

AutoNUMA

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AutoNUMA components

- `knuma_scand`
 - If stopped, everything stops
 - Triggers the chain reaction when started
- NUMA hinting page faults
- `knuma_migratedN` (per node)
- scheduler (CPU follow memory & active idle balancing)
- Memory follow CPU (NUMA hinting page faults)
- False sharing detection (page->`autonuma_last_nid`)

AutoNUMA data

- sched_autonuma
 - task_struct (per-thread statistical NUMA info)
 - Generated by NUMA hinting page faults
- mm_autonuma
 - mm_struct (per-process statistical NUMA info)
 - Working set or ~RSS
 - Generated by knuma_scand

sched_autonuma

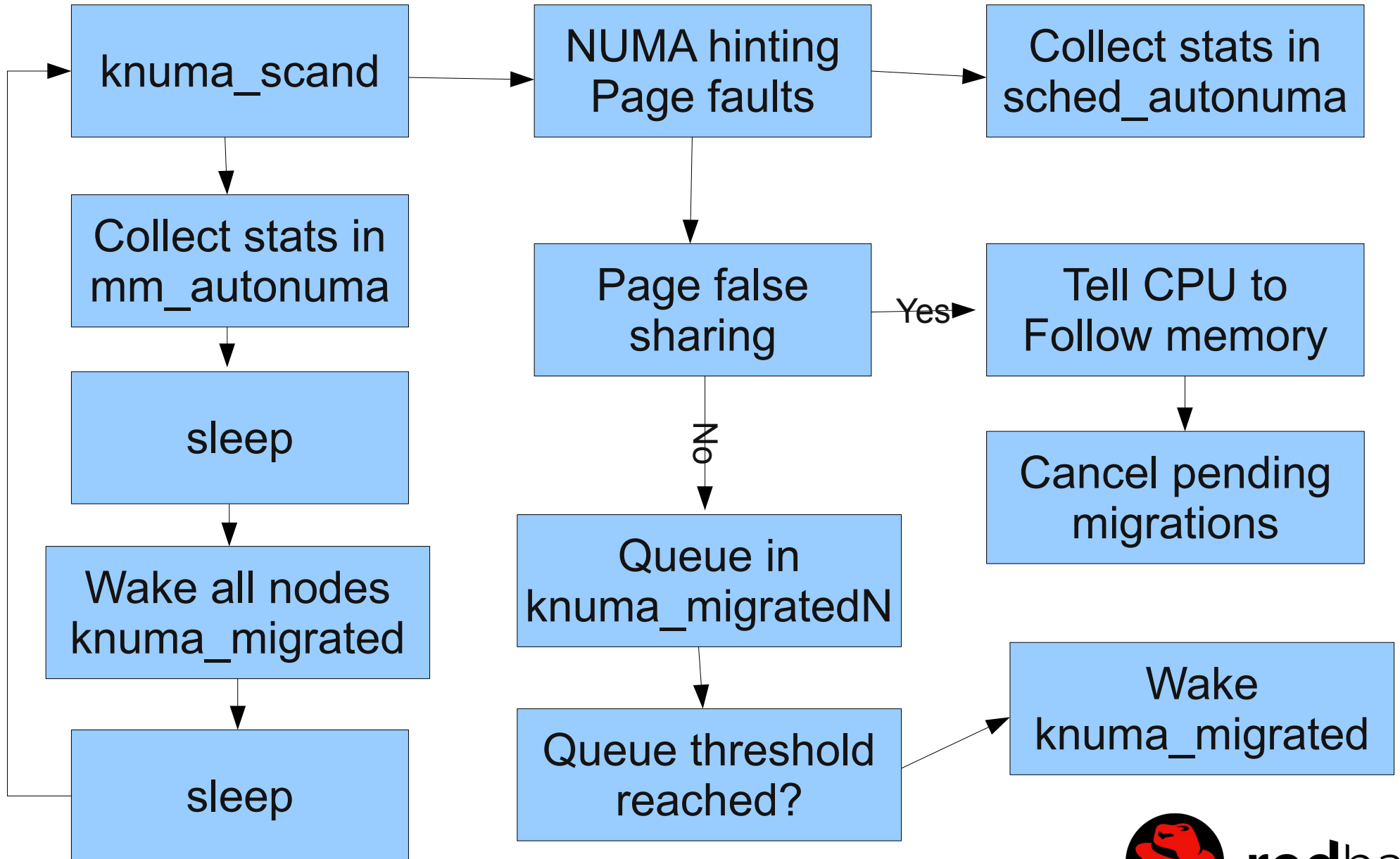
```
struct sched_autonuma {  
    int autonuma_node;  
    bool autonuma_stop_one_cpu;  
    unsigned long numa_fault_pass;  
    unsigned long numa_fault_tot;  
    unsigned long numa_fault[0];  
};
```



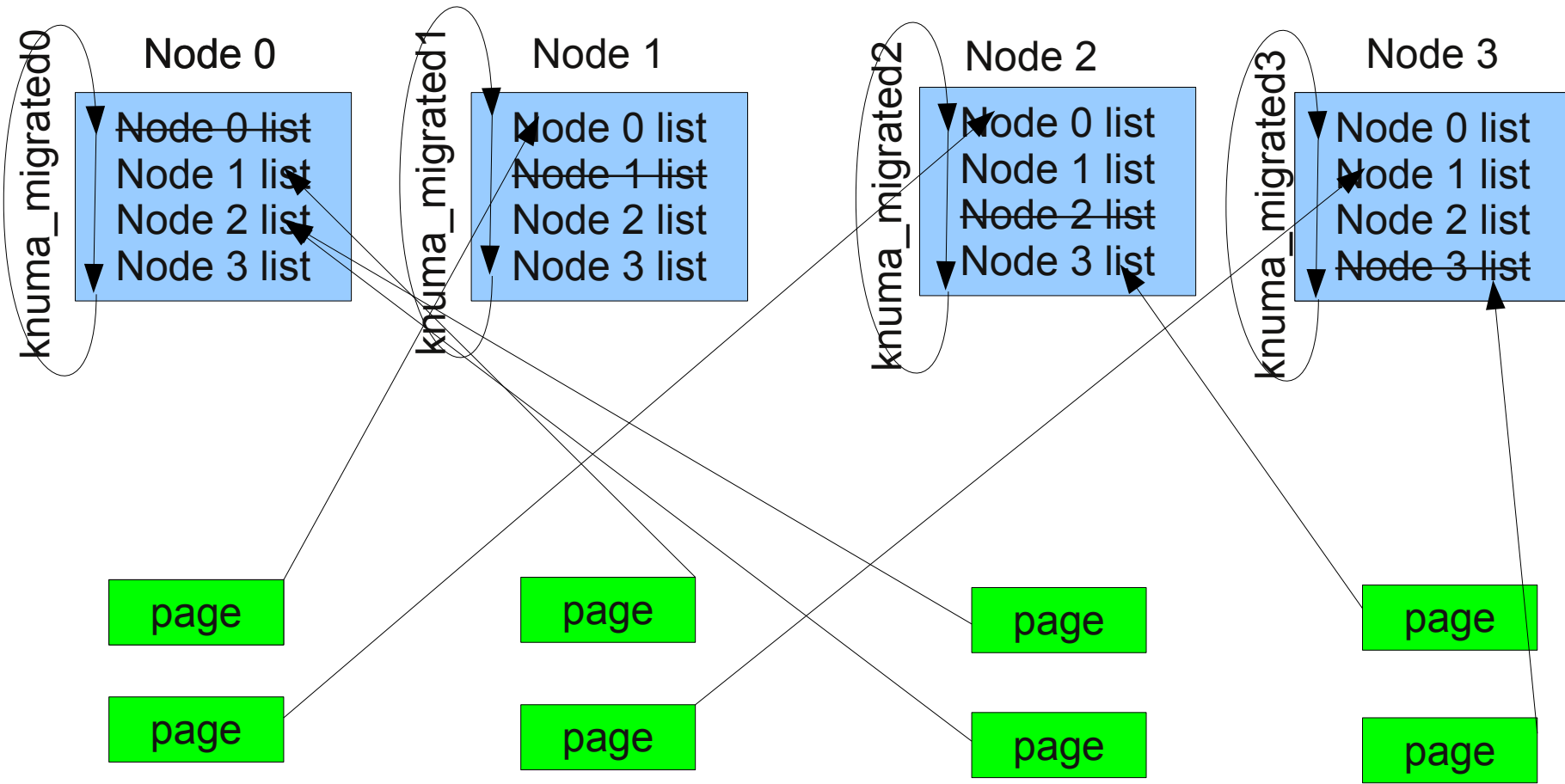
mm_autonuma

```
struct mm_autonuma {  
    struct list_head mm_node;  
    struct mm_struct *mm;  
    unsigned long numa_fault_tot;  
  
    unsigned long numa_fault_pass;  
    unsigned long numa_fault[0];  
};
```

AutoNUMA logic



AutoNUMA knuma_migratedN

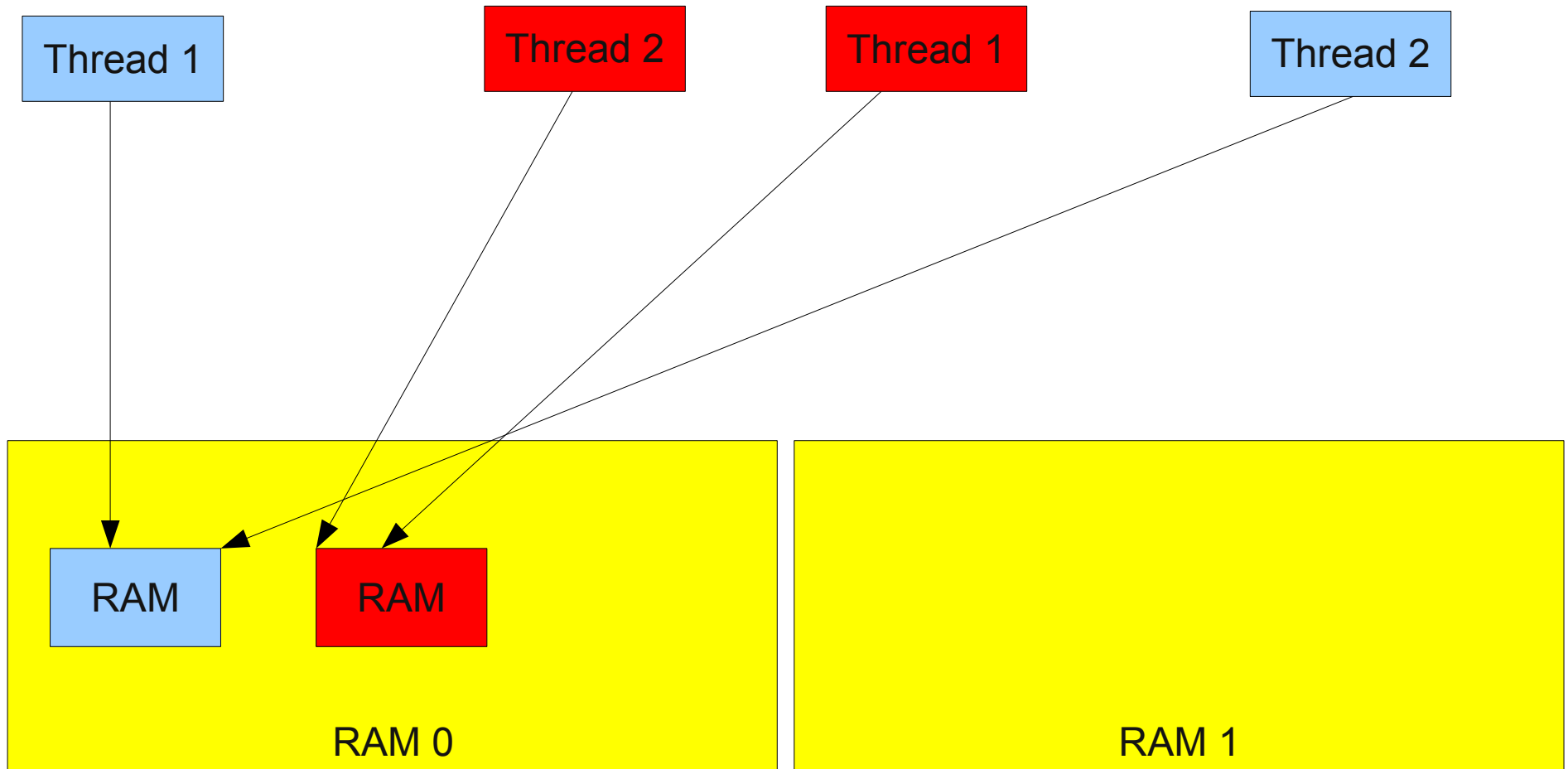


Hardware

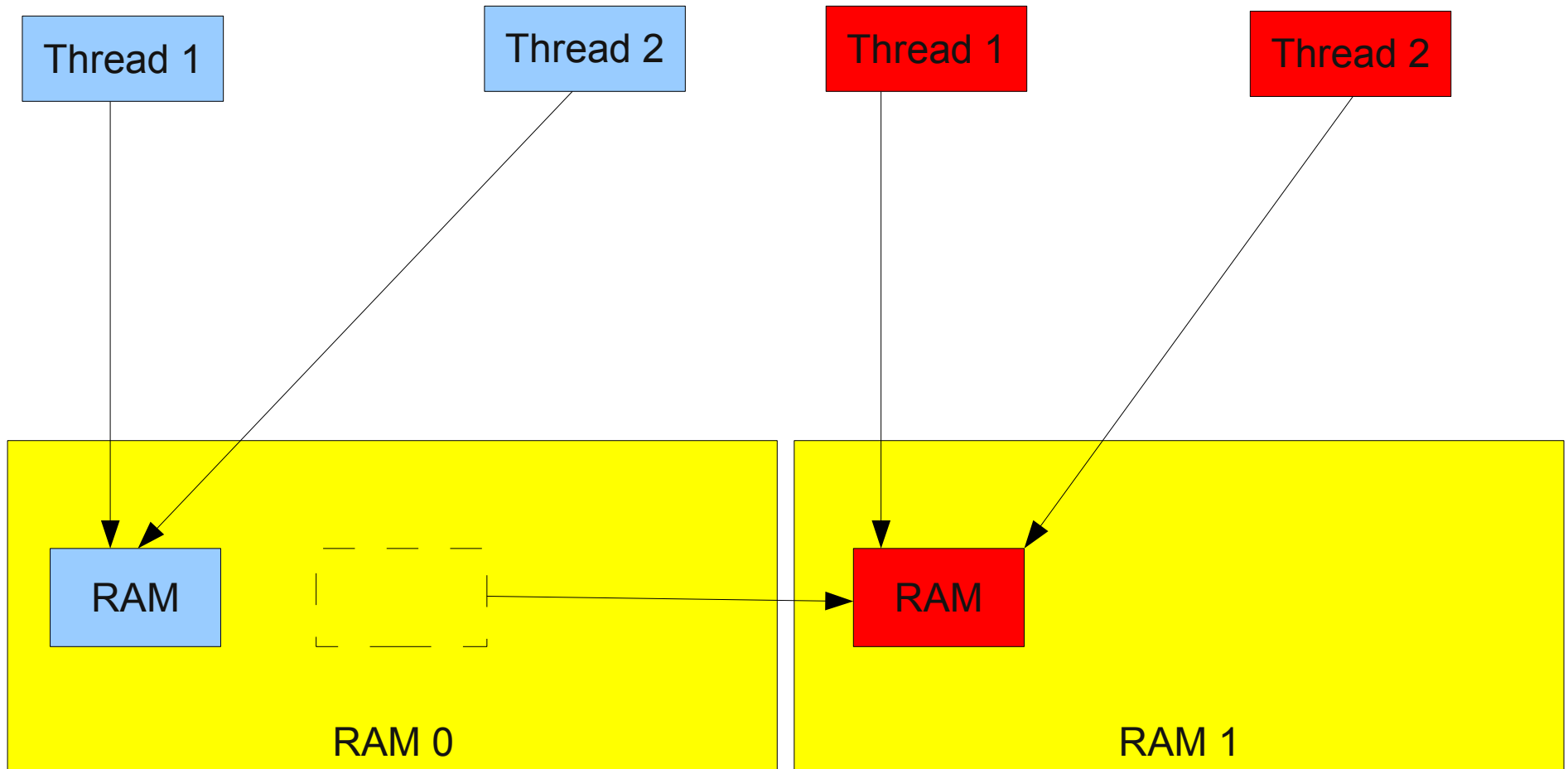
- 2 NUMA nodes
- 2 CPU sockets
- 6 CPU cores per socket
- 2 HT CPU threads per core (total 24 CPUs)
- 8GB of RAM per node (total 16 GB of RAM)



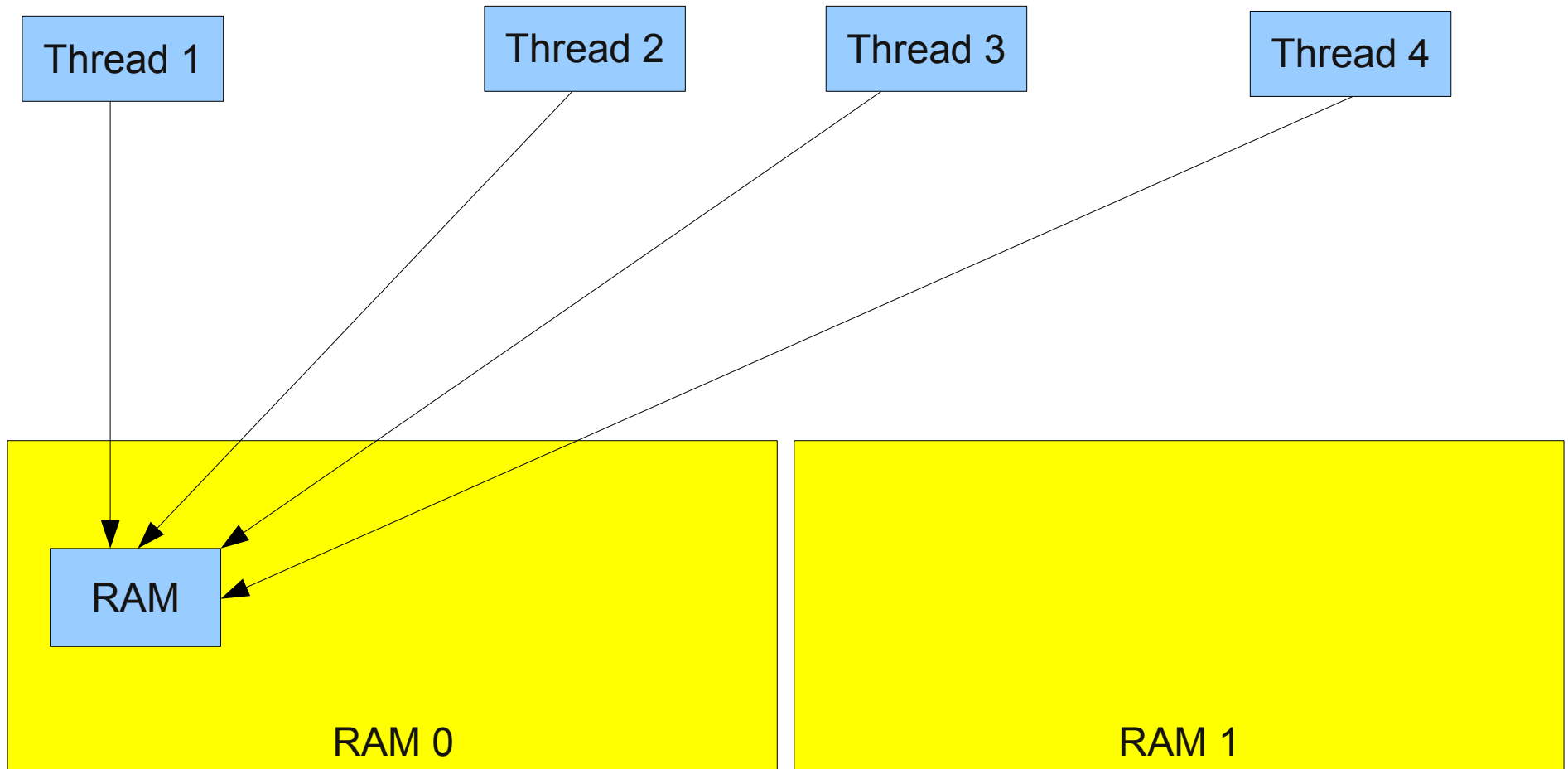
Numa01 (same node)



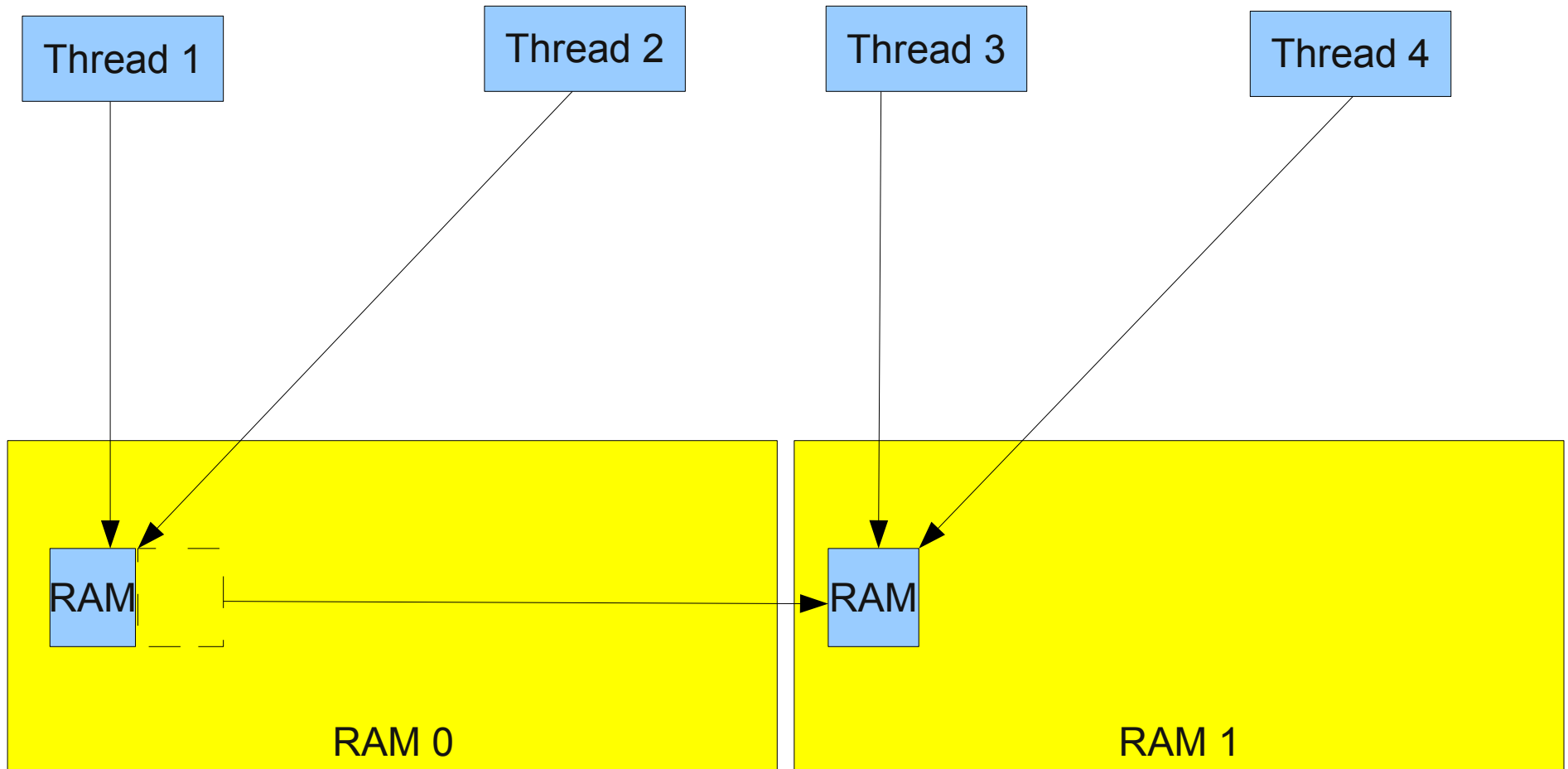
Numa01 (same node)



Numa02

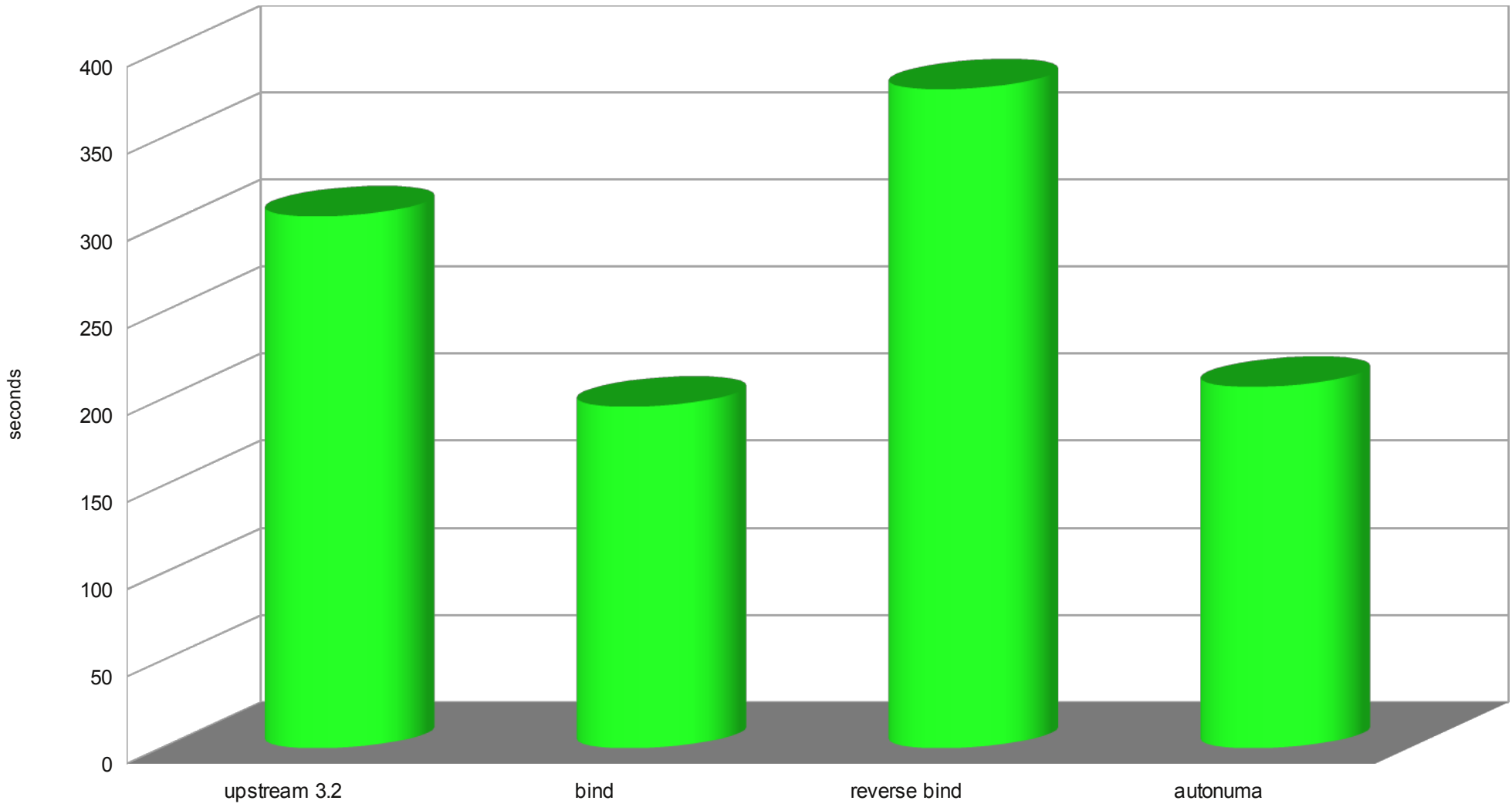


Numa02



numa01 -DNO_BIND_FORCE_SAME_NODE
all threads shares the same memory, 12 threads per process, 2 processes

lower is better

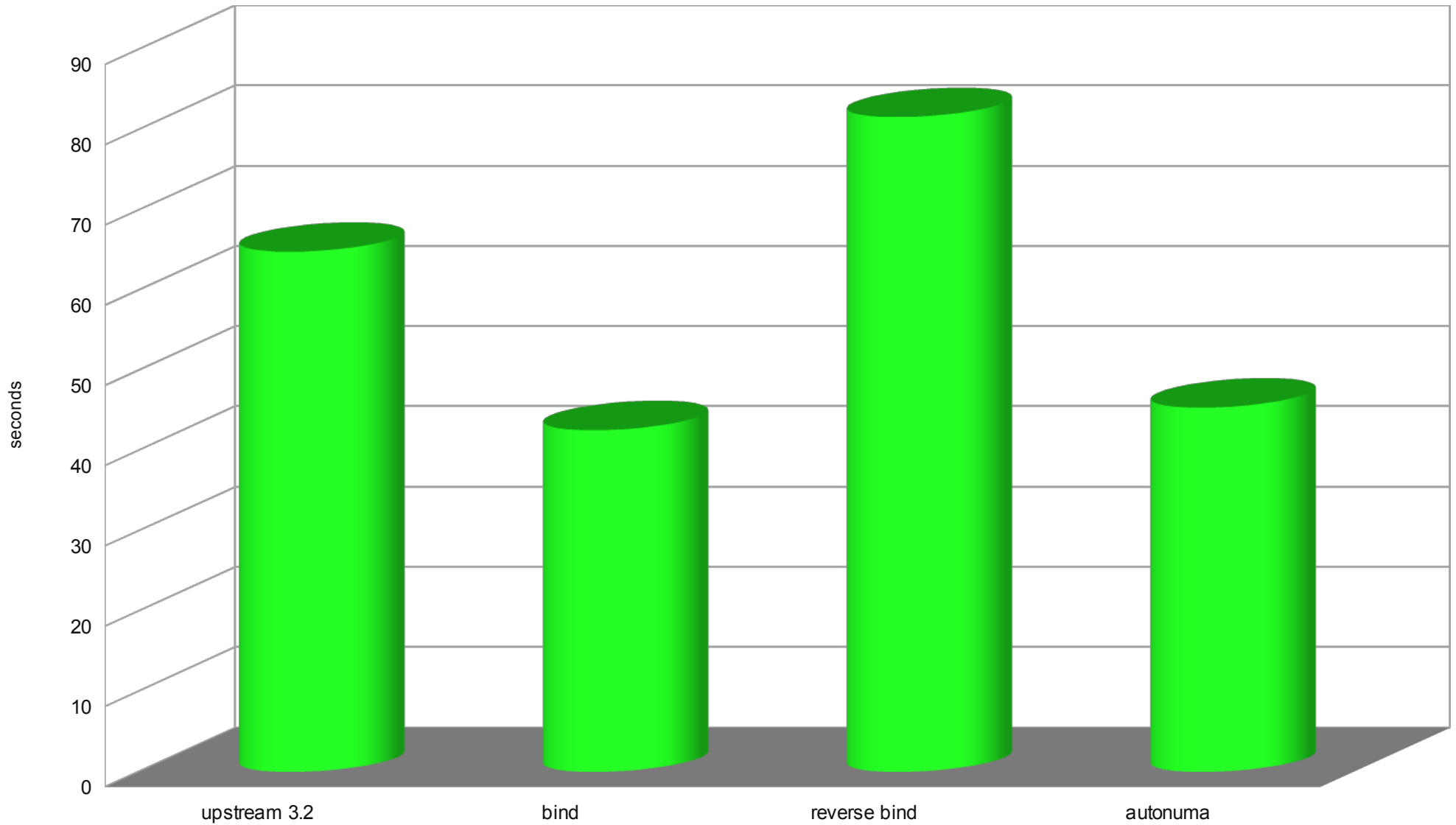


■ numa01 -DNO_BIND_FORCE_SAME_NODE (12 thread per process, 2 process) thread uses shared memory



numa02 per-thread local memory, 24 threads per process 1 process

lower is better

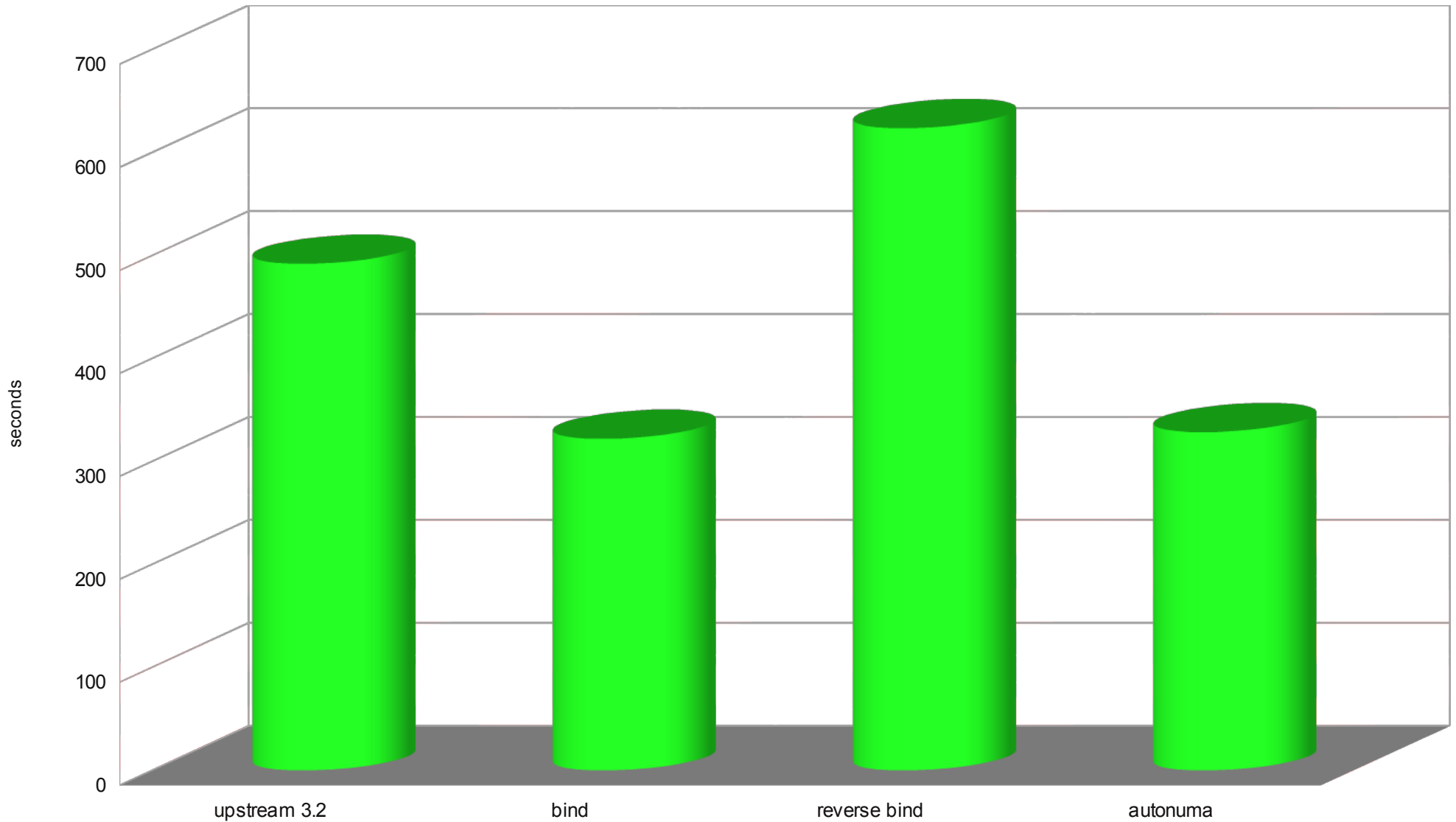


■ Numa02 (24 thread per process, 1 process) thread uses local memory



numa01 per-thread local memory, 12 threads per process, 2 processes

lower is better

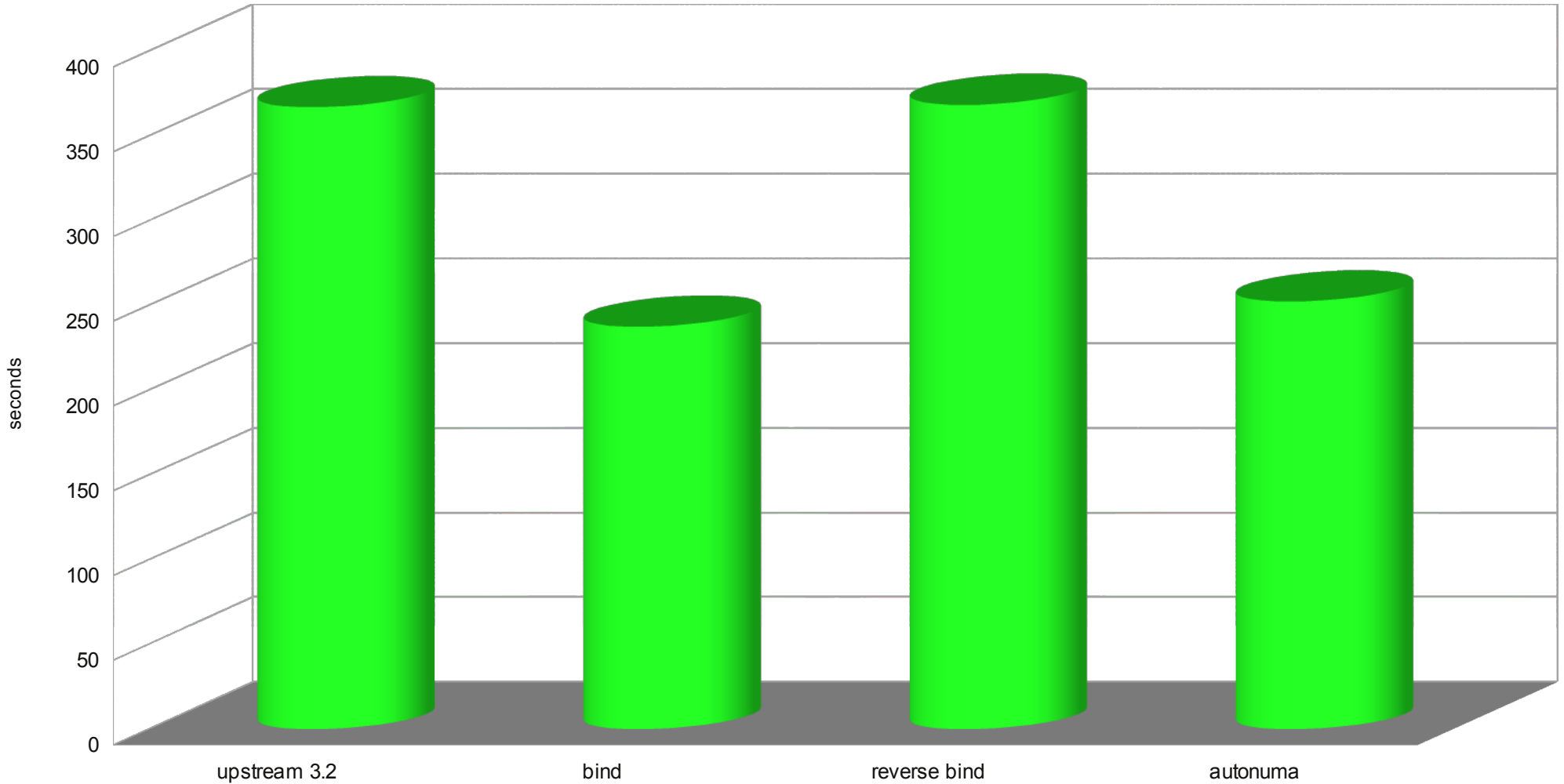


■ numa01 -DTHREAD_ALLOC (12 threads per process, 2 process) thread uses local memory



x2 CPU overcommit: numa01 -DNO_BIND_FORCE_SAME_NODE + numa02
24 threads using local memory +
12 threads using shared memory +
12 threads using shared memory

lower is better

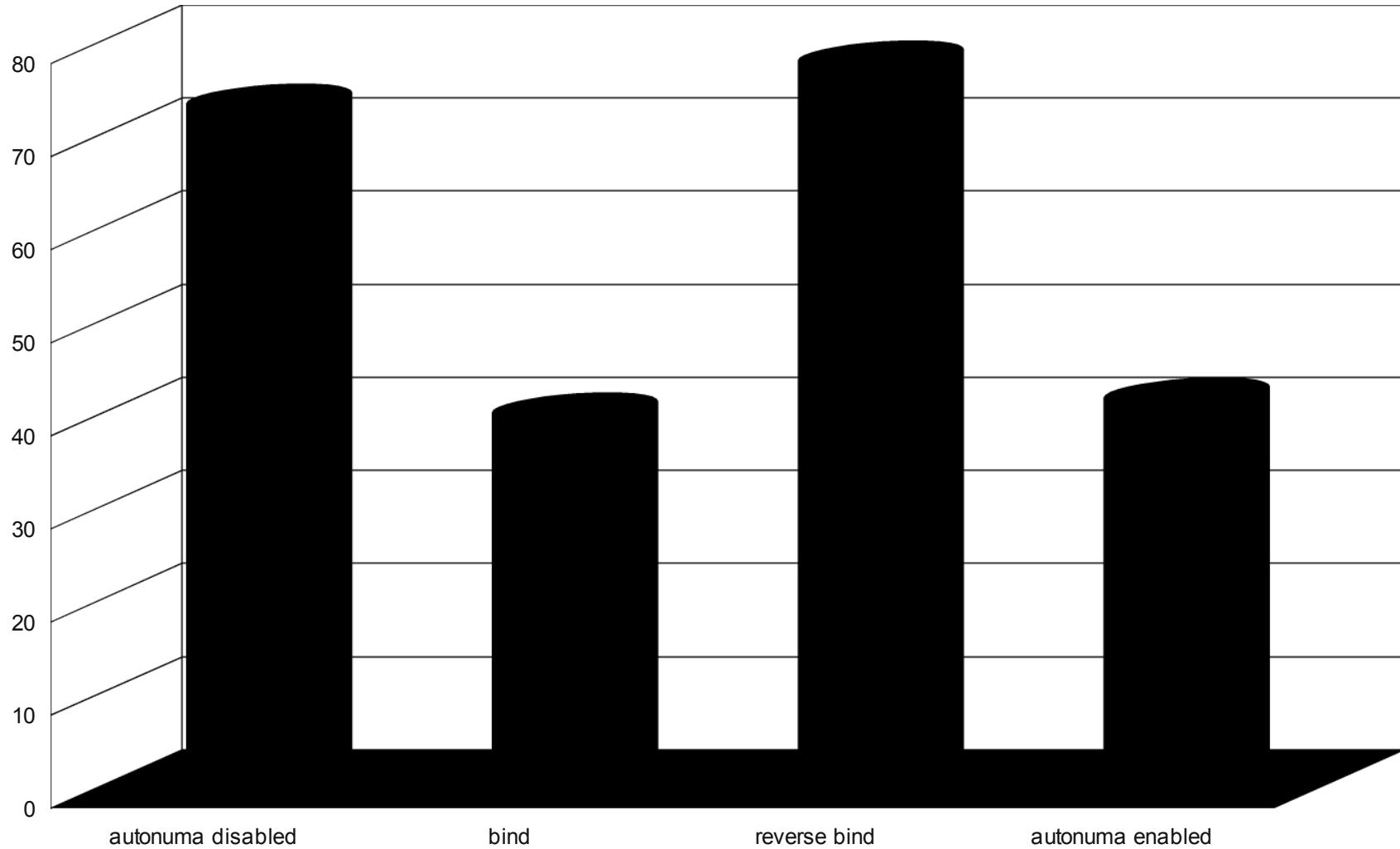


■ numa01 -DNO_BIND_FORCE_SAME_NODE + numa02 (3 processes total, 48 threads total) x2 overcommit



numa02 per-thread local memory, 12 threads per process 1 process (HT enabled)
SMT testcase

lower is better



■ Numa02 (16 threads per process, 1 process) thread uses local memory (hyperthreading enabled)

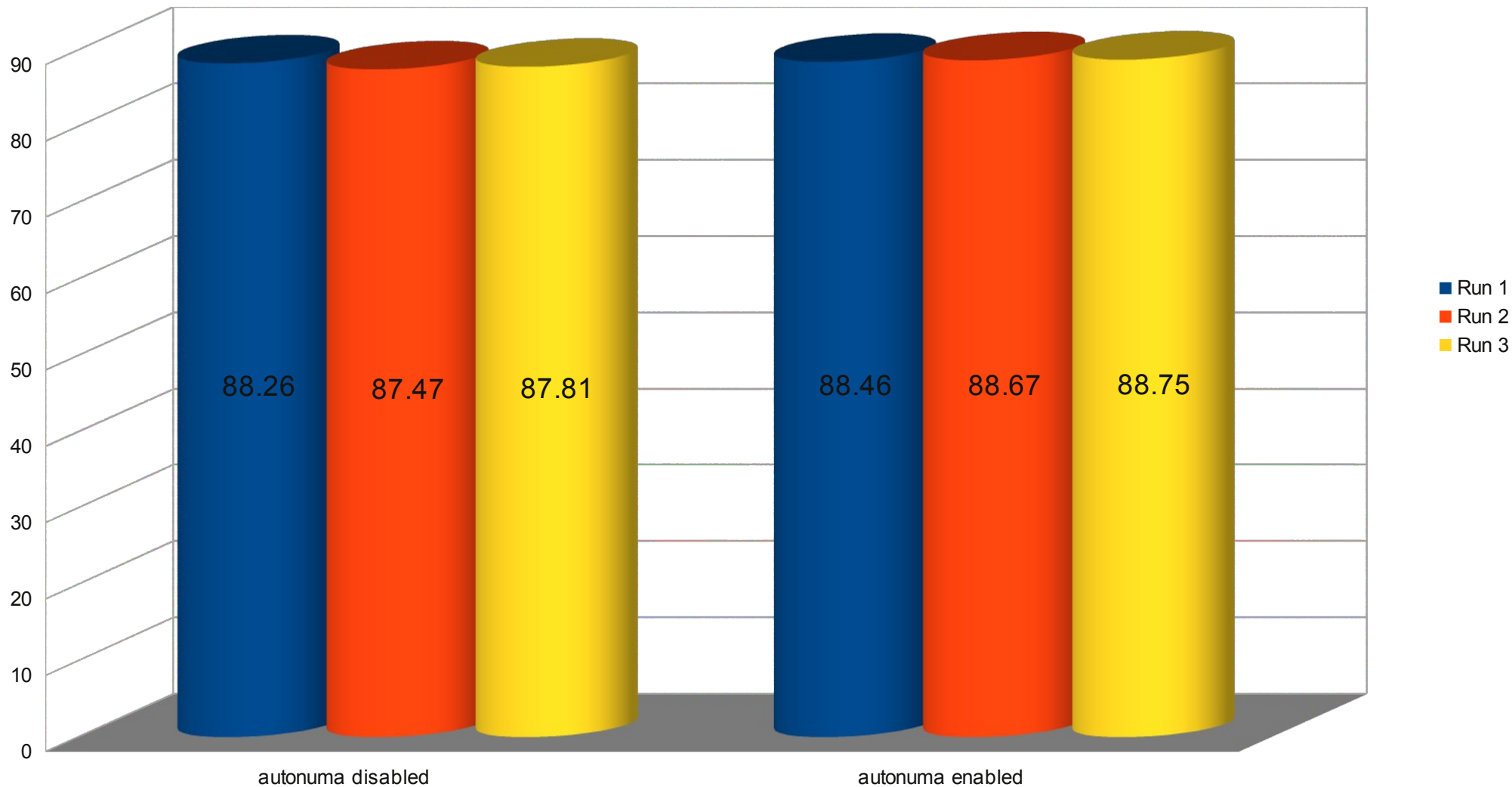


autonuma benchmark (hash 7e4dc3dbbda23b873ca7771b5cf296078e6ed1f7 vs 3.2 upstream default vs 3.2 upstream bind vs upstream inverse bind)				
	autonuma off	bind	reverse bind	autonuma
numa01 -DNO_BIND_FORCE_SAME_NODE (12 thread per process, 2 process) thread uses shared memory	305.36	196.0 7	378.34	207.47
Numa02 (24 thread per process, 1 process) thread uses local memory	64.81	42.58	81.6	45.39
numa01 -DTHREAD_ALLOC (12 threads per process, 2 process) thread uses local memory	491.88	321.9 4	623.62	328.43
numa01 -DNO_BIND_FORCE_SAME_NODE + numa02 (3 processes total, 48 threads total) x2 overcommit	366.96	237.4 3	368.35	252.31
Autonuma SMT fix uses hash 6e7267f0c9973f207a826c6b1fdae4e69c54ea80 Numa02 (16 threads per process, 1 process) thread uses local memory (hyperthreading enabled)	73.16	39.99	77.8	41.59



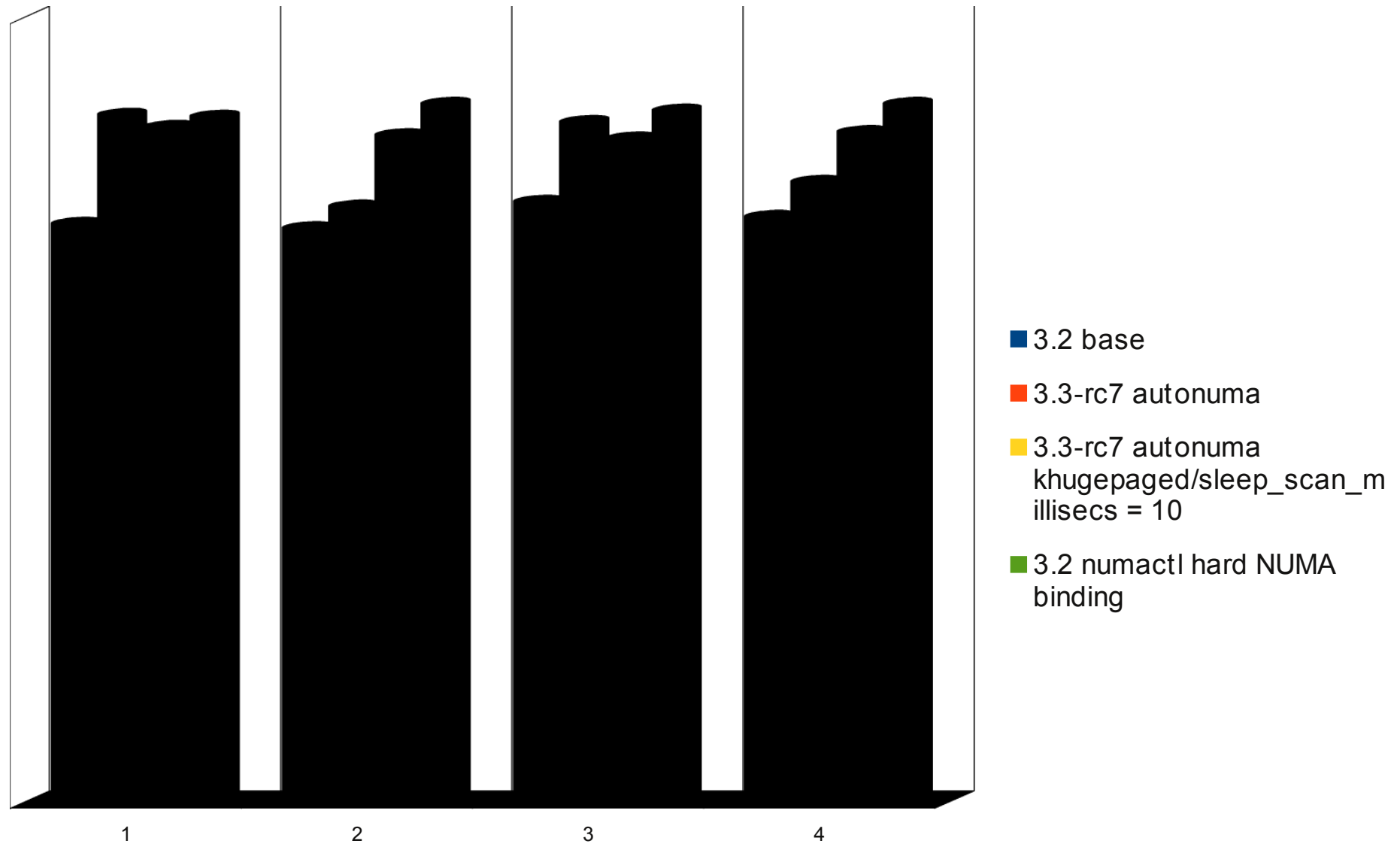
Kernel build time in seconds on tmpfs (make -j32)
Autonuma enabled includes one knuma_scand pass every 10sec

Worst possible case for AutoNUMA (gcc too short lived)
Average increase in build time 0.88%

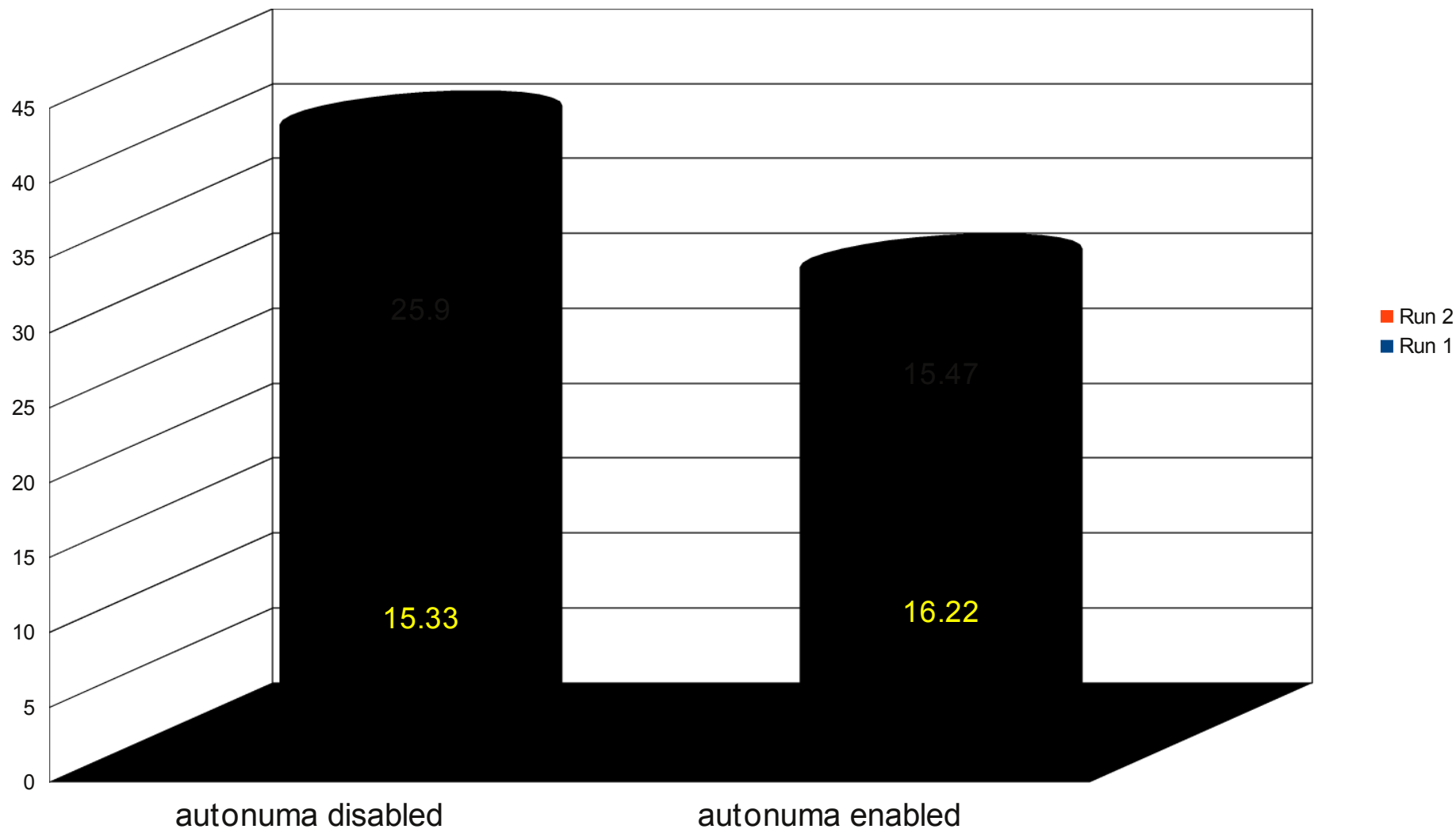


autonuma overhead kernel build tmpfs (make -j32)	Run 1	Run 2	Run 3
autonuma disabled	88.262	87.465	87.807
autonuma enabled	88.459	88.669	88.745

SPECjbb results 2 NUMA nodes, 8 CPUs per node, 16 CPUs total
THP enabled, no virt

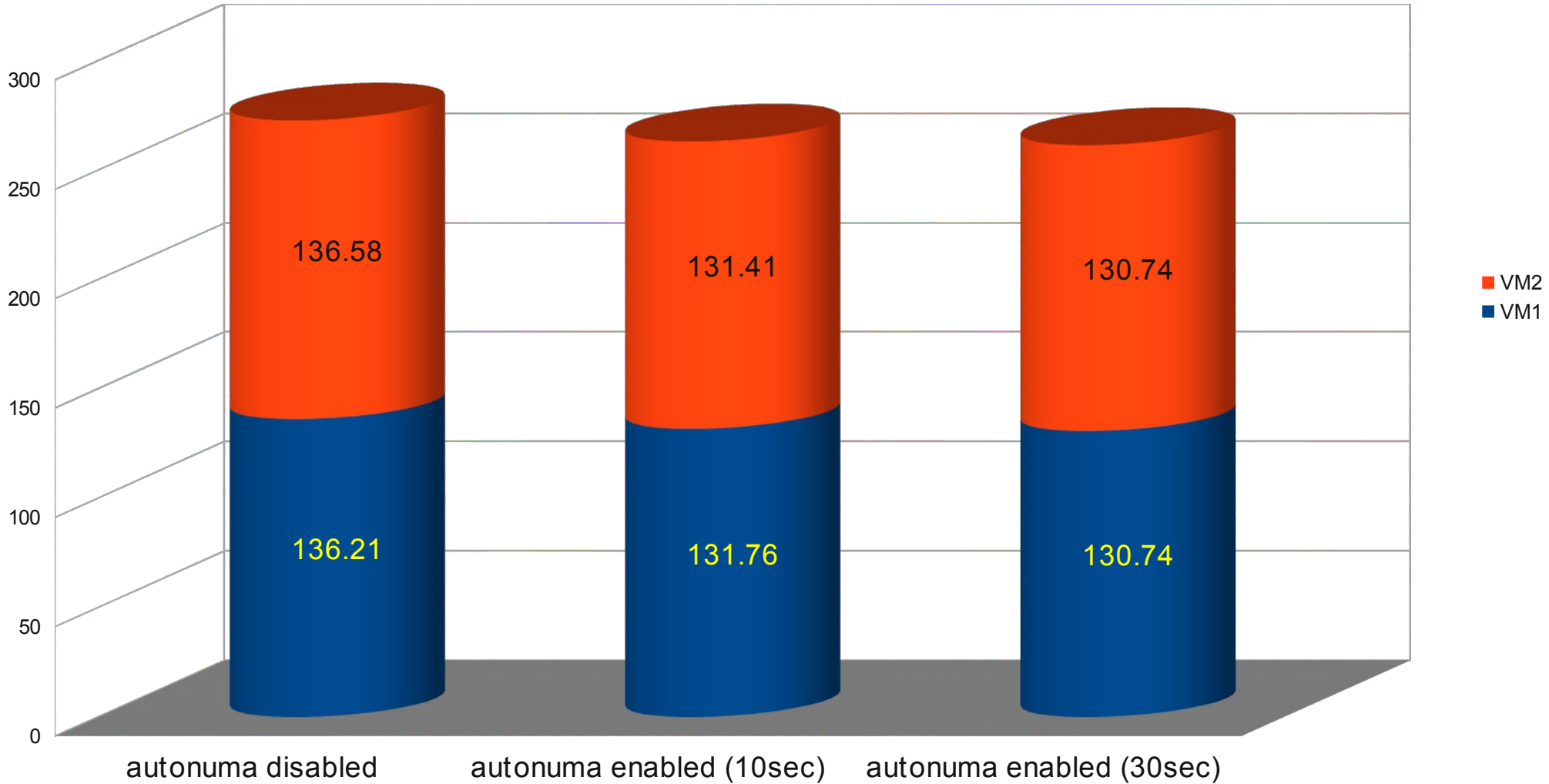


Virt guest "memhog -r100 1g" (autonuma includes 1 knuma_scand pass every 10 sec)
KVM host autonuma enabled/disabled, THP enabled
Guest VM fits in one host NUMA node



kernel build -j16 in parallel in 2 KVM (both in tmpfs, in a loop started in sync)
Both guest VM fits in one host NUMA node
autonuma/knuma_scand/scan_sleep_pass_millisecs = 5000 | 15000 (10sec | 30sec)

Host autonuma enabled/disabled, THP on, 12 vcpu per guest, 24 CPUs total on host



TODO: THP native migration

- THP native migration
 - SPECjbb results with khugepaged boosted shows the main bottleneck left is lack of THP native migration:
 - One copy in migration
 - One copy in khugepaged to rebuild the hugepage
 - Once this feature is added, AutoNUMA should perform even closer to numactl than it does now with khugepaged boosted (3rd column for every SPECjbb pass).
 - Urgent



TODO: scheduler

- Reduce autonuma_balance invocation frequency
 - Possibly run it from softirq like the load balance
- Possibly integrate it more closely into CFS



TODO: struct page

- Allocate the 24 bytes per page only when booted on NUMA hardware



TODO: document sched/numa.c

- And write proper high level documentation to put in Documentation/vm/autonuma.txt .

