constant-time (modulo synchronization) allocation and eager deallocation

Local Allocation & Deallocation

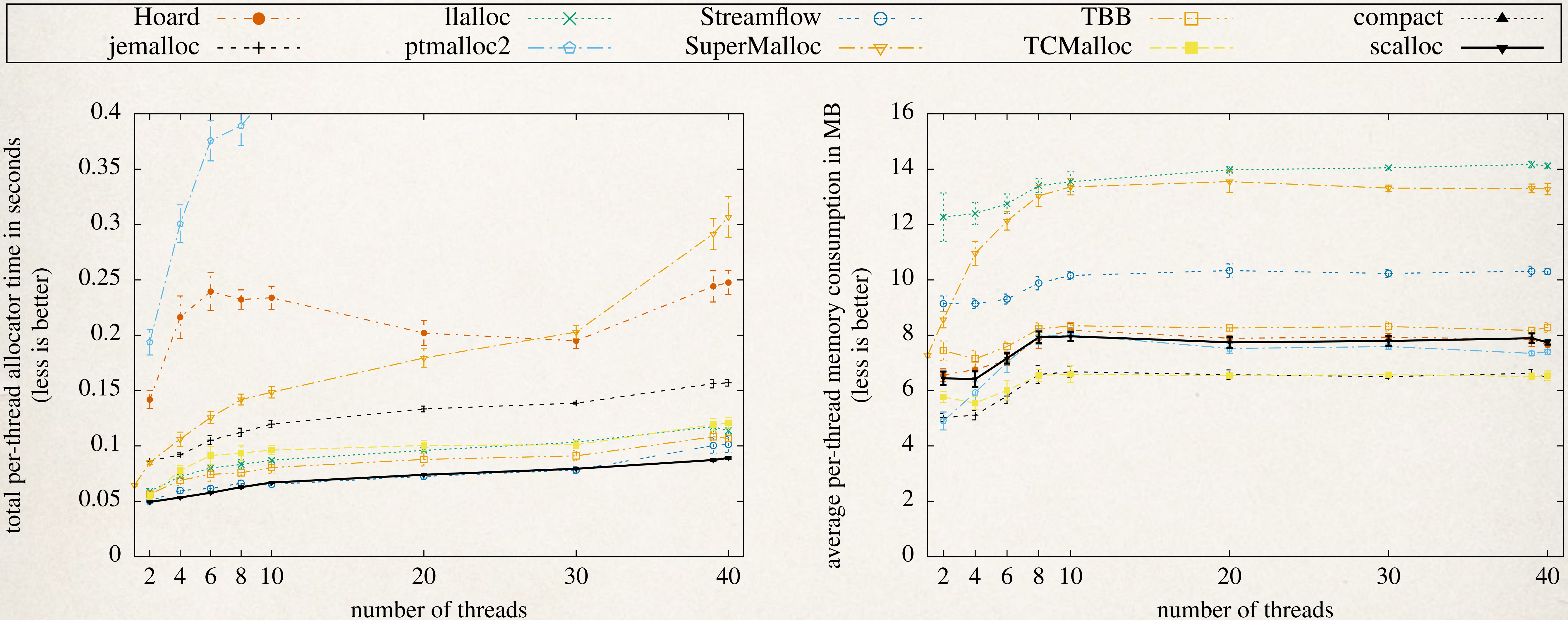


(a) Speedup

(b) Memory consumption

Figure 6: Thread-local workload: Threadtest benchmark

Remote Deallocation

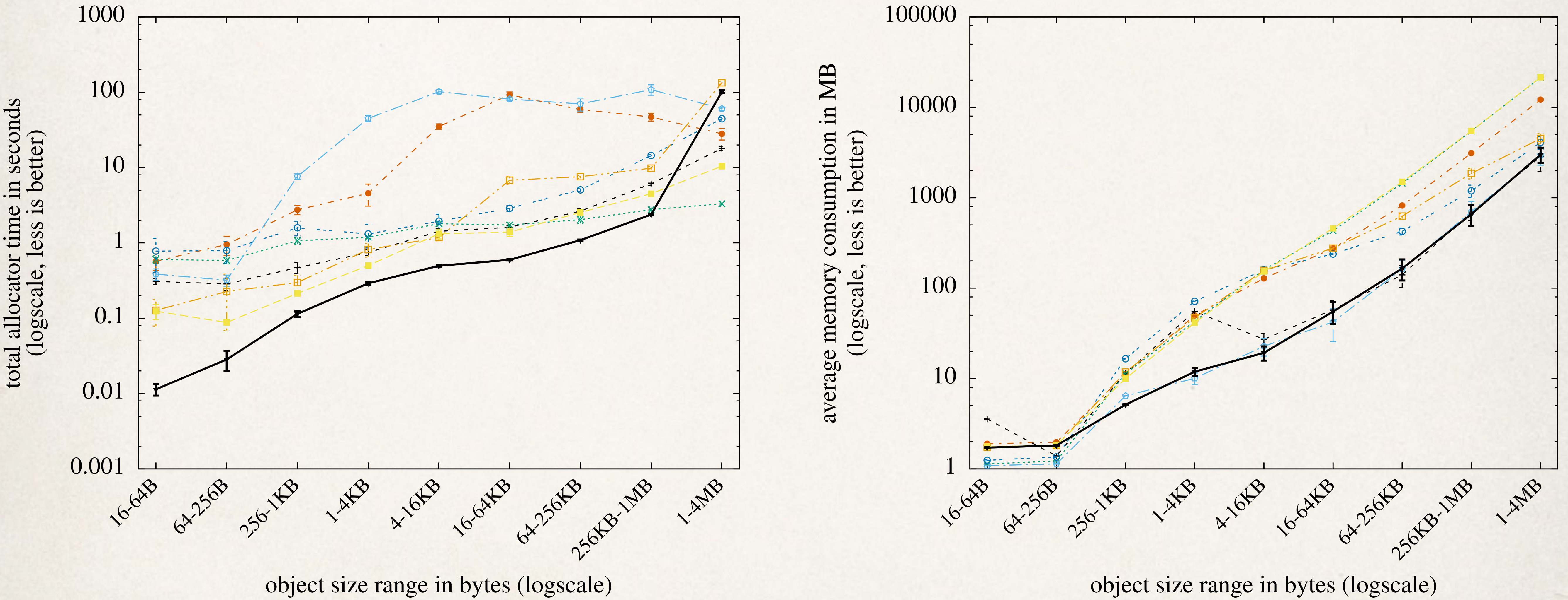


(a) Total per-thread allocator time

(b) Average per-thread memory consumption

Figure 9: Temporal and spatial performance for the producer-consumer experiment

Object Size



(a) Total allocator time (b) Average memory consumption

Figure 10: Temporal and spatial performance for the object-size robustness experiment at 40 threads

Memory Access

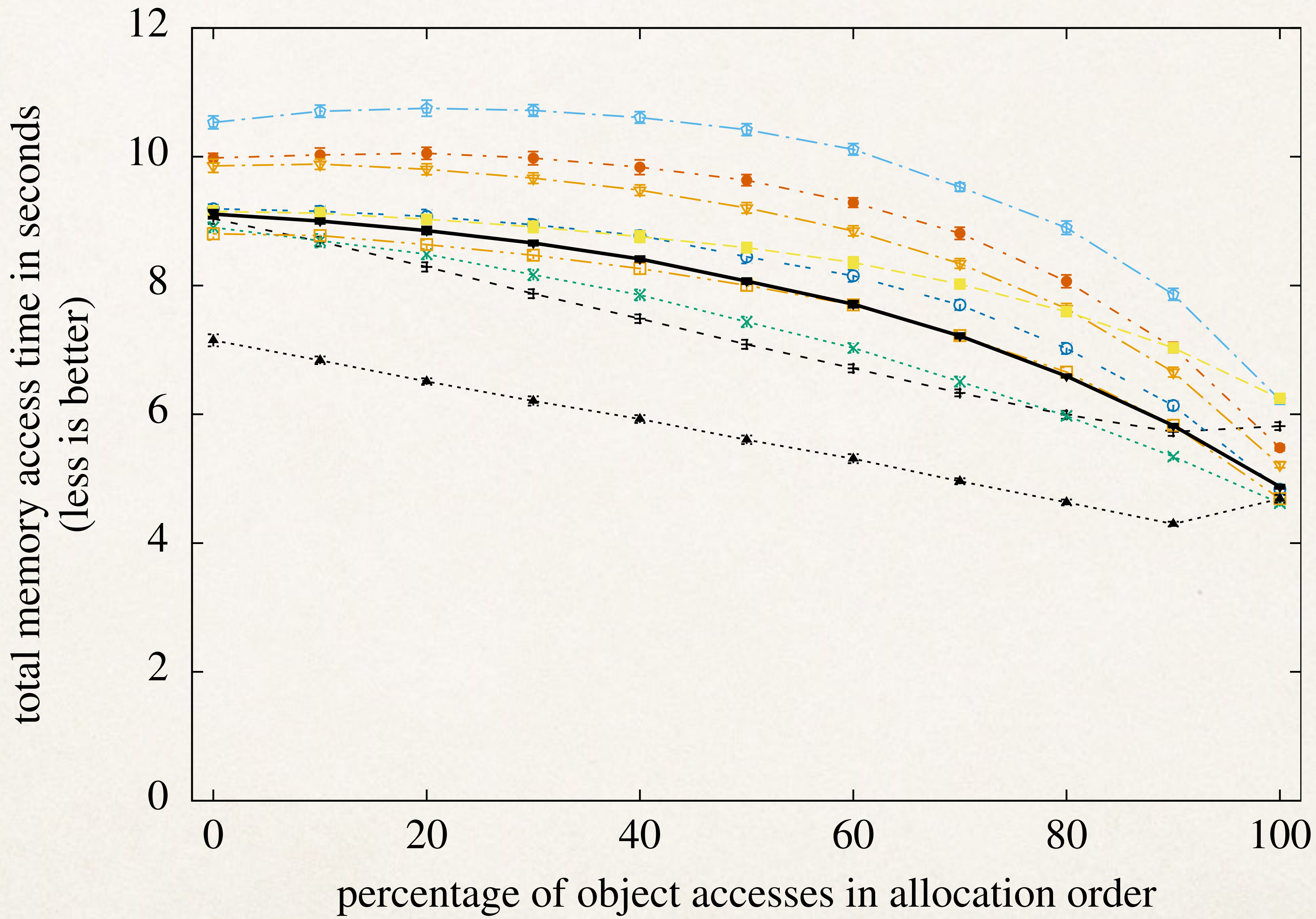


Figure 11: Memory access time for the locality experiment

Virtual Spans: 64-bit Address Space

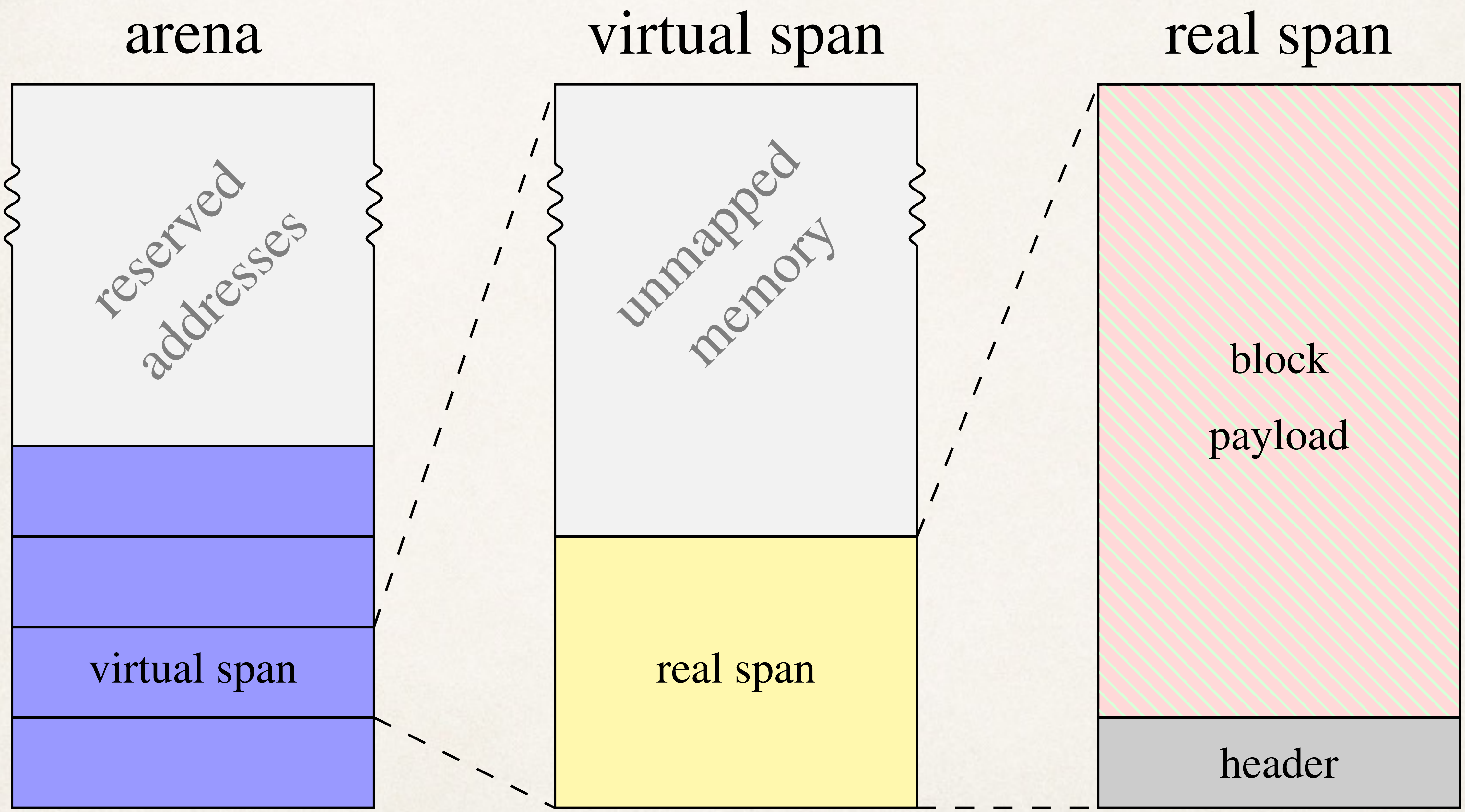


Figure 1: Structure of arena, virtual spans, and real spans

Backend: Double Segregation

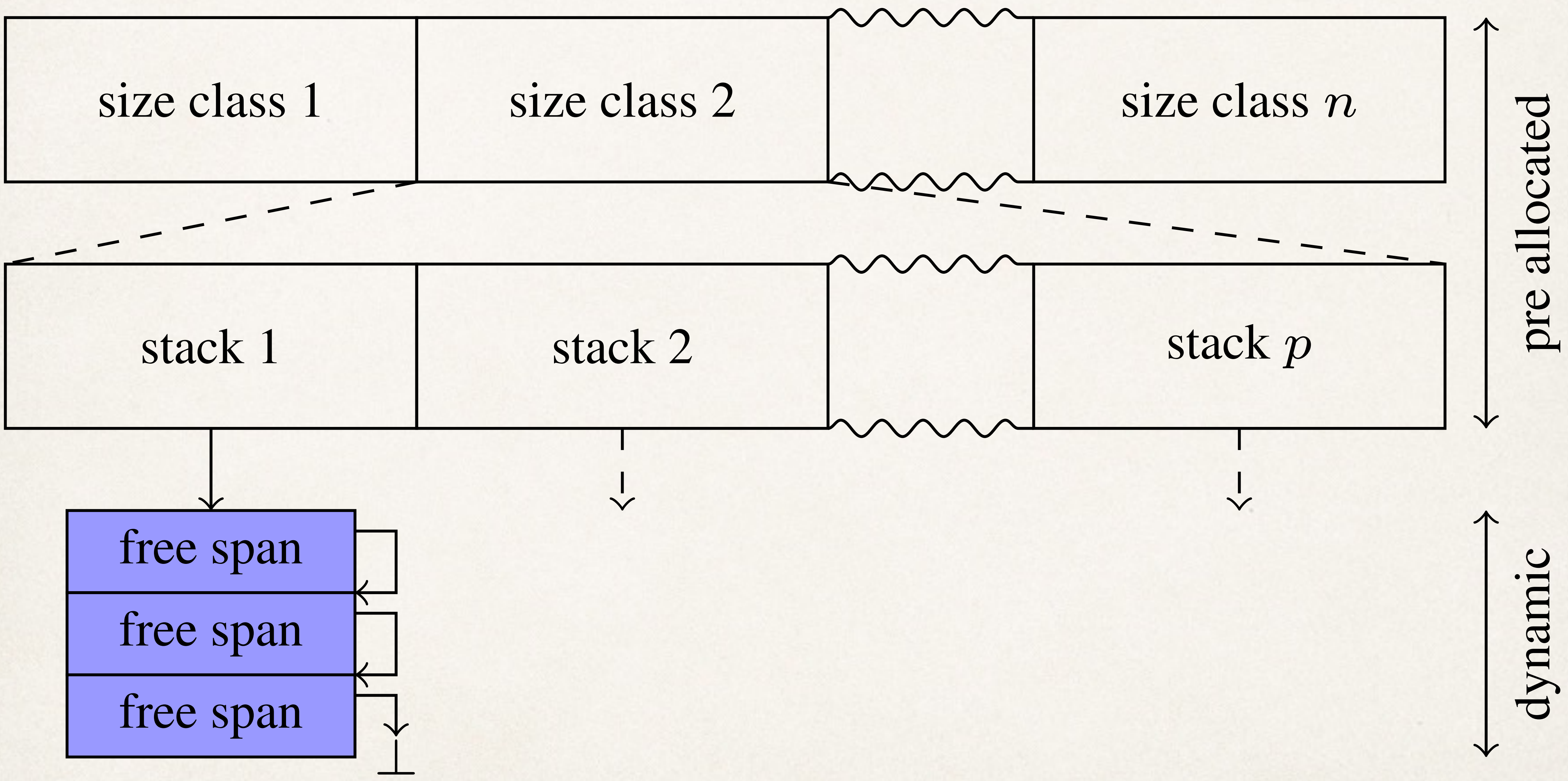


Figure 2: Span pool layout

Frontend: Eager Memory Reuse

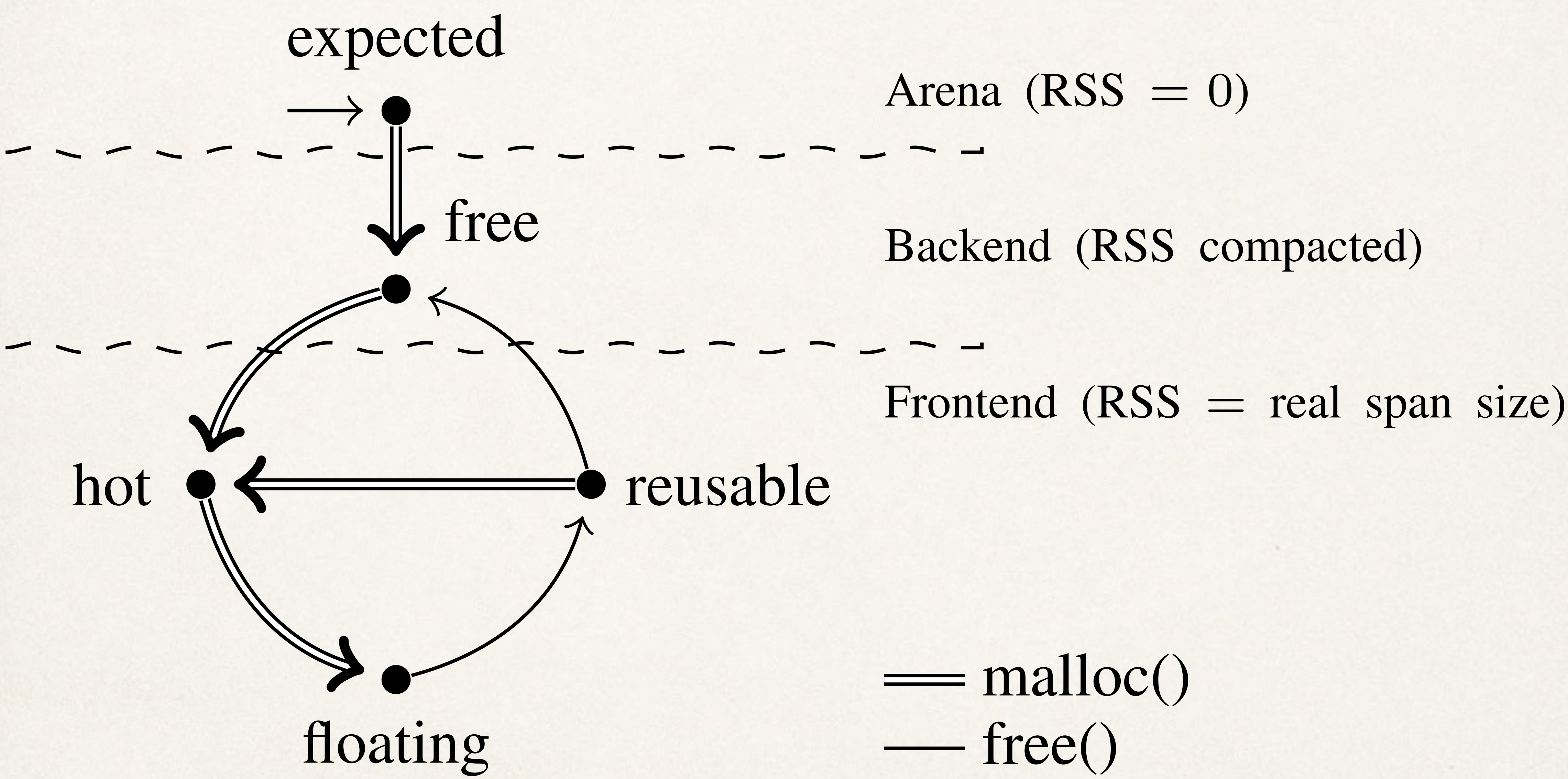


Figure 3: Life cycle of a span


K31
K32

Selfie: Teaching Systems Engineering [selfie.cs.uni-salzburg.at]

- *Selfie* is a self-referential 6k-line C implementation (in a single file) of:

  1. a self-compiling compiler called *starc* that compiles a tiny subset of C called C Star (C*) to a tiny subset of MIPS32 called MIPSter,

  2. a self-executing emulator called *mipster* that executes MIPSter code including itself when compiled with starc,

  3. a self-hosting hypervisor called *hypster* that virtualizes mipster and can host all of selfie including itself, and

  4. a tiny C* library called *libcstar* utilized by starc and mipster.

5 statements:
assignment
while
if
return
procedure()

```
int atoi(int *s) {
    int i;
    int n;
    int c;

    i = 0;
    n = 0;
    c = *(s+i);

    while (c != 0) {
        n = n * 10 + c - '0';
        if (n < 0)
            return -1;

        i = i + 1;
        c = *(s+i);
    }

    return n;
}
```

no data structures, just `int` and `int*` and dereferencing: the * operator

character literals
string literals

integer arithmetics
pointer arithmetics

no bitwise operators
no Boolean operators

library: `exit`, `malloc`, `open`, `read`, `write`

MIPSter: 17 out of 43 Instructions

```
atoi.c: $pc=0x000001CC: lw $t0,-4($fp)
atoi.c: $pc=0x000001D0: addiu $t1,$zero,1
atoi.c: $pc=0x000001D4: addu $t0,$t0,$t1
atoi.c: $pc=0x000001D8: sw $t0,-4($fp)
atoi.c: $pc=0x000001DC: lw $t0,8($fp)
atoi.c: $pc=0x000001E0: lw $t1,-4($fp)
atoi.c: $pc=0x000001E4: addiu $t2,$zero,4
atoi.c: $pc=0x000001E8: multu $t1,$t2
atoi.c: $pc=0x000001EC: mflo $t1
atoi.c: $pc=0x000001F0: nop
atoi.c: $pc=0x000001F4: nop
atoi.c: $pc=0x000001F8: addu $t0,$t0,$t1
atoi.c: $pc=0x000001FC: lw $t0,0($t0)
atoi.c: $pc=0x00000200: sw $t0,-12($fp)
```

```
i = i + 1;
```

```
c = *(s + i);
```

Future Work with Selfie et al.

- I/O
- file systems
- memory allocation
- garbage collection
- concurrency: <u>semantics</u>
- parallelism: <u>multicore</u>
- volatility: <u>persistent</u> memory


Thank you!