DevConf CZ 2019

Performance Analysis and Tuning

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Agenda: Performance Analysis & Tuning

- RHEL Evolution 5->6->7->8
- Tuned
- NonUniform Memory Access (NUMA)
- Latency versus Throughput performance
- System Performance monitoring Tools
- Huge Pages
- Cgroups cpuset, memory, network and IO
- Disk and Filesystem IO - Throughput-performance - RHS / Cloud
- Sneak peak at RHEL8

Red Hat Enterprise Linux Performance Evolution

RHEL5

Static Hugepages

Ktune – on/off

CPU Affinity (taskset)

NUMA Pinning (numactl)

Irqbalance

RHEL6

Transparent HugePage

Tuned – choose profile

CPU Affinity (ts/numactl)

NUMAD – uerspace tool

Cgroups -

irqbalance – NUMA enhanced

RHEL7

Transparent Hugepages

Tuned – throughput-performance (default)

CPU Affinity (ts/numactl)

Autonuma-Balance

LXC – Container/Docker

irqbalance – NUMA enhanced

RHEL8

RHEV – out-of-the-box

virt-host/guest

RHEL OSP – blueprints

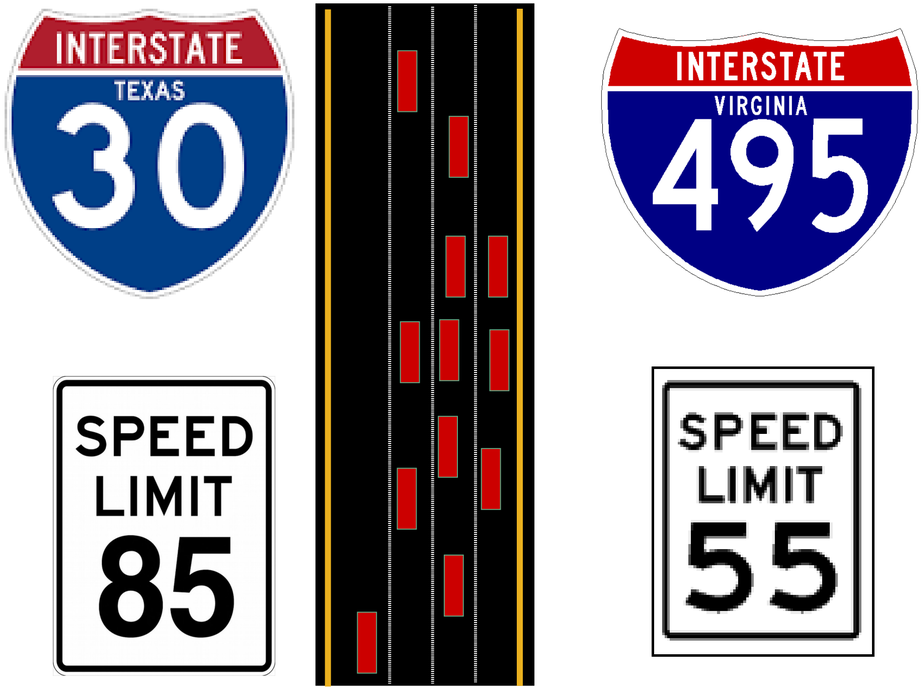
Tuned, Numa pining NIC – jumbo sriov

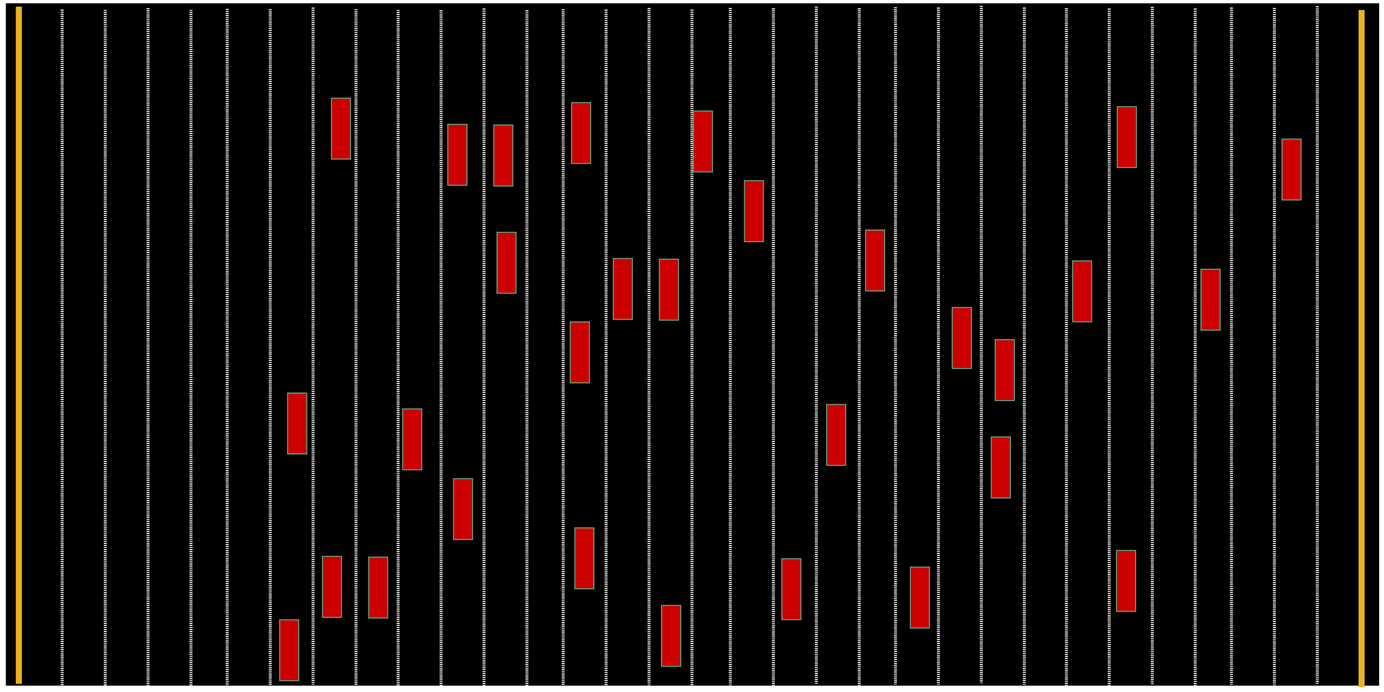
RHEL Atomic Host/Atomic Enterprise

RH OpenShift v3

Cloud Forms

Performance Metrics - Latency==Speed - Throughput==Bandwidth

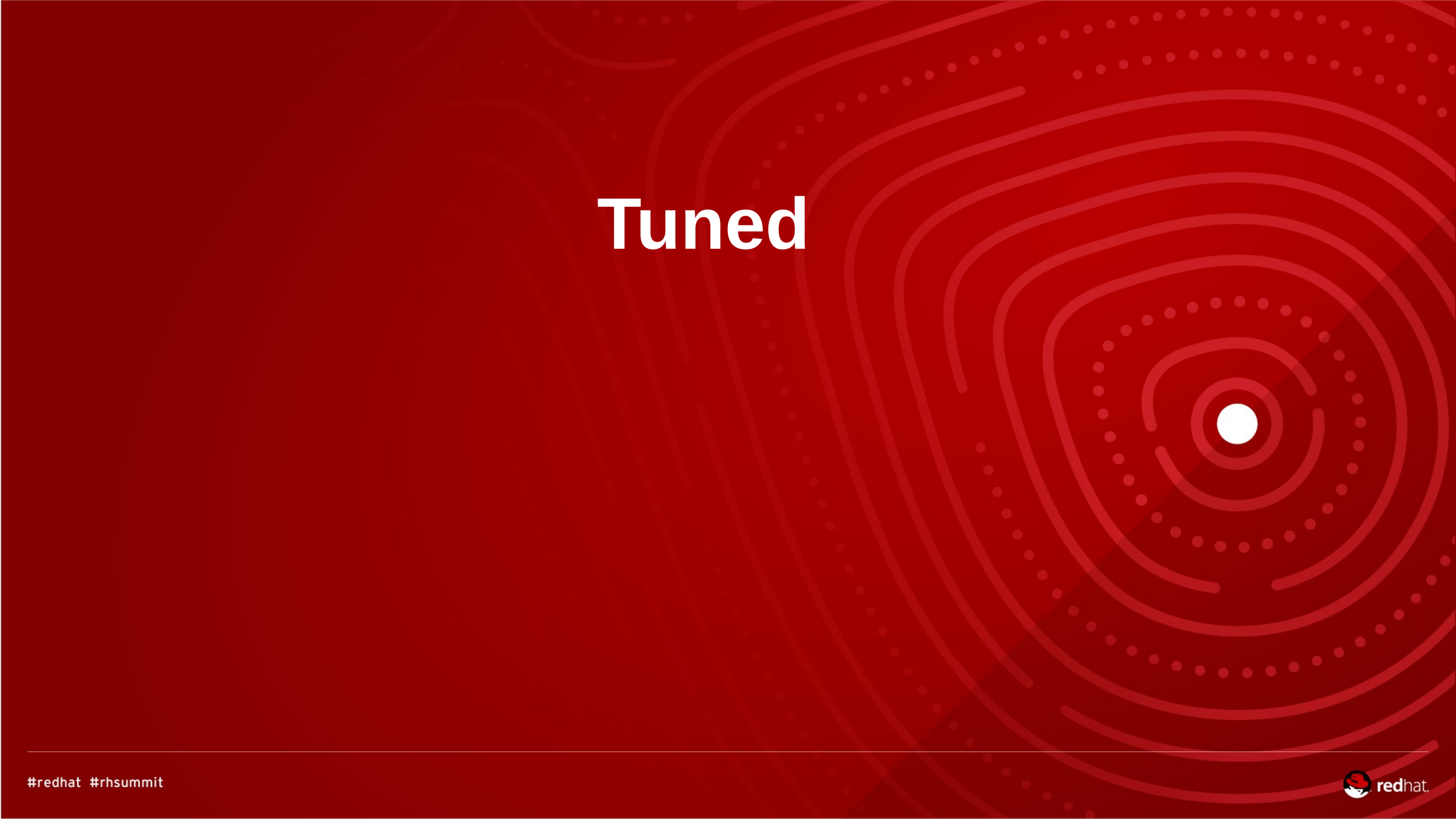




- **Latency – Speed Limit**
  - **Ghz of CPU, Memory PCI**
  - **Small transfers, disable aggregation – TCP nodelay**
  - **Dataplane optimization DPDK**

Throughput – Bandwidth - # lanes in Highway
- **Width of data path / cachelines**
- **Bus Bandwidth, QPI links, PCI 1-2-3**
- **Network 1 / 10 / 40 Gb – aggregation, NAPI**
- **Fiberchannel 4/8/16, SSD, NVME Drivers**

Tuned



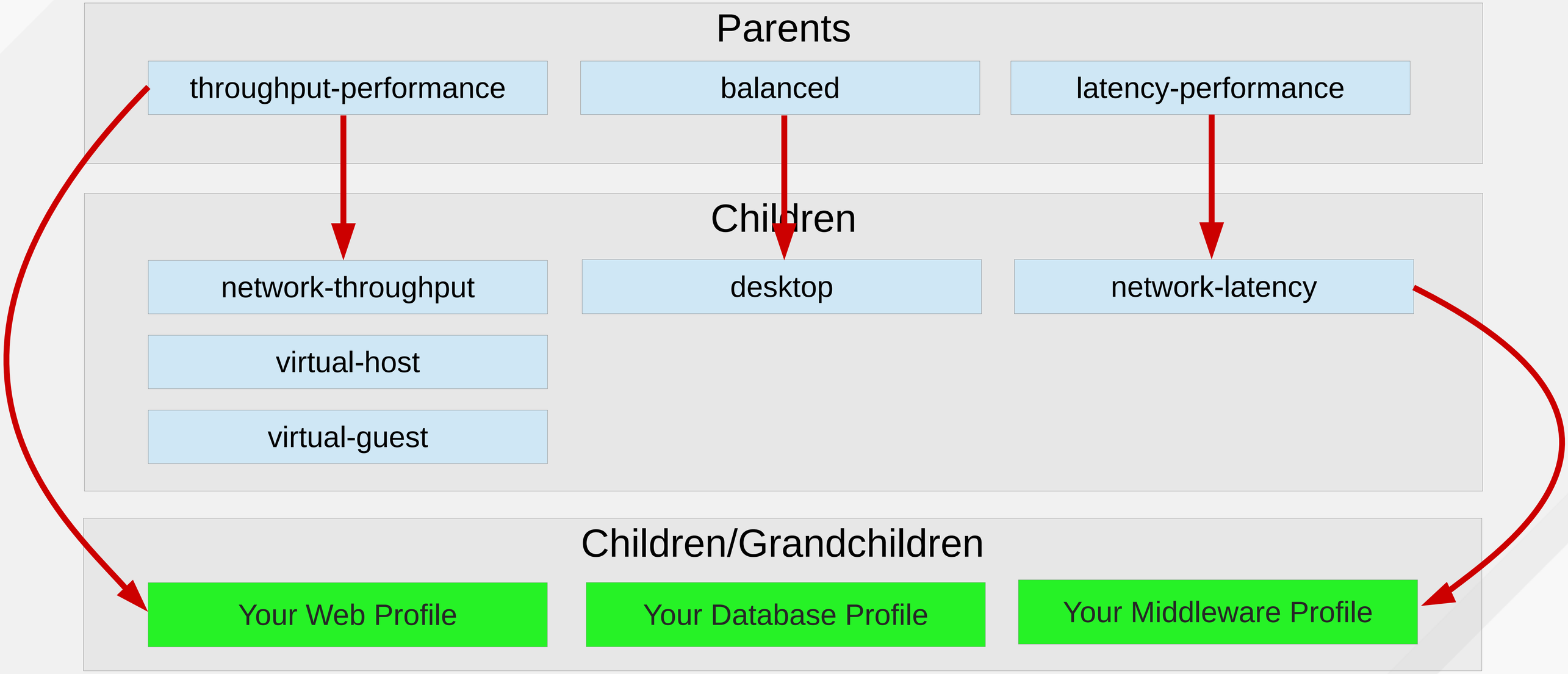
Tuned Overview

- Installed by default
- Auto-set Profiles
- Single config file
- Inheritance/Hooks
- loader/cmdline configs

- New Profiles
  - Realtime
  - NFV
  - RHEL Atomic Host
  - OpenShift
  - Oracle

See “`man tuned-profiles`” for profile definitions

Tuned: Your Custom Profiles



Tuned Profile Examples

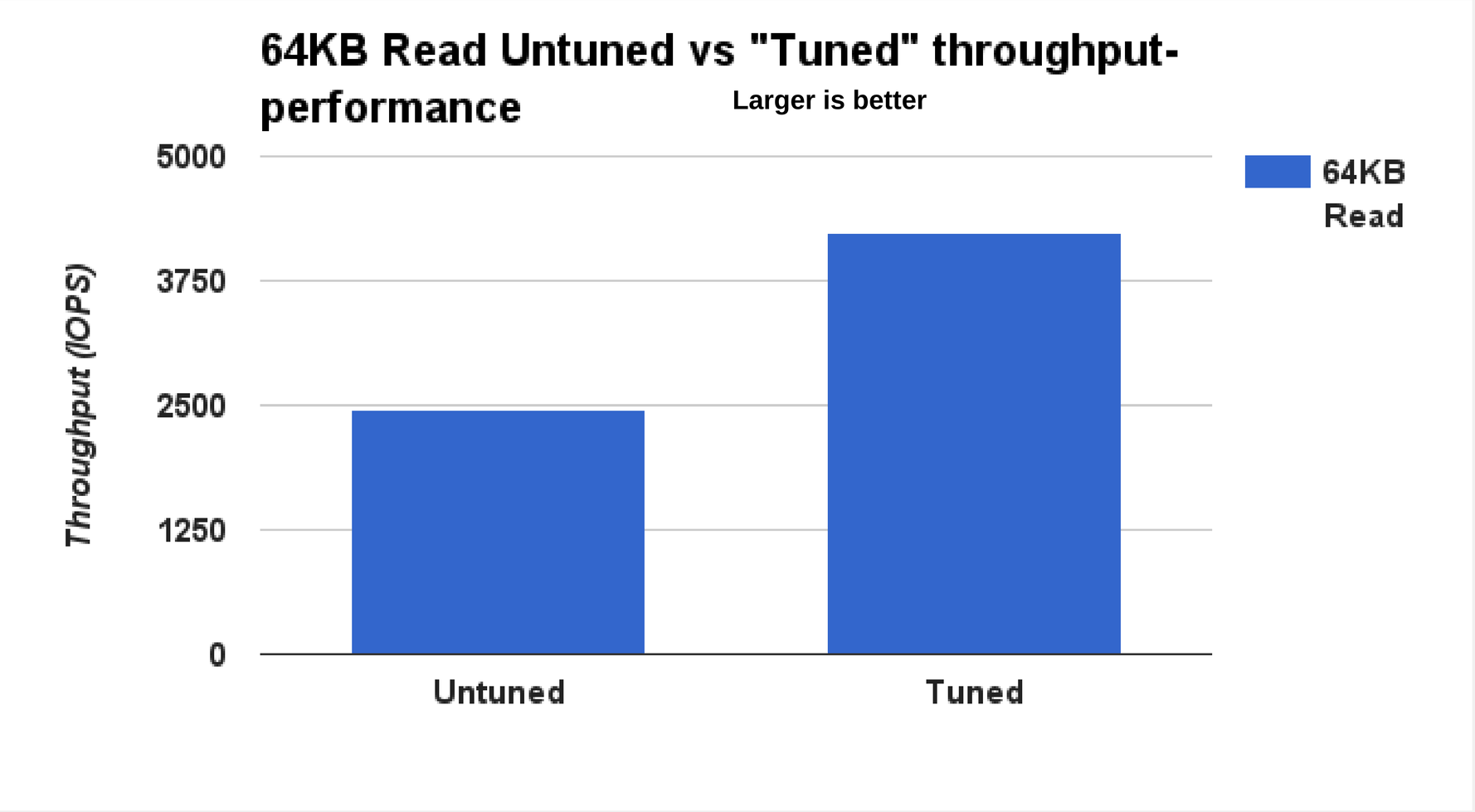
throughput-performance

governor=performance
energy_perf_bias=performance
min_perf_pct=100
transparent_hugepages=always
readahead=>4096
sched_min_granularity_ns = 10000000
sched_wakeup_granularity_ns = 15000000
vm.dirty_ratio = 40
vm.dirty_background_ratio = 10
vm.swappiness=10

latency-performance

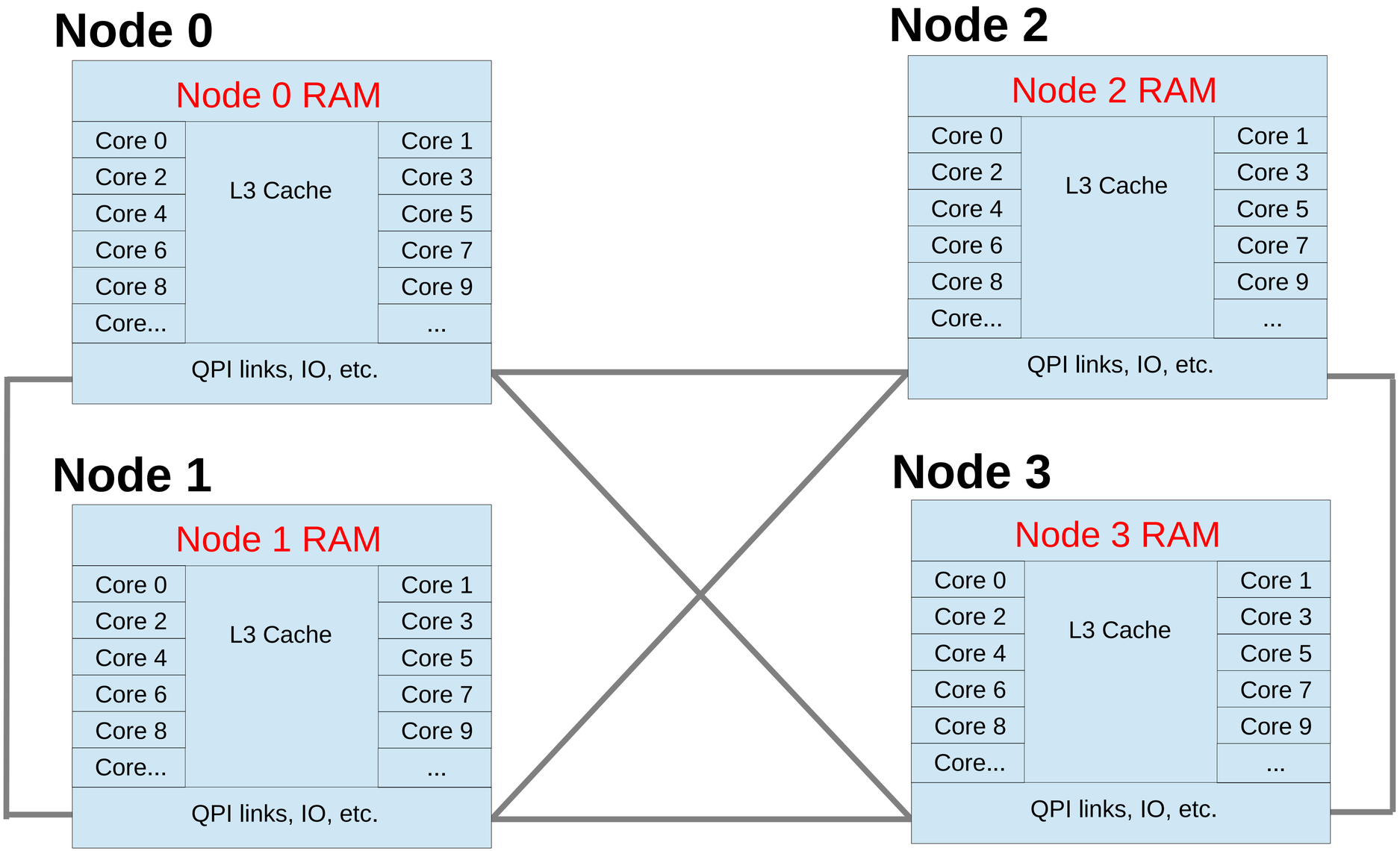
force_latency=1
governor=performance
energy_perf_bias=performance
min_perf_pct=100
kernel.sched_min_granularity_ns=10000000
vm.dirty_ratio=10
vm.dirty_background_ratio=3
vm.swappiness=10
kernel.sched_migration_cost_ns=5000000

Tuned: Storage Performance Boost: throughput-performance (default in RHEL7)



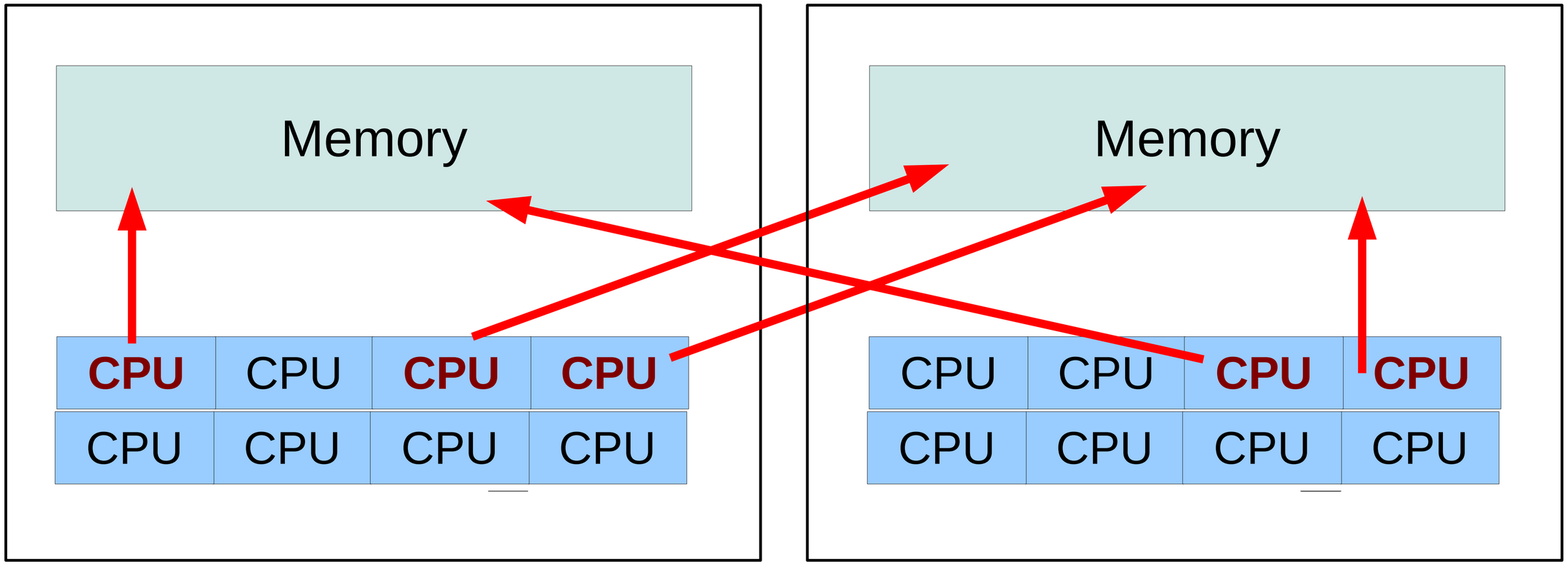
RHEL 6/7/8 Non-Uniform Memory Access (NUMA)

Typical Four-Node NUMA System



Non-optimal numa setup

Process 1 in **red**, 5 threads

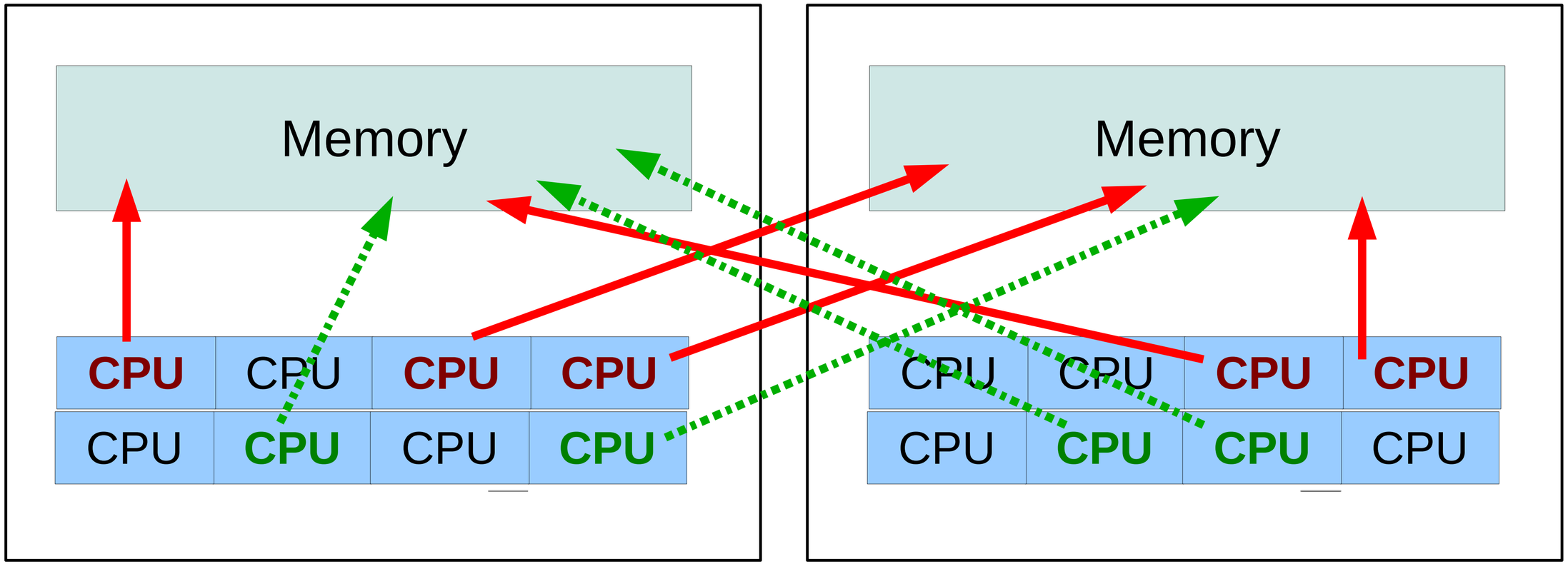


Numa node **0**

Numa node **1**

Add in more processes: non-optimal

Process 1 in **red**, 5 threads
Process 2 in **green**, 4 threads.

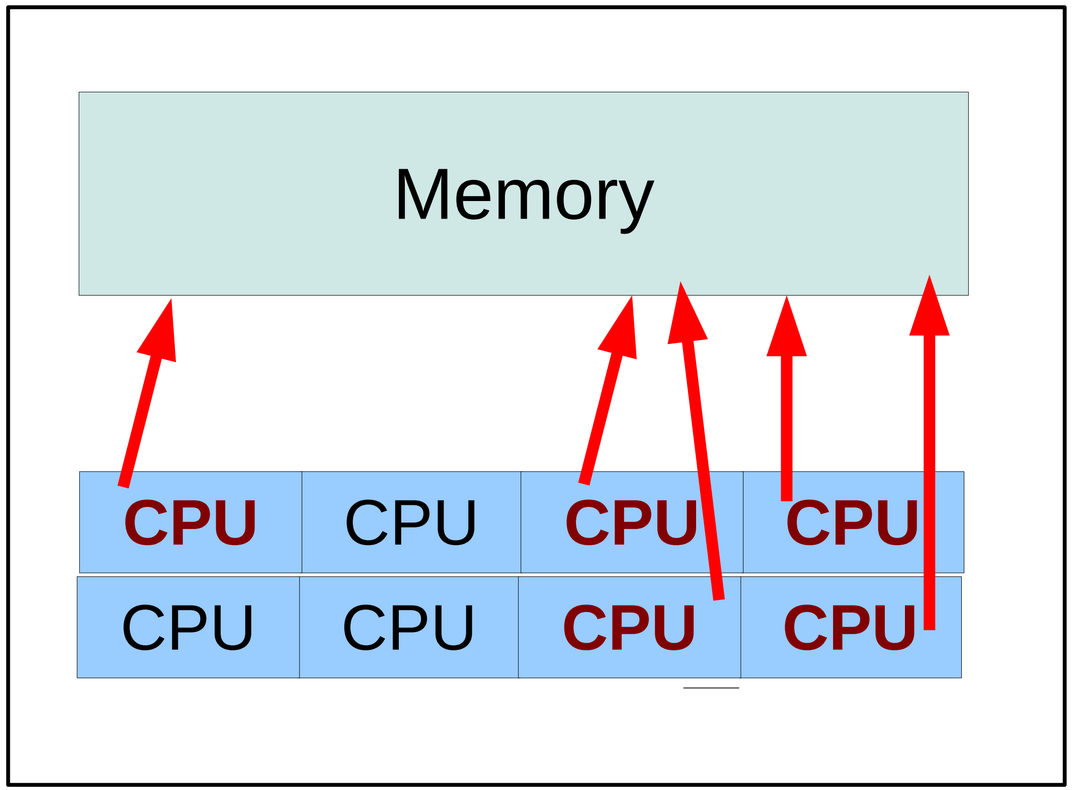


Numa node 0

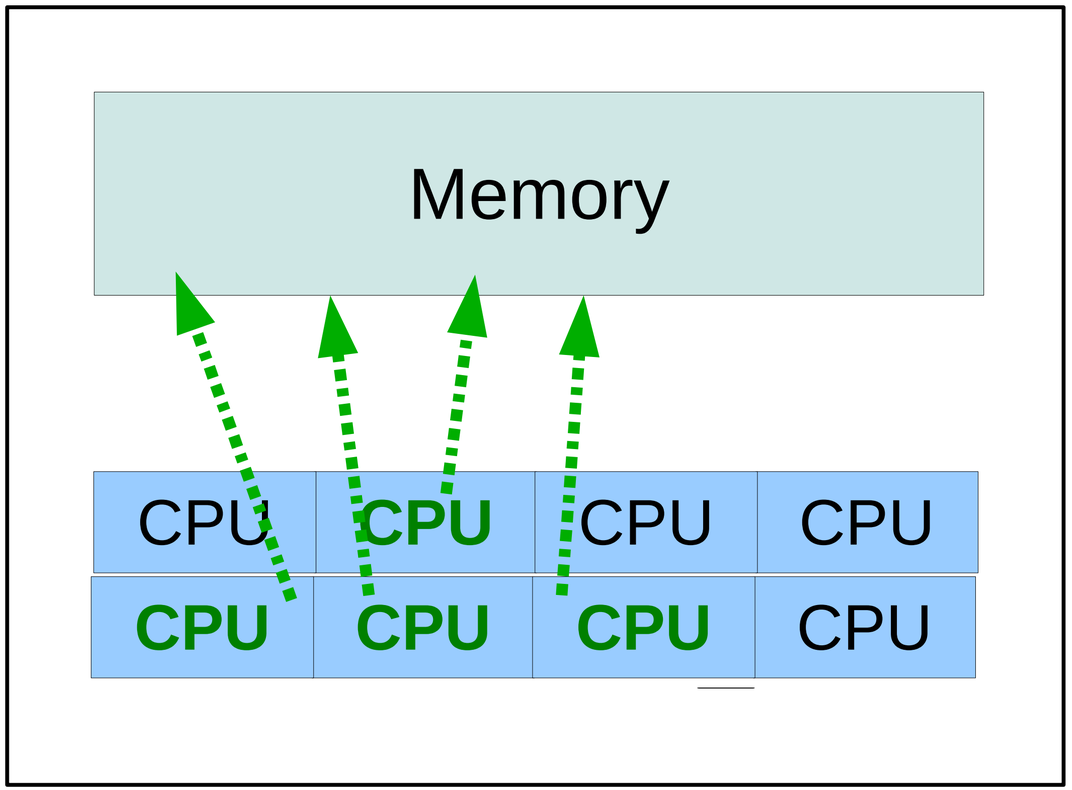
Numa node 1

Optimal numa setup

Process 1 in **green**, 4 threads
Process 2 in **red**, 5 threads



Numa node 0



Numa node 1

Tools to display CPU and Memory (NUMA)

```
# lscpu
Architecture:          x86_64
CPU op-mode(s):        32-bit, 64-bit
Byte Order:            Little Endian
CPU(s):                40
On-line CPU(s) list:   0-39
Thread(s) per core:    1
Core(s) per socket:    10
CPU socket(s):         4
NUMA node(s):          4
  . . . .
L1d cache:             32K
L1i cache:             32K
L2 cache:              256K
L3 cache:              30720K
NUMA node0 CPU(s):     0,4,8,12,16,20,24,28,32,36
NUMA node1 CPU(s):     2,6,10,14,18,22,26,30,34,38
NUMA node2 CPU(s):     1,5,9,13,17,21,25,29,33,37
NUMA node3 CPU(s):     3,7,11,15,19,23,27,31,35,39
```

cpu, core, socket, node info

The cpu numbers for each node

Tools to display CPU and Memory (NUMA)

```
# numactl --hardware
available: 4 nodes (0-3)
node 0 cpus: 0 4 8 12 16 20 24 28 32 36
node 0 size: 65415 MB
node 0 free: 63482 MB
node 1 cpus: 2 6 10 14 18 22 26 30 34 38
node 1 size: 65536 MB
node 1 free: 63968 MB
node 2 cpus: 1 5 9 13 17 21 25 29 33 37
node 2 size: 65536 MB
node 2 free: 63897 MB
node 3 cpus: 3 7 11 15 19 23 27 31 35 39
node 3 size: 65536 MB
node 3 free: 63971 MB
node distances:
node   0   1   2   3
  0:  10  21  21  21
  1:  21  10  21  21
  2:  21  21  10  21
  3:  21  21  21  10
```

cpus & memory for each node

Relative “node-to-node” latency costs.

Visualize CPUs via lstopo (hwloc-gui rpm)

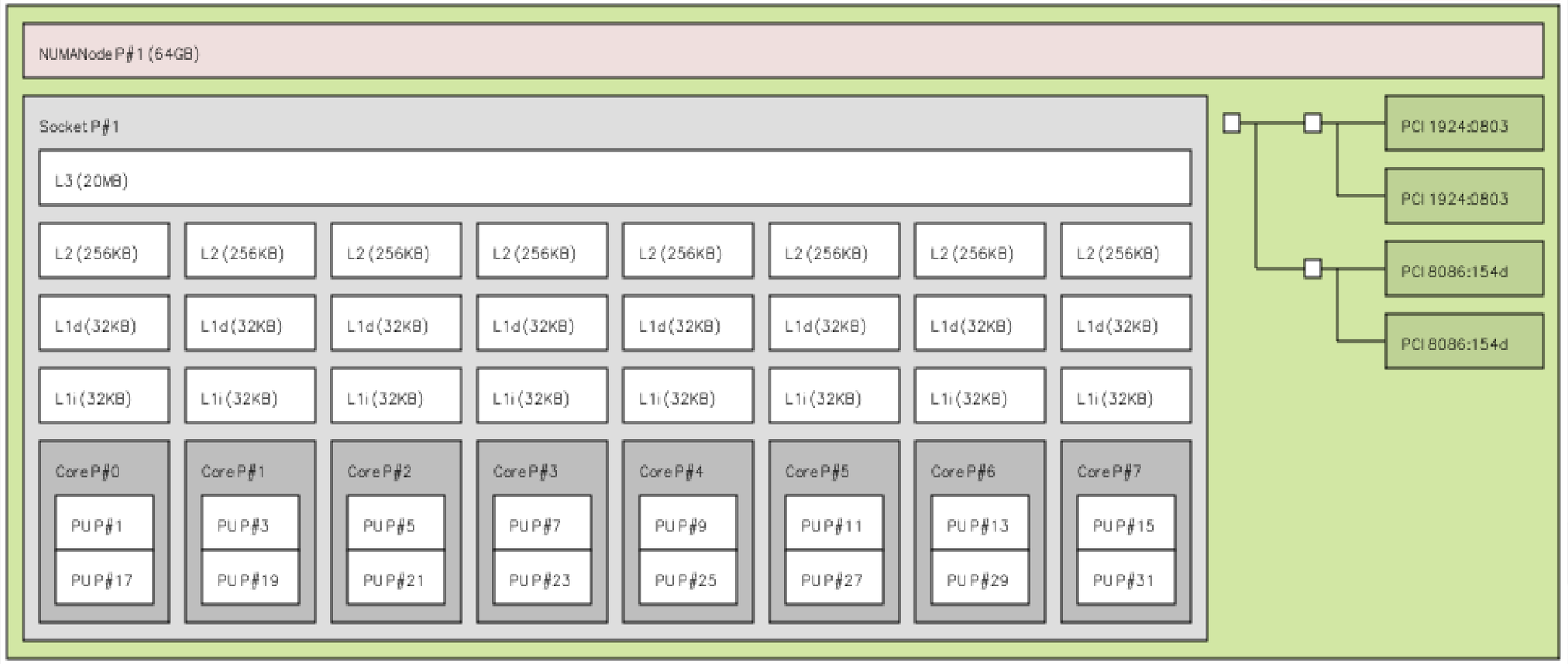
```
# lstopo
```

PCIe

NUMA

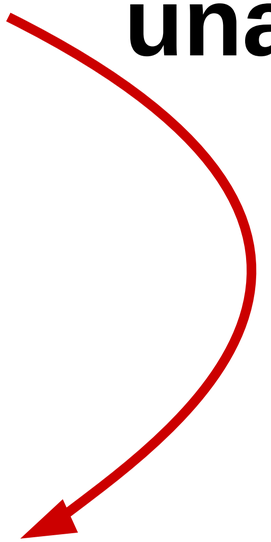
CACHE

cores
cpus
HT



numastat shows need for NUMA management

```
# numastat -c qemu  Per-node process memory usage (in Mbs)

PID              Node 0 Node 1 Node 2 Node 3 Total
---------------  ------ ------ ------ ------ -----
10587 (qemu-kvm)   1216   4022   4028   1456 10722
10629 (qemu-kvm)   2108     56    473   8077 10714
10671 (qemu-kvm)   4096   3470   3036    110 10712
10713 (qemu-kvm)   4043   3498   2135   1055 10730
---------------  ------ ------ ------ ------ -----
Total             11462  11045   9672  10698 42877

# numastat -c qemu

Per-node process memory usage (in Mbs)

PID              Node 0 Node 1 Node 2 Node 3 Total
---------------  ------ ------ ------ ------ -----
10587 (qemu-kvm)      0  10723      5      0 10728
10629 (qemu-kvm)      0      0      5  10717 10722
10671 (qemu-kvm)      0      0  10726      0 10726
10713 (qemu-kvm)  10733      0      5      0 10738
---------------  ------ ------ ------ ------ -----
Total             10733  10723  10740  10717 42913
```



unaligned

aligned

Techniques to control placement:

numactl:

- Control NUMA policy for processes or shared memory:

taskset:

- Retrieve or set a process's CPU affinity

*sched_**g**etaffinity(), sched_**s**etaffinity()*

- for process affinity from within program

*mbind(), **g**et_mempolicy(), **s**et_mempolicy()*

- set default NUMA memory policy for a process children.

Cgroups

- cpuset.cpus, cpuset.mems

Techniques to control placement (cont):

numad:

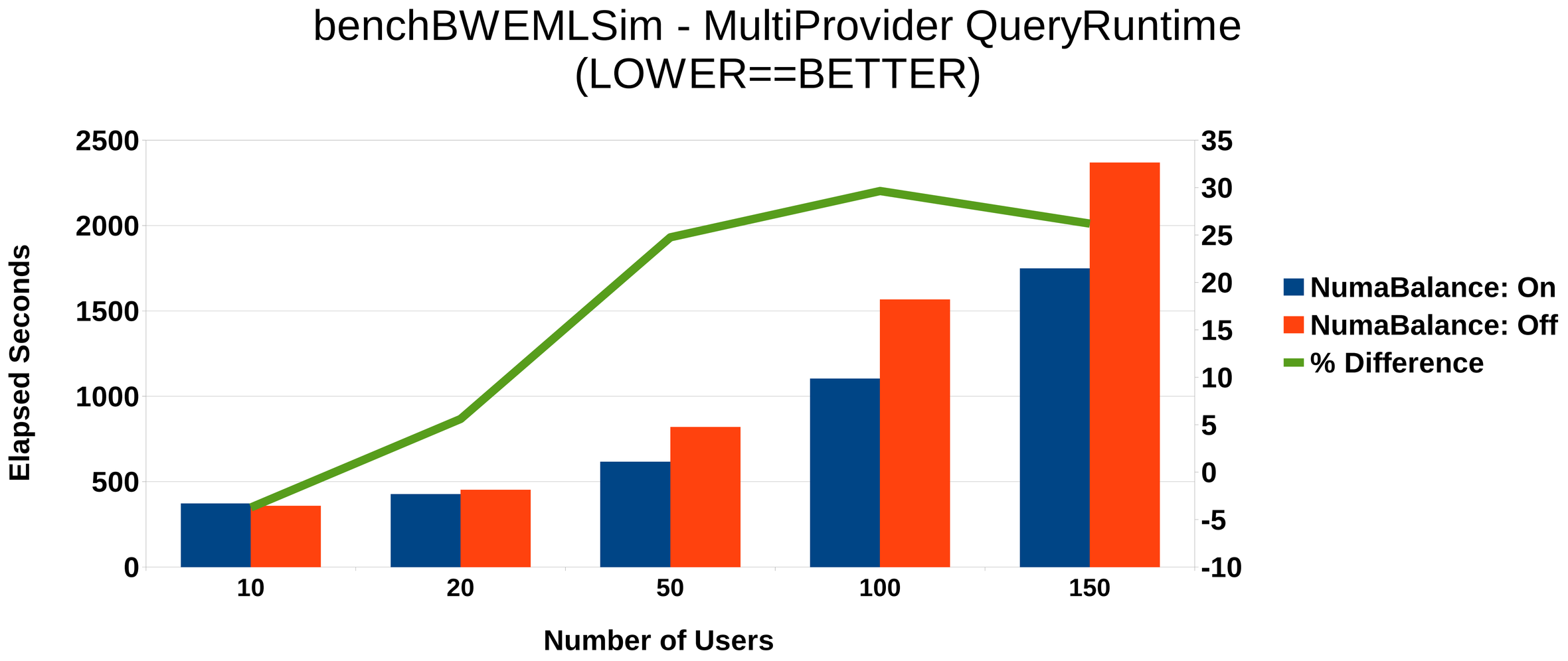
- User-mode daemon.
- Attempts to locate processes for efficient NUMA locality and affinity.
- Dynamically adjusting to changing system conditions.
- Available in RHEL 6 & 7.

Auto-Numa-Balance kernel scheduler:

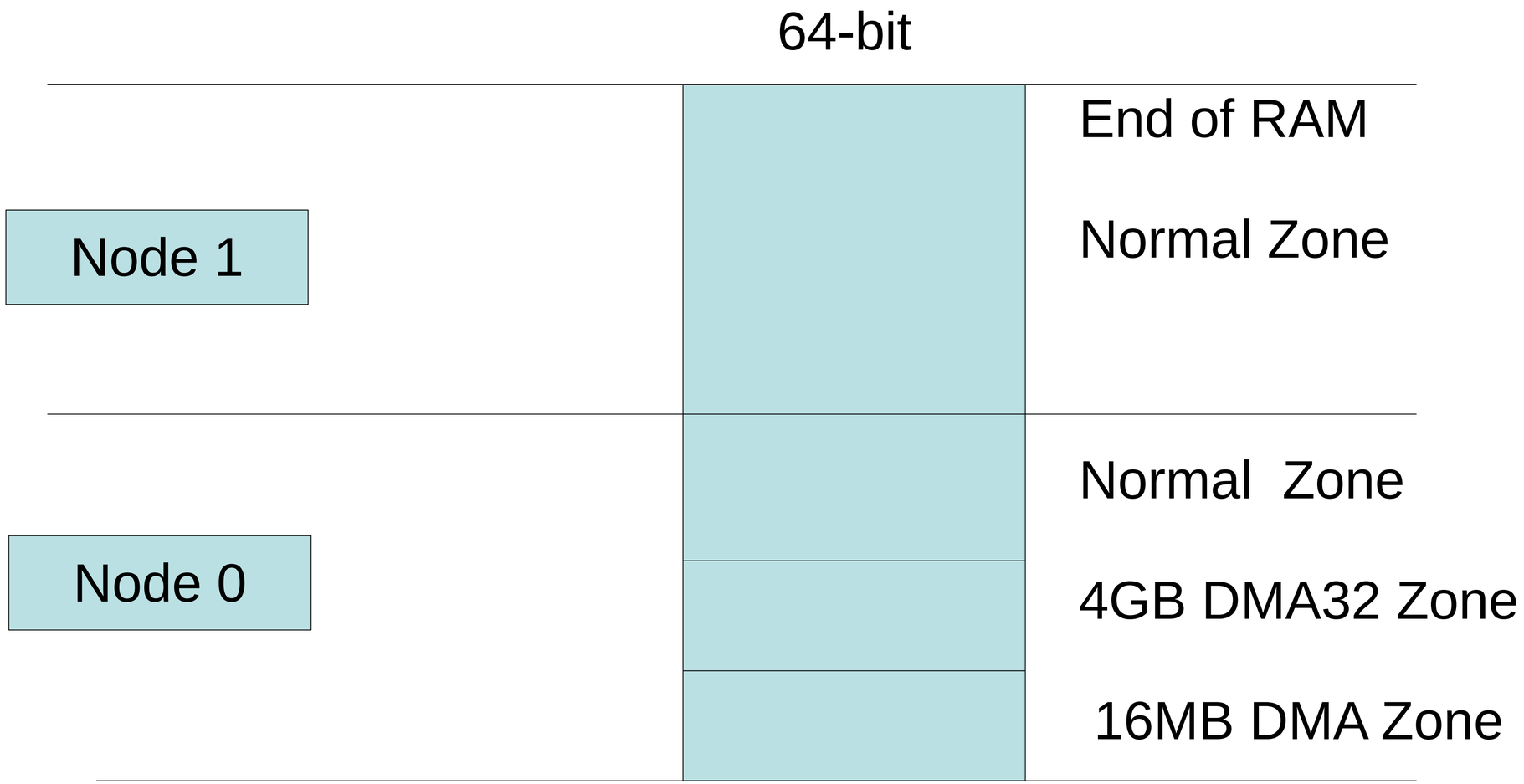
- Automatically run programs near their memory, and moves memory near the programs using it.
- Default enabled. Available in RHEL 7+
- Great video on how it works:
  - https://www.youtube.com/watch?v=mjVw_oe1hEA

Early SAP HANA benefit from Auto-Numa-Balance

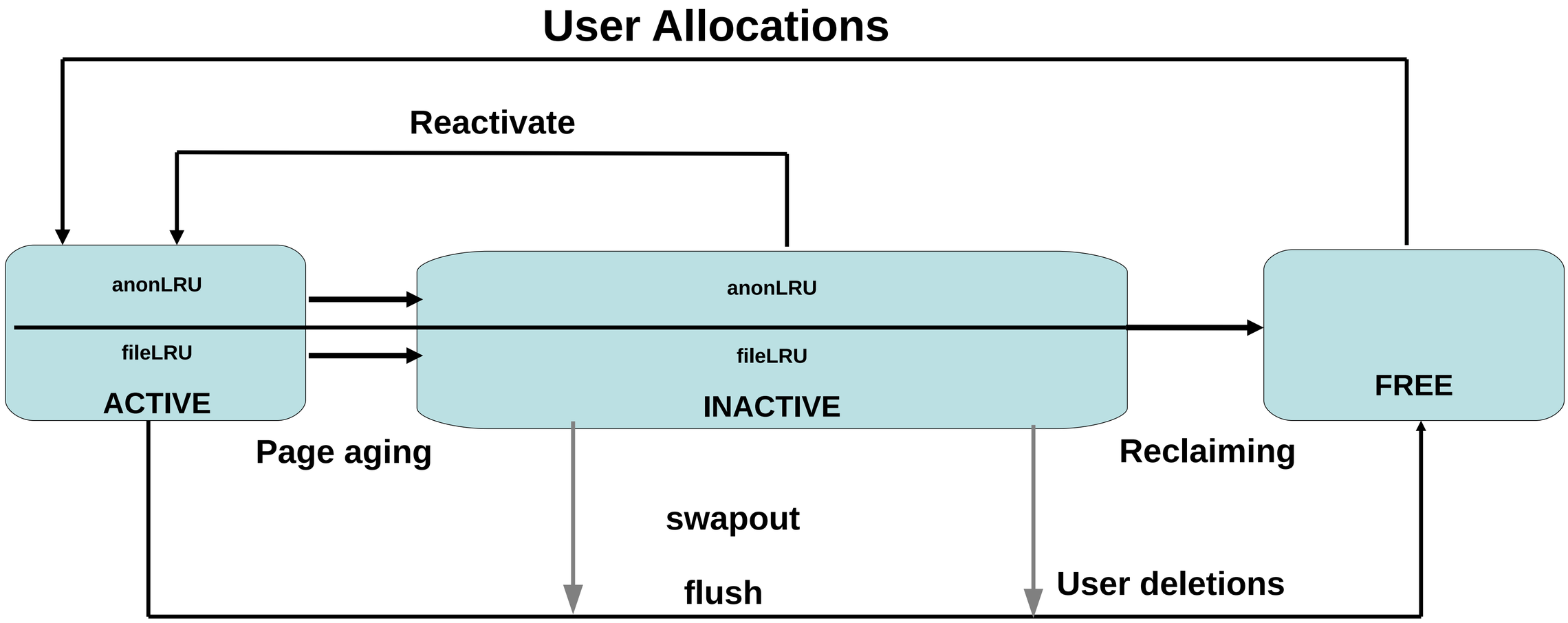
25+% gain. [Recent HANA numa-aware binary closed gap.]



NUMA Nodes and Zones



Per Node / Zone split LRU Page Reclaim Dynamics



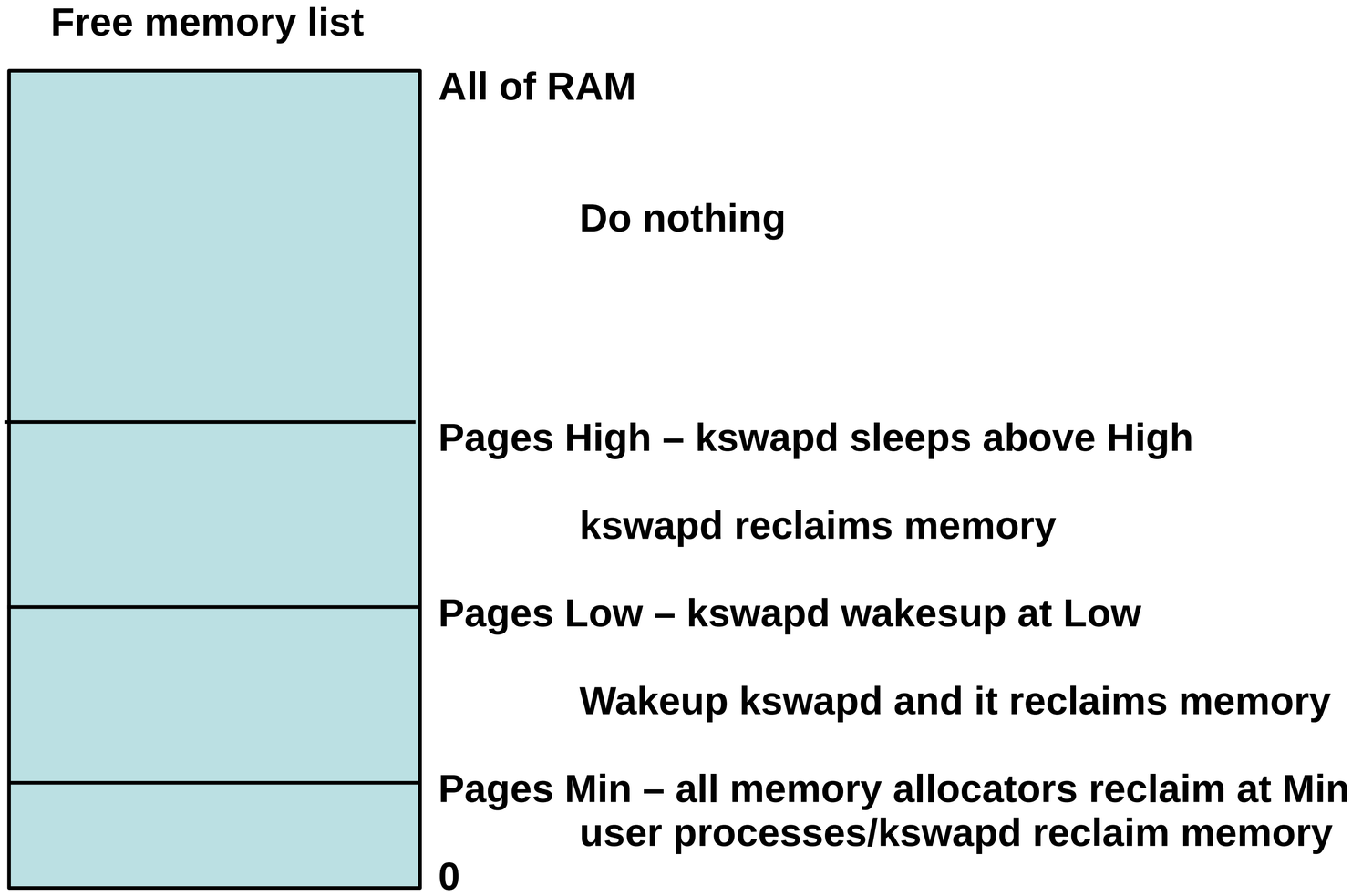
Interaction between VM Tunables and NUMA

- Dependent on NUMA: Reclaim Ratios
  - /proc/sys/vm/swappiness
  - /proc/sys/vm/min_free_kbytes
  - /proc/sys/vm/zone_reclaim_mode
- Independent of NUMA: Reclaim Ratios
  - /proc/sys/vm/vfs_cache_pressure
- Writeback Parameters
  - /proc/sys/vm/dirty_background_ratio
  - /proc/sys/vm/dirty_ratio
- Readahead parameters
  - /sys/block/<bdev>/queue/read_ahead_kb

swappiness

- Controls how aggressively the system reclaims anonymous memory versus pagecache memory:
  - Anonymous memory – swapping and freeing
  - File pages – writing if dirty and freeing
  - System V shared memory – swapping and freeing
- Default is 60
- Decrease: more aggressive reclaiming of pagecache memory
- Increase: more aggressive swapping of anonymous memory
- Can effect Numa nodes differently.
- Tuning not as necessary on RHEL7 than RHEL6 and even less than RHEL5

Memory reclaim Watermarks



min_free_kbytes

Directly controls the page reclaim watermarks in KB

Distributed between the Numa nodes

Defaults are higher when THP is enabled

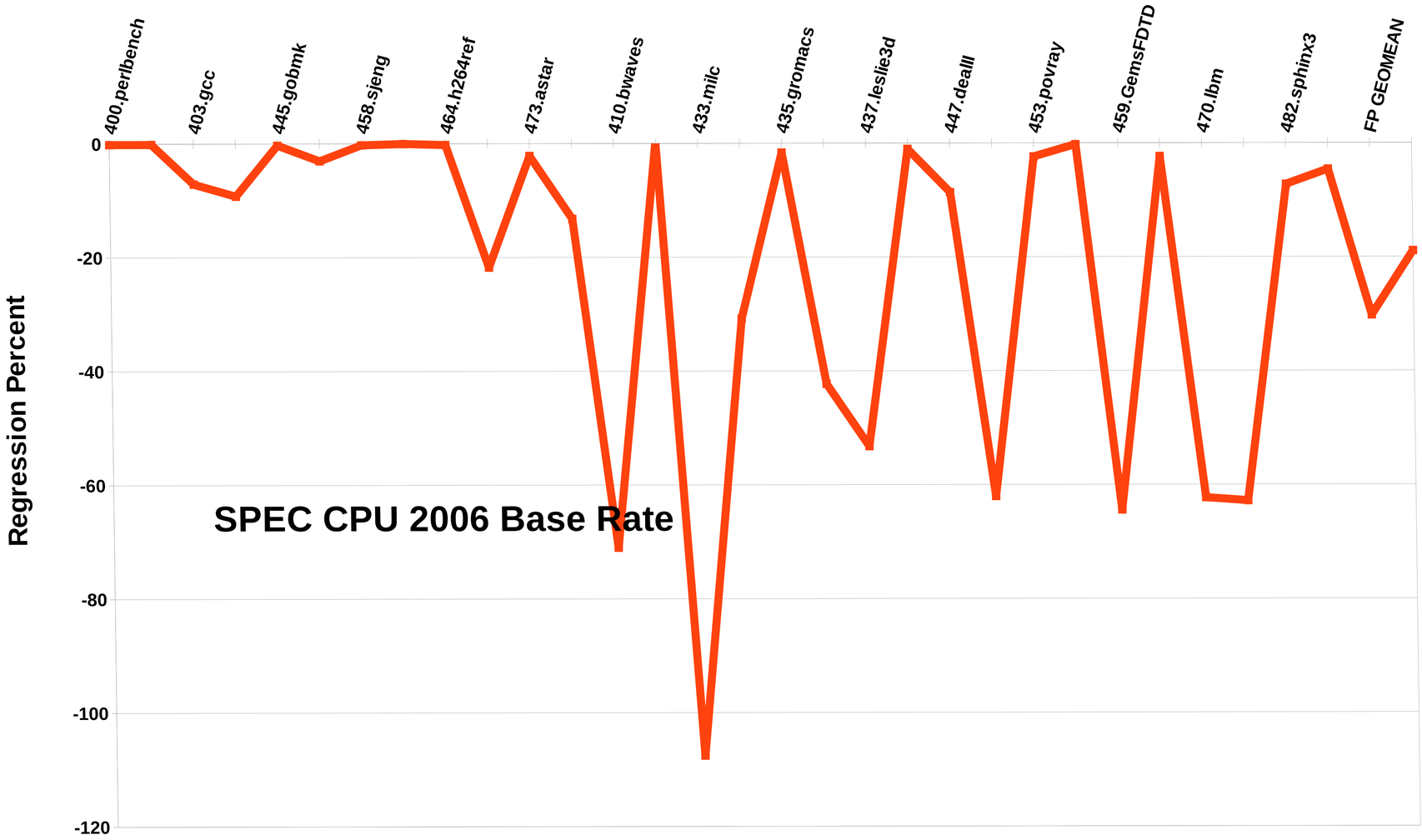
```
# cat /proc/sys/vm/min_free_kbytes
90100
-----------------------------------------------------
Node 0 DMA    min:80 low:100kB high:120kB
Node 0 DMA32 min:15312kB low:19140kB high:22968kB
Node 0 Normal min:29600kB low:37000kB high:44400kB
Node 1 Normal min:45108kB low:56384kB high:67660kB
-----------------------------------------------------

echo 180200 > /proc/sys/vm/min_free_kbytes
-----------------------------------------------------2
Node 0 DMA    min:160kB low:200kB high:240kB
Node 0 DMA32 min:30624kB low:38280kB high:45936kB
Node 0 Normal min:59200kB low:74000kB high:88800kB
Node 1 Normal min:90216kB low:112768kB high:135320kB
-----------------------------------------------------
```

zone_reclaim_mode

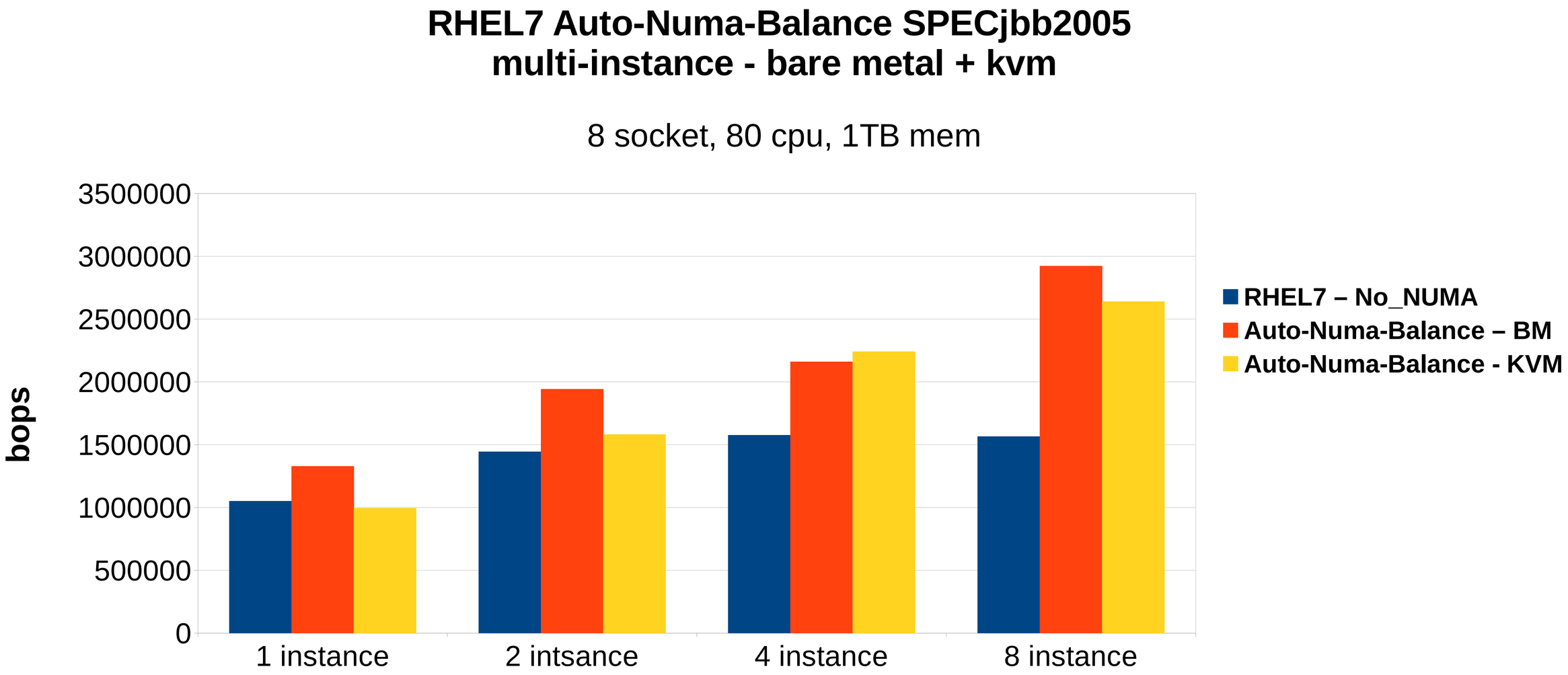
- Controls NUMA specific memory allocation policy
- To see current setting: cat /proc/sys/vm/zone_reclaim_mode
  - Turn ON: echo 1 > /proc/sys/vm/zone_reclaim_mode
    - Reclaim memory from local node rather than allocating from next node
  - Turn OFF: echo 0 > /proc/sys/vm/zone_reclaim_mode
    - Allocate from all nodes before reclaiming memory
- Default is set at boot time based on NUMA factor
- In Red Hat Enterprise Linux 6.6+ and 7+, the default is usually OFF – because this is better for many applications

zone_reclaim_mode (continued)

- Low-memory SPEC CPU loses huge performance with wrong zone reclaim mode setting! Several benchmarks off more than 40%.
- (BTW, Don't run SPEC CPU with low memory!!)



NUMA Performance – SPECjbb2005 on DL980 Westmere EX



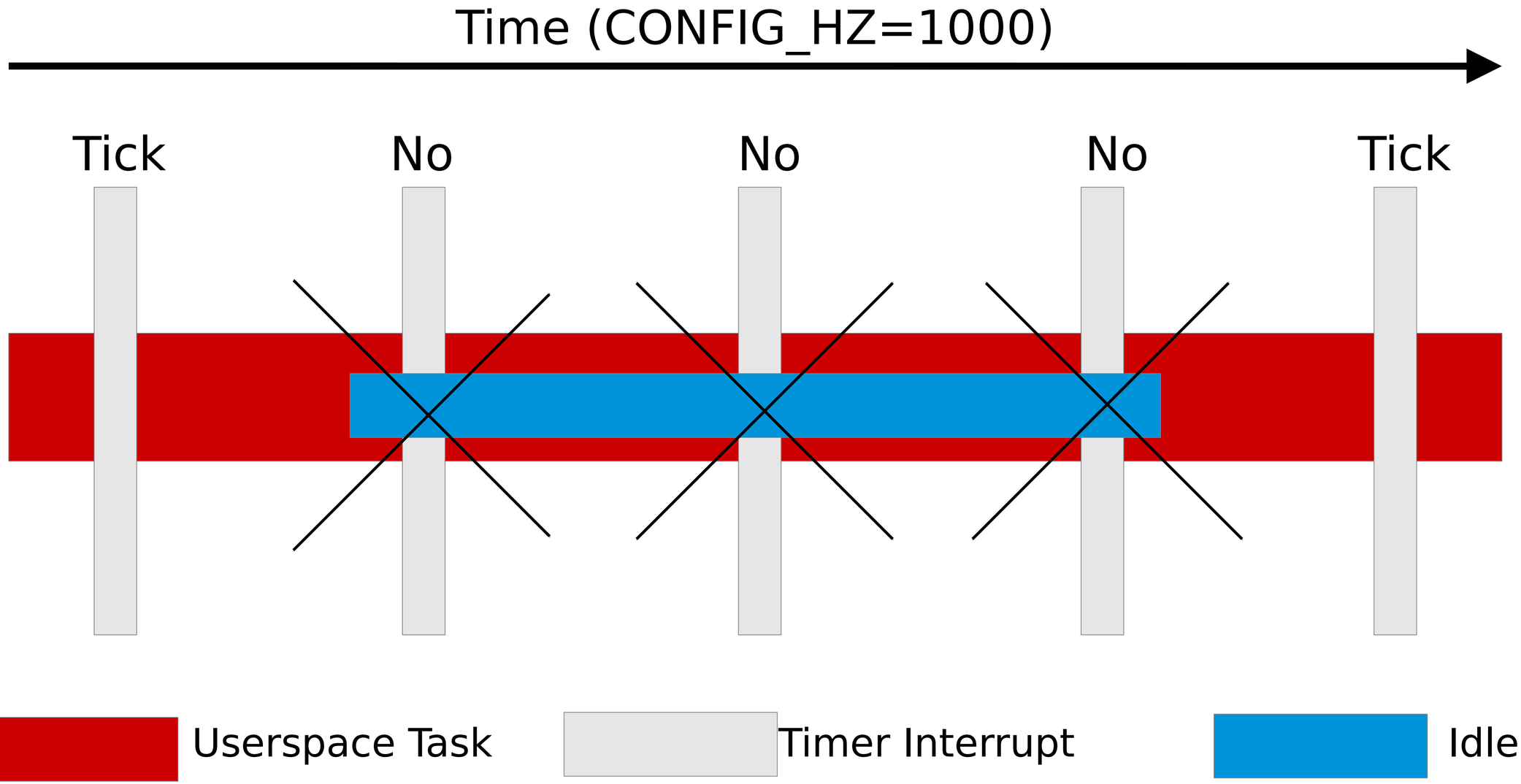
Low Latency

RHEL7/8 nohz_full

- Patchset Goal:
  - Stop interrupting userspace tasks
  - Move timekeeping to non-latency-sensitive cores
  -
- If nr_running=1, then scheduler/tick can avoid that core
- Default disabled...Opt-in via nohz_full cmdline option

- Kernel Tick:
- timekeeping (gettimeofday)
- Scheduler load balancing
- Memory statistics (vmstat)

RHEL6 and 7 Tickless



Performance Tools - Perf

perf list

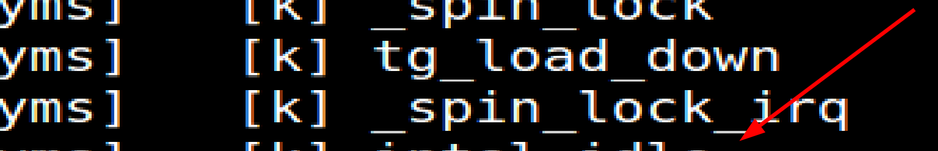
List counters/tracepoints available on your system

```
# perf list

List of pre-defined events (to be used in -e):
  cpu-cycles OR cycles                               [Hardware event]
  instructions                                       [Hardware event]
  cache-references                                   [Hardware event]
  cache-misses                                       [Hardware event]
  branch-instructions OR branches                    [Hardware event]
  branch-misses                                      [Hardware event]
  cpu-clock                                          [Software event]
  task-clock                                         [Software event]
  page-faults OR faults                              [Software event]
  context-switches OR cs                             [Software event]
  cpu-migrations OR migrations                       [Software event]
  minor-faults                                       [Software event]
  major-faults                                       [Software event]
```

perf top

System-wide 'top' view of busy functions

```
Samples: 10K of event 'cycles', Event count (approx.): 5973713325
 34.35%          httpd  [kernel.kallsyms]    [k] avtab_search_node
 12.70%          httpd  [kernel.kallsyms]    [k] _spin_lock
  8.61%          httpd  [kernel.kallsyms]    [k] tg_load_down
  7.42%          httpd  [kernel.kallsyms]    [k] _spin_lock_irq
  5.79%           init  [kernel.kallsyms]    [k] intel_idle
  3.92%          httpd  [kernel.kallsyms]    [k] _spin_lock_irqsave
  1.75%          httpd  [kernel.kallsyms]    [k] sidtab_search_core
  1.74%          httpd  [kernel.kallsyms]    [k] load_balance_fair
  1.18%          httpd  [kernel.kallsyms]    [k] tg_nop
  1.13%           init  [kernel.kallsyms]    [k] _spin_lock
```



perf record

- Record system-wide (-a)
  - perf record -a sleep 10
  - perf record -a // Hit ctrl-c when done.
- Or record a single command
  - perf record myapp.exe
- Or record an existing process (-p)
  - perf record -p <pid>
- Or add call-chain recording (-g)
  - perf record -g ls -rl /root
- *Or only record specific events (-e)*
  - *perf record -e branch-misses -p <pid>*

perf report

```
#  Overhead   Command        Shared Object
#  ........   .......   ....................   ..........................
#
    43.53%         dd   [kernel.kallsyms]   [k] __clear_user
                   |
                   --- __clear_user
                      |
                      |--99.75%-- read_zero.part.5
                      |          read_zero
                      |          vfs_read
                      |          sys_read
                      |          system_call_fastpath
                      |          __GI___libc_read
                       --0.25%-- [...]

     5.37%         dd   [kernel.kallsyms]   [k] do_blockdev_direct_IO
                   |
                   --- do_blockdev_direct_IO
                       __blockdev_direct_IO
                       xfs_vm_direct_IO
                       generic_file_direct_write
                       xfs_file_dio_aio_write
                       xfs_file_aio_write
                       do_sync_write
```

/dev/zero

oflag=direct

perf diff / sched

Compare 2 perf recordings

```
# perf diff

# Event 'cycles'
#
# Baseline    Delta             Shared Object                  Symbol
# ........  .......  ..............................  ......................
#
    12.88%  -12.27%  [kernel.kallsyms]               [k] __lookup_mnt
    11.97%  -11.17%  systemd                         [.] 0x0000000000064968
     4.32%   +6.43%  libdbus-1.so.3.7.4              [.] 0x0000000000029258
     4.06%   +4.72%  dbus-daemon                     [.] 0x000000000014a6e
     3.79%   -3.79%  libglib-2.0.so.0.3600.3         [.] 0x000000000088d6a
     3.72%   +0.25%  [kernel.kallsyms]               [k] seq_list_start
```

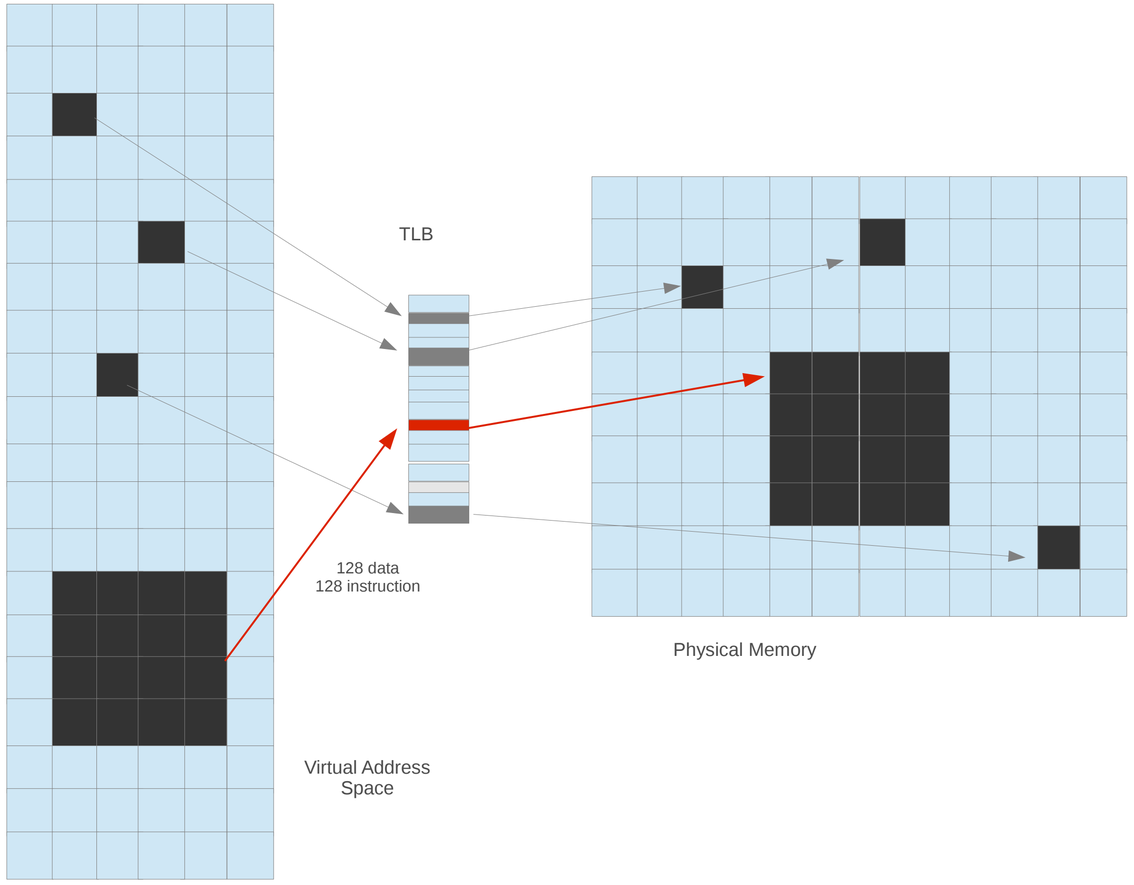
grep for something interesting, maybe to see what numabalance is doing ?

```
# perf list | grep sched: | grep numa
  sched:sched_move_numa                              [Tracepoint event]
  sched:sched_stick_numa                             [Tracepoint event]
  sched:sched_swap_numa                              [Tracepoint event]
```

Huge Pages

RHEL Hugepages/ VM Tuning

- Standard HugePages 2MB
  - Reserve/free via
    - /proc/sys/vm/nr_hugepages
    - /sys/devices/node/* /hugepages/*/nrhugepages
  - Used via hugetlbfs
- GB Hugepages 1GB
  - Reserved at boot time/no freeing
  - RHEL7 allows runtime allocation & freeing
  - Used via hugetlbfs
- Transparent HugePages 2MB
  - On by default via boot args or /sys
  - Used for anonymous memory



Transparent Hugepages

- Disable transparent_hugepages

```
#echo never > /sys/kernel/mm/transparent_hugepages=never

#time ./memory 15 0
real    0m12.434s
user    0m0.936s
sys     0m11.416s

 # cat /proc/meminfo
 MemTotal:       16331124 kB
 AnonHugePages:  0 kB
```

- Boot argument: transparent_hugepages=always (enabled by default)

```
#echo always > /sys/kernel/mm/redhat_transparent_hugepage/enabled

#time ./memory 15GB
real    0m7.024s
user    0m0.073s
sys     0m6.847s

#cat /proc/meminfo
MemTotal:       16331124 kB
AnonHugePages:  15590528 kB
```

SPEEDUP 12.4/7.0 = 1.77x, 56%

2MB standard Hugepages

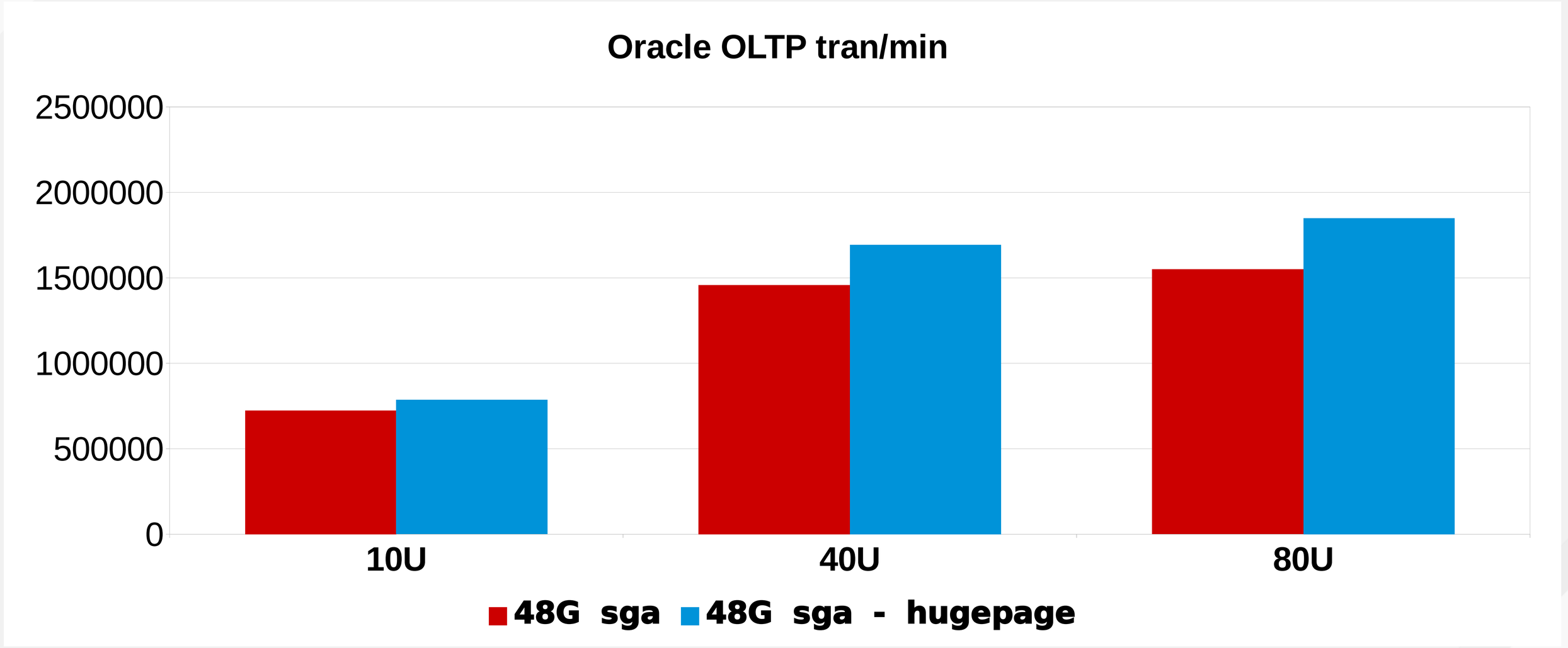
```
# echo 2000 > /proc/sys/vm/nr_hugepages
# cat /proc/meminfo
MemTotal:       16331124 kB
MemFree:        11788608 kB

HugePages_Total:    2000
HugePages_Free:     2000
HugePages_Rsvd:        0
HugePages_Surp:        0
Hugepagesize:       2048 kB

# ./hugeshm 1000

# cat /proc/meminfo
MemTotal:       16331124 kB
MemFree:        11788608 kB

HugePages_Total:    2000
HugePages_Free:     1000
HugePages_Rsvd:     1000
HugePages_Surp:        0
Hugepagesize:       2048 kB
```

2MB Hugepages - specific node allocation

```
# echo 0 > /proc/sys/vm/nr_hugepages
# cat /proc/meminfo | grep HugePages_Free
HugePages_Free:     0

# echo 1000 > /proc/sys/vm/nr_hugepages
# cat /proc/meminfo | grep HugePages_Free
HugePages_Free:     1000
# cat /sys/devices/system/node/node*/hugepages/hugepages-2048kB/nr_hugepages
500
500

# echo 0 > /proc/sys/vm/nr_hugepages
# echo 1000 > /sys/devices/system/node/node0/hugepages/hugepages-2048kB/nr_hugepages
# cat /proc/meminfo | grep HugePages_Free
HugePages_Free:     1000
# cat /sys/devices/system/node/node*/hugepages/hugepages-2048kB/nr_hugepages
1000
0
```

Database Performance OLTP (Higher = Better)

huge pages on Bare Metal



The effect of hugepages are more pronounced as system drive to saturaton

Boot-time allocated 1GB Hugepages

Boot arguments

- default_hugepagesz=1G, hugepagesz=1G, hugepages=8

```
# cat /proc/meminfo | grep HugePages
HugePages_Total:       8
HugePages_Free:        8
HugePages_Rsvd:        0
HugePages_Surp:        0
```

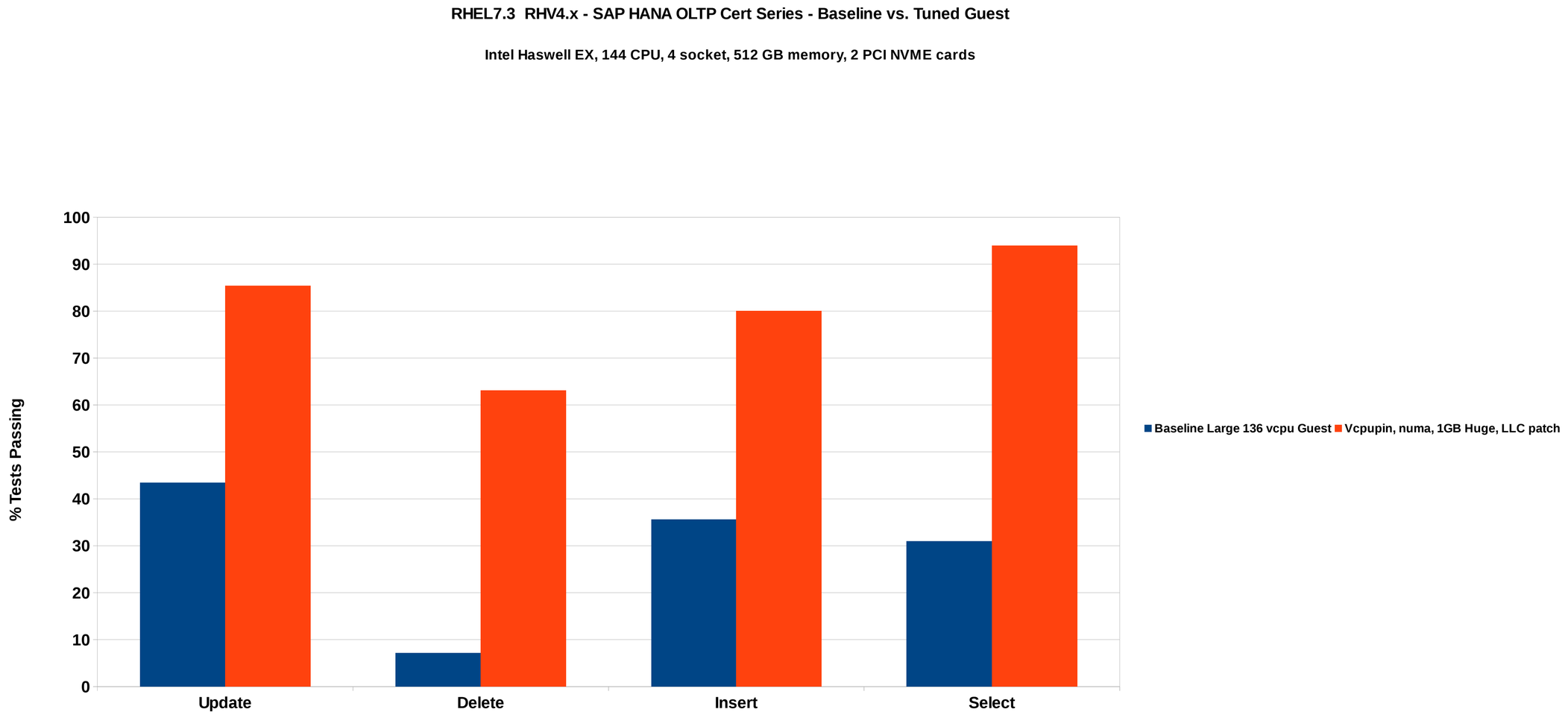
```
#mount -t hugetlbfs none /mnt
# ./mmapwrite /mnt/junk 33
writing 2097152 pages of random junk to file /mnt/junk
wrote 8589934592 bytes to file /mnt/junk
```

```
# cat /proc/meminfo | grep HugePages
HugePages_Total:       8
HugePages_Free:        0
HugePages_Rsvd:        0
HugePages_Surp:        0
```

Dynamic per-node allocation/deallocation of 1GB Hugepages

```
# cat /sys/devices/system/node/node*/hugepages/hugepages-1048576kB/nr_hugepages
0
0

# echo 8 >  /sys/devices/system/node/node0/hugepages/hugepages-1048576kB/nr_hugepages
# cat /proc/meminfo | grep HugePages_Free
HugePages_Free:     8
# cat /sys/devices/system/node/node*/hugepages/hugepages-1048576kB/nr_hugepages
8
0

# echo 0 >  /sys/devices/system/node/node0/hugepages/hugepages-1048576kB/nr_hugepages
# cat /proc/meminfo | grep HugePages_Free
HugePages_Free:     0
# cat /sys/devices/system/node/node*/hugepages/hugepages-1048576kB/nr_hugepages
0
0
```

SAP Performance w/ Hana



CGroups

Cgroup default mount points

RHEL6

```
# cat /etc/cgconfig.conf

mount {
    cpuset= /cgroup/cpuset;
    cpu  = /cgroup/cpu;
    cpuacct  = /cgroup/cpuacct;
    memory  = /cgroup/memory;
    devices  = /cgroup/devices;
    freezer   = /cgroup/freezer;
    net_cls   = /cgroup/net_cls;
    blkio    = /cgroup/blkio;
 }
```

RHEL7

/sys/fs/cgroup/

```
# ls -l /cgroup
drwxr-xr-x 2 root root 0 Jun 21 13:33 blkio
drwxr-xr-x 3 root root 0 Jun 21 13:33 cpu
drwxr-xr-x 3 root root 0 Jun 21 13:33 cpuacct
drwxr-xr-x 3 root root 0 Jun 21 13:33 cpuset
drwxr-xr-x 3 root root 0 Jun 21 13:33 devices
drwxr-xr-x 3 root root 0 Jun 21 13:33 freezer
drwxr-xr-x 3 root root 0 Jun 21 13:33 memory
drwxr-xr-x 2 root root 0 Jun 21 13:33 net_cls
```

RHEL7

```
#ls -l /sys/fs/cgroup/
drwxr-xr-x. 2 root root  0 Mar 20 16:40 blkio
drwxr-xr-x. 2 root root  0 Mar 20 16:40 cpu,cpuacct
drwxr-xr-x. 2 root root  0 Mar 20 16:40 cpuset
drwxr-xr-x. 2 root root  0 Mar 20 16:40 devices
drwxr-xr-x. 2 root root  0 Mar 20 16:40 freezer
drwxr-xr-x. 2 root root  0 Mar 20 16:40 hugetlb
drwxr-xr-x. 3 root root  0 Mar 20 16:40 memory
drwxr-xr-x. 2 root root  0 Mar 20 16:40 net_cls
drwxr-xr-x. 2 root root  0 Mar 20 16:40 perf_event
drwxr-xr-x. 4 root root  0 Mar 20 16:40 systemd
```

Cgroup how-to

Create a 2GB/4CPU subset of a 16GB/8CPU system

```
# numactl --hardware
# mount -t cgroup xxx /cgroups
# mkdir -p /cgroups/test
# cd /cgroups/test
# echo 0 > cpuset.mems
# echo 0-3 > cpuset.cpus
# echo 2G > memory.limit_in_bytes
# echo $$ > tasks
```

cgroups

```
# echo 0-3 > cpuset.cpus
# runmany 20MB 110procs &
# top -d 5
top - 12:24:13 up  1:36,  4 users,  load average: 22.70, 5.32, 1.79
Tasks: 315 total,  93 running, 222 sleeping,   0 stopped,   0 zombie
Cpu0  : 100.0%us,  0.0%sy,  0.0%ni,  0.0%id,  0.0%wa,  0.0%hi,  0.0%si,  0.0%st
Cpu1  : 100.0%us,  0.0%sy,  0.0%ni,  0.0%id,  0.0%wa,  0.0%hi,  0.0%si,  0.0%st
Cpu2  : 100.0%us,  0.0%sy,  0.0%ni,  0.0%id,  0.0%wa,  0.0%hi,  0.0%si,  0.0%st
Cpu3  : 100.0%us,  0.0%sy,  0.0%ni,  0.0%id,  0.0%wa,  0.0%hi,  0.0%si,  0.0%st
Cpu4  :  0.4%us,  0.6%sy,  0.0%ni, 98.8%id,  0.0%wa,  0.0%hi,  0.2%si,  0.0%st
Cpu5  :  0.4%us,  0.0%sy,  0.0%ni, 99.2%id,  0.0%wa,  0.0%hi,  0.4%si,  0.0%st
Cpu6  :  0.0%us,  0.0%sy,  0.0%ni,100.0%id,  0.0%wa,  0.0%hi,  0.0%si,  0.0%st
Cpu7  :  0.0%us,  0.0%sy,  0.0%ni, 99.8%id,  0.0%wa,  0.0%hi,  0.2%si,  0.0%st
```

Correct NUMA bindings

```
# echo 0 > cpuset.mems
# echo 0-3 > cpuset.cpus
# numastat
                           node0       node1
numa_hit                 1648772      438778
numa_miss                  23459     2134520
local_node               1648648      423162
other_node                 23583     2150136

# /common/lwoodman/code/memory 4G
faulting took 1.616062s
touching took 0.364937s

# numastat
                           node0       node1
numa_hit                 2700423      439550
numa_miss                  23459     2134520
local_node               2700299      423934
other_node                 23583     2150136
```

Incorrect NUMA bindings

```
# echo 1 > cpuset.mems
# echo 0-3 > cpuset.cpus
# numastat
                           node0       node1
numa_hit                 1623318      434106
numa_miss                  23459     1082458
local_node               1623194      418490
other_node                 23583     1098074

# /common/lwoodman/code/memory 4G
faulting took 1.976627s
touching took 0.454322s

# numastat
                           node0       node1
numa_hit                 1623341      434147
numa_miss                  23459     2133738
local_node               1623217      418531
other_node                 23583     2149354
```

cpu.shares default

 # cat cpu.shares
1024

top - 10:04:19 up 13 days, 17:24, 11 users, load average: 8.41, 8.31, 6.17

PID	USER	PR	NI	VIRT	RES	SHR	S	%CPU	%MEM	TIME
20104	root	20	0	4160	360	284	R	99.4	0.0	12:35.83 useless
20103	root	20	0	4160	356	284	R	91.4	0.0	12:34.78 useless
20105	root	20	0	4160	360	284	R	90.4	0.0	12:33.08 useless
20106	root	20	0	4160	360	284	R	88.4	0.0	12:32.81 useless
20102	root	20	0	4160	360	284	R	86.4	0.0	12:35.29 useless
20107	root	20	0	4160	356	284	R	85.4	0.0	12:33.51 useless
20110	root	20	0	4160	360	284	R	84.8	0.0	12:31.87 useless
20108	root	20	0	4160	360	284	R	82.1	0.0	12:30.55 useless
20410	**root**	**20**	**0**	**4160**	**360**	**284**	**R**	**91.4**	**0.0**	**0:18.51 useful**

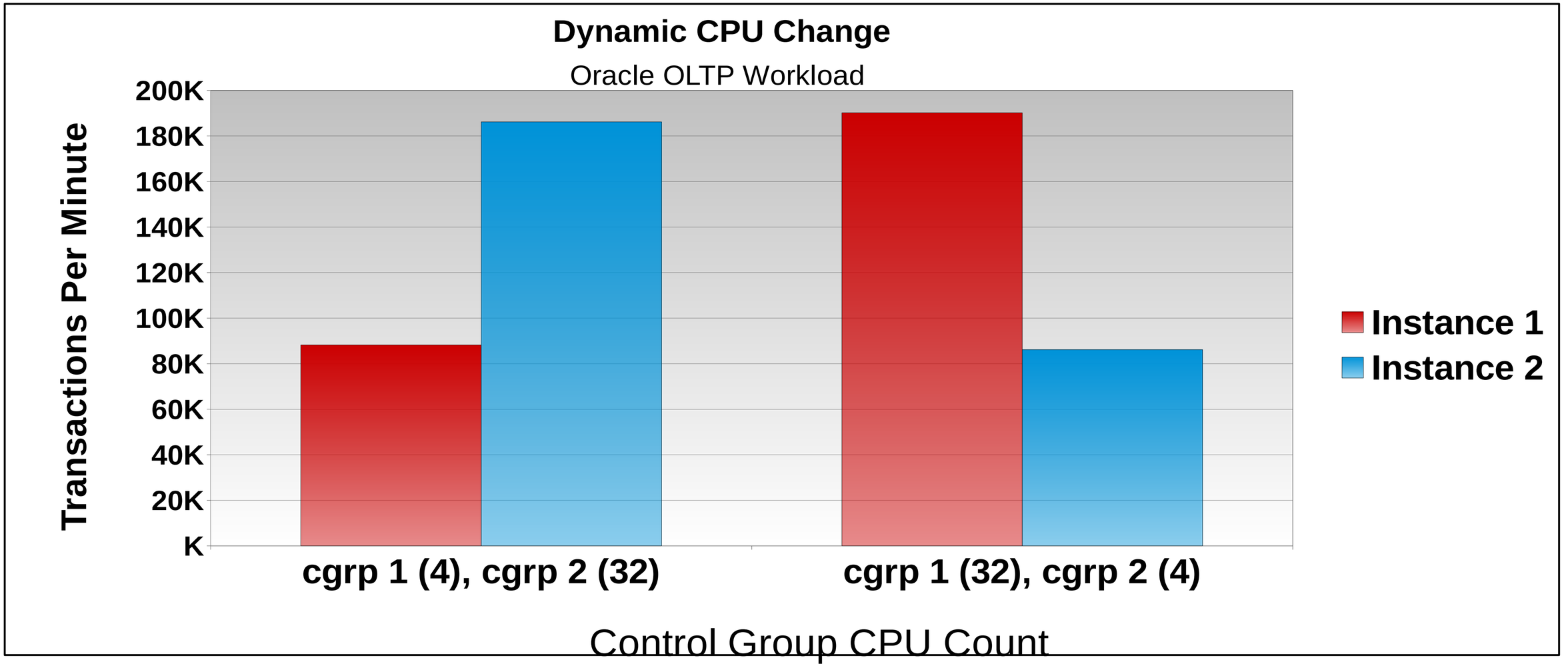
cpu.shares throttled

 # echo 10 > cpu.shares

top - 09:51:58 up 13 days, 17:11, 11 users, load average: 7.14, 5.78, 3.09

PID	USER	PR	NI	VIRT	RES	SHR	S	%CPU	%MEM	TIME
20102	root	20	0	4160	360	284	R	100.0	0.0	0:17.45 useless
20103	root	20	0	4160	356	284	R	100.0	0.0	0:17.03 useless
20107	root	20	0	4160	356	284	R	100.0	0.0	0:15.57 useless
20104	root	20	0	4160	360	284	R	99.8	0.0	0:16.66 useless
20105	root	20	0	4160	360	284	R	99.8	0.0	0:16.31 useless
20108	root	20	0	4160	360	284	R	99.8	0.0	0:15.19 useless
20110	root	20	0	4160	360	284	R	99.4	0.0	0:14.74 useless
20106	root	20	0	4160	360	284	R	99.1	0.0	0:15.87 useless
20111	**root**	**20**	**0**	**4160**	**356**	**284**	**R**	**1.0**	**0.0**	**0:00.08 useful**

C-group Dynamic resource control



cpu.cfs_quota_us unlimited

 # cat cpu.cfs_period_us
100000
 # cat cpu.cfs_quota_us
-1

top - 10:11:33 up 13 days, 17:31, 11 users, load average: 6.21, 7.78, 6.80

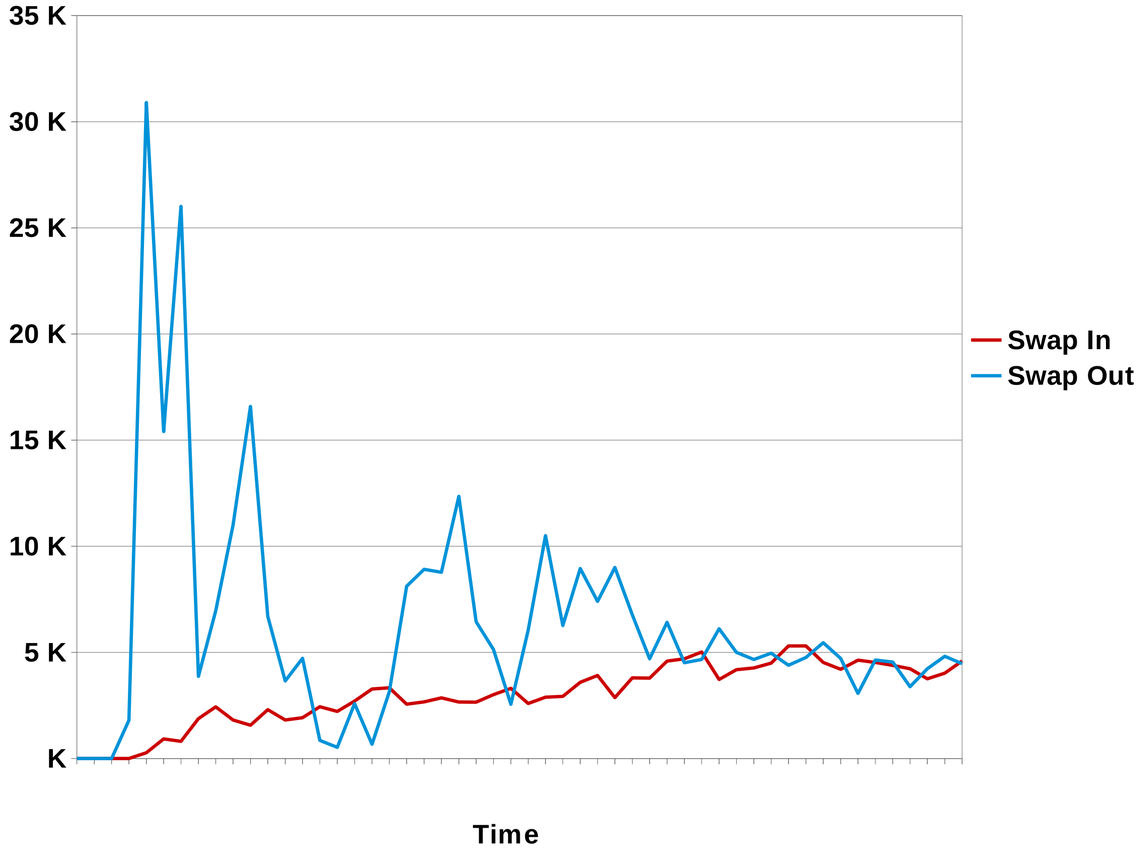
PID	USER	PR	NI	VIRT	RES	SHR	S	%CPU	%MEM	TIME+	COMMAND
20614	root	20	0	4160	360	284	R	**100.0**	0.0	0:30.77	useful

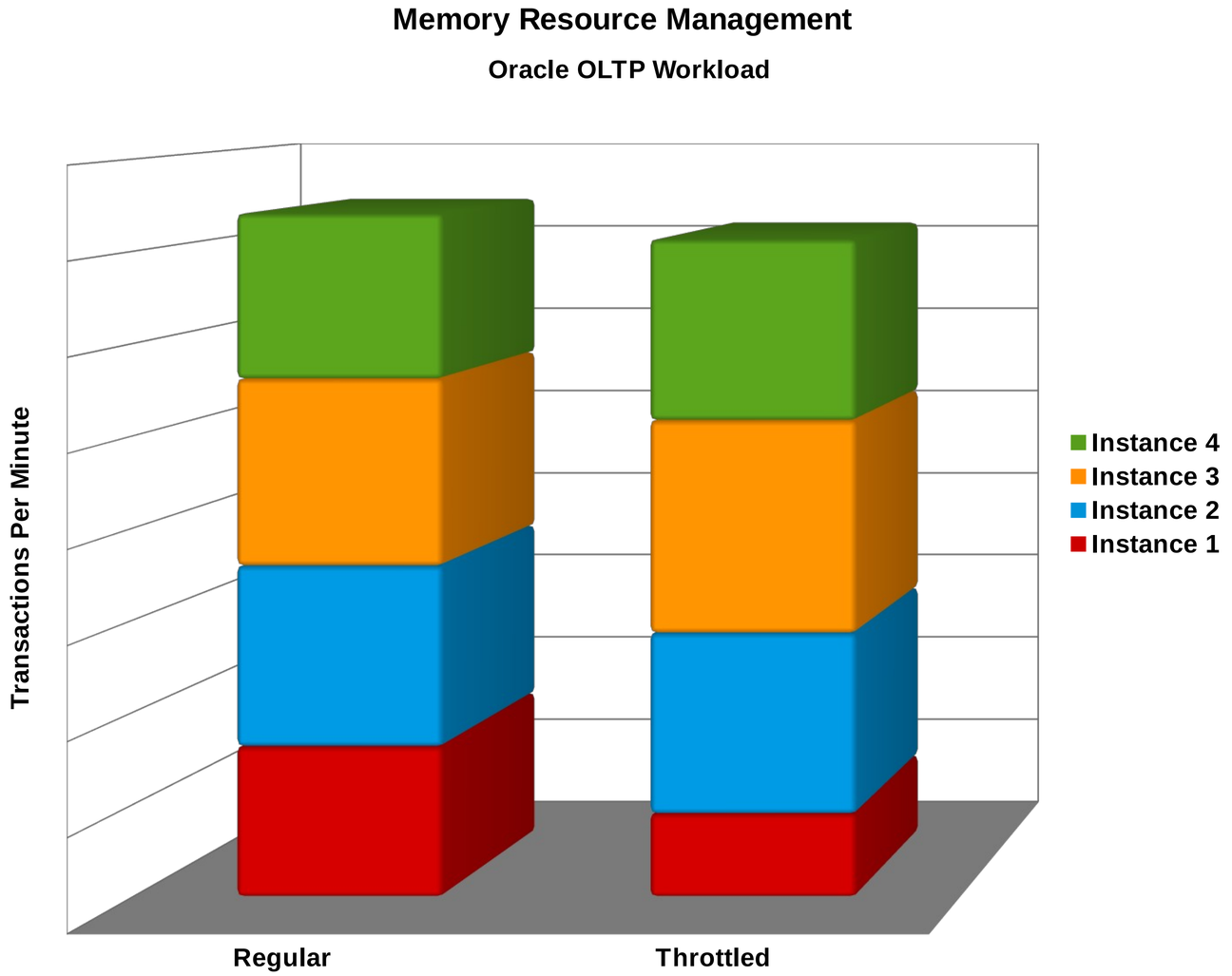
 # echo 1000 > cpu.cfs_quota_us

top - 10:16:55 up 13 days, 17:36, 11 users, load average: 0.07, 2.87, 4.93

PID	USER	PR	NI	VIRT	RES	SHR	S	%CPU	%MEM	TIME+	COMMAND
20645	root	20	0	4160	360	284	R	**1.0**	0.0	0:01.54	useful

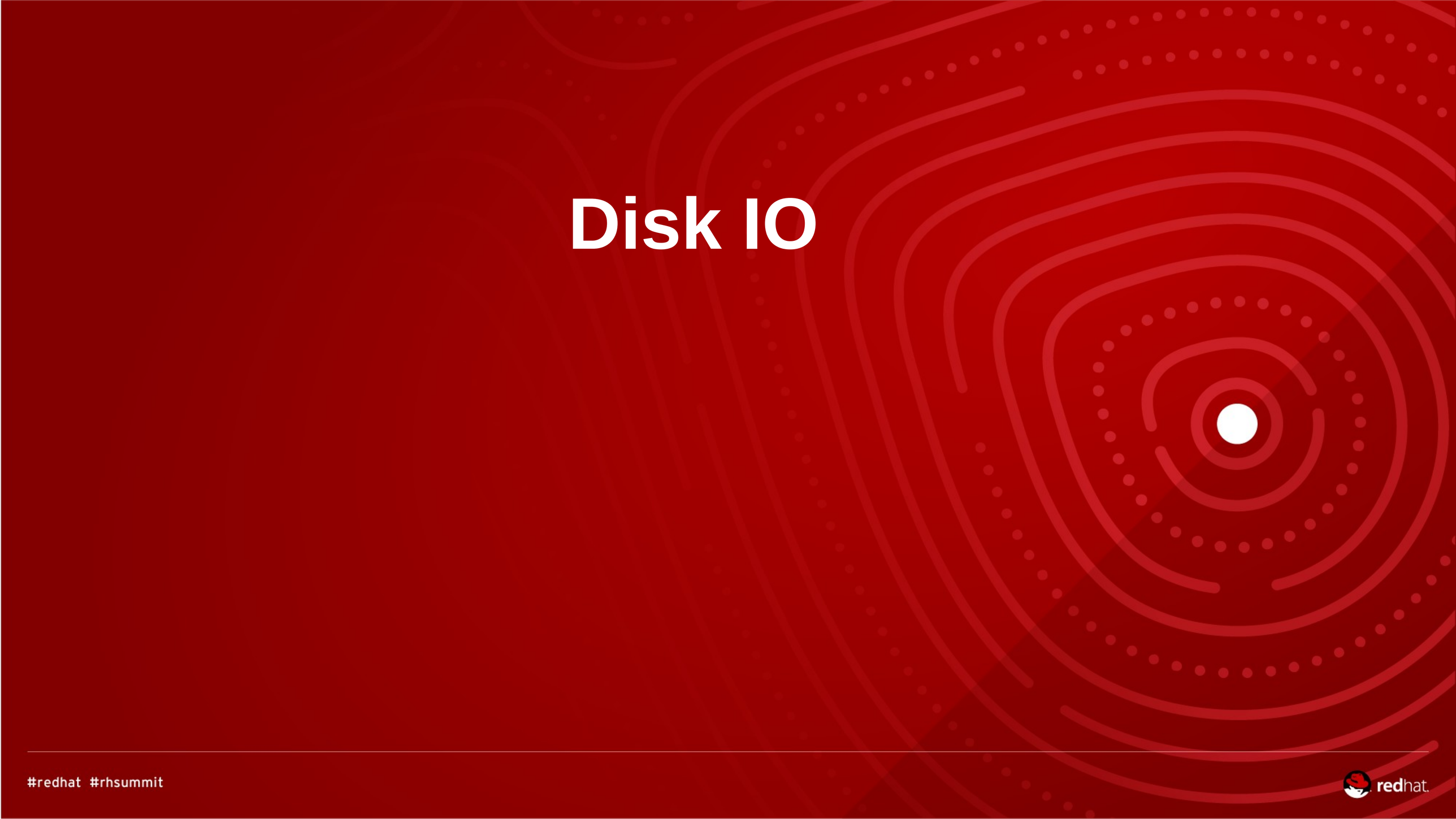
Cgroup – Application Isolation





Even though the “RED” application does not have resources and starts swapping,
The other applications are not affected.

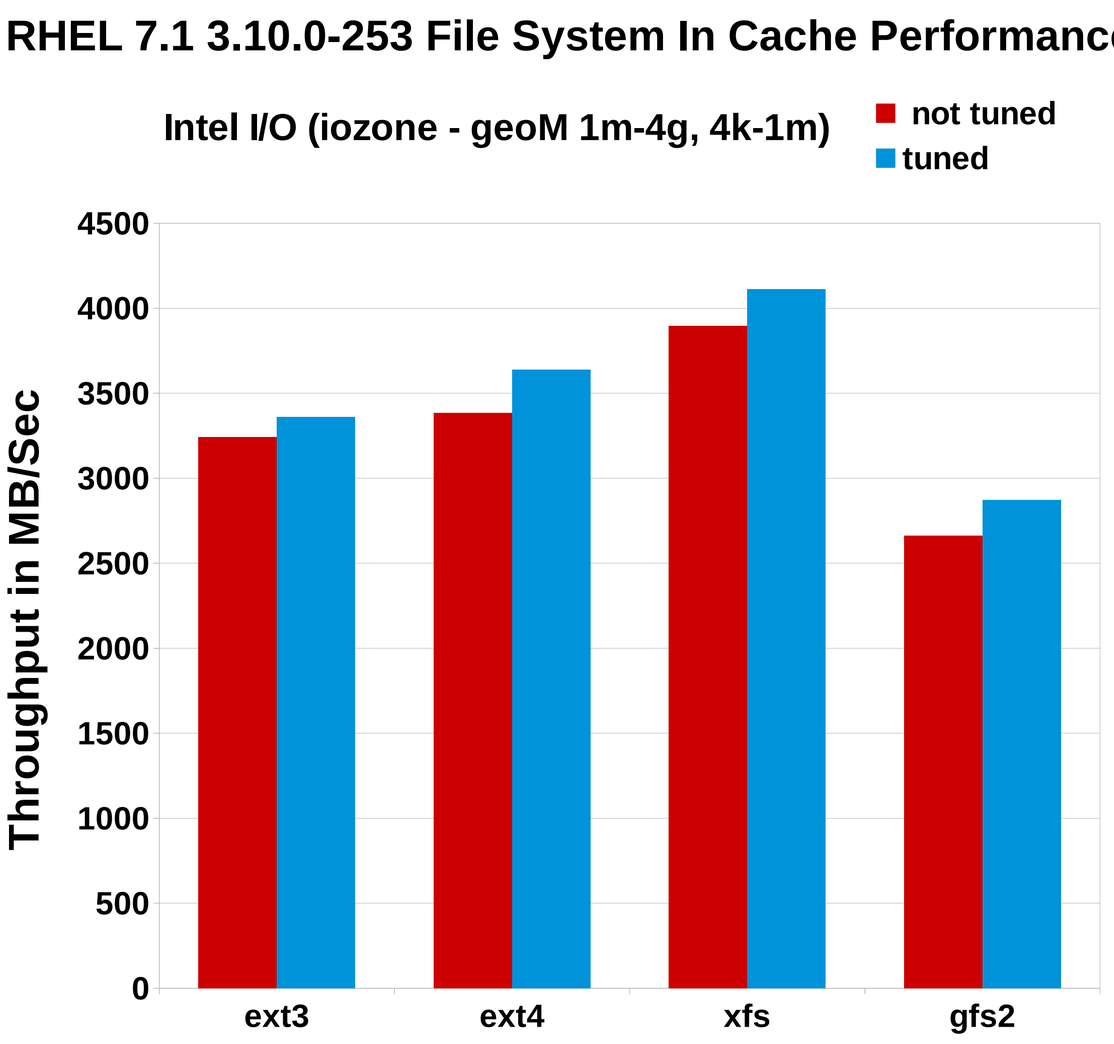
Disk IO

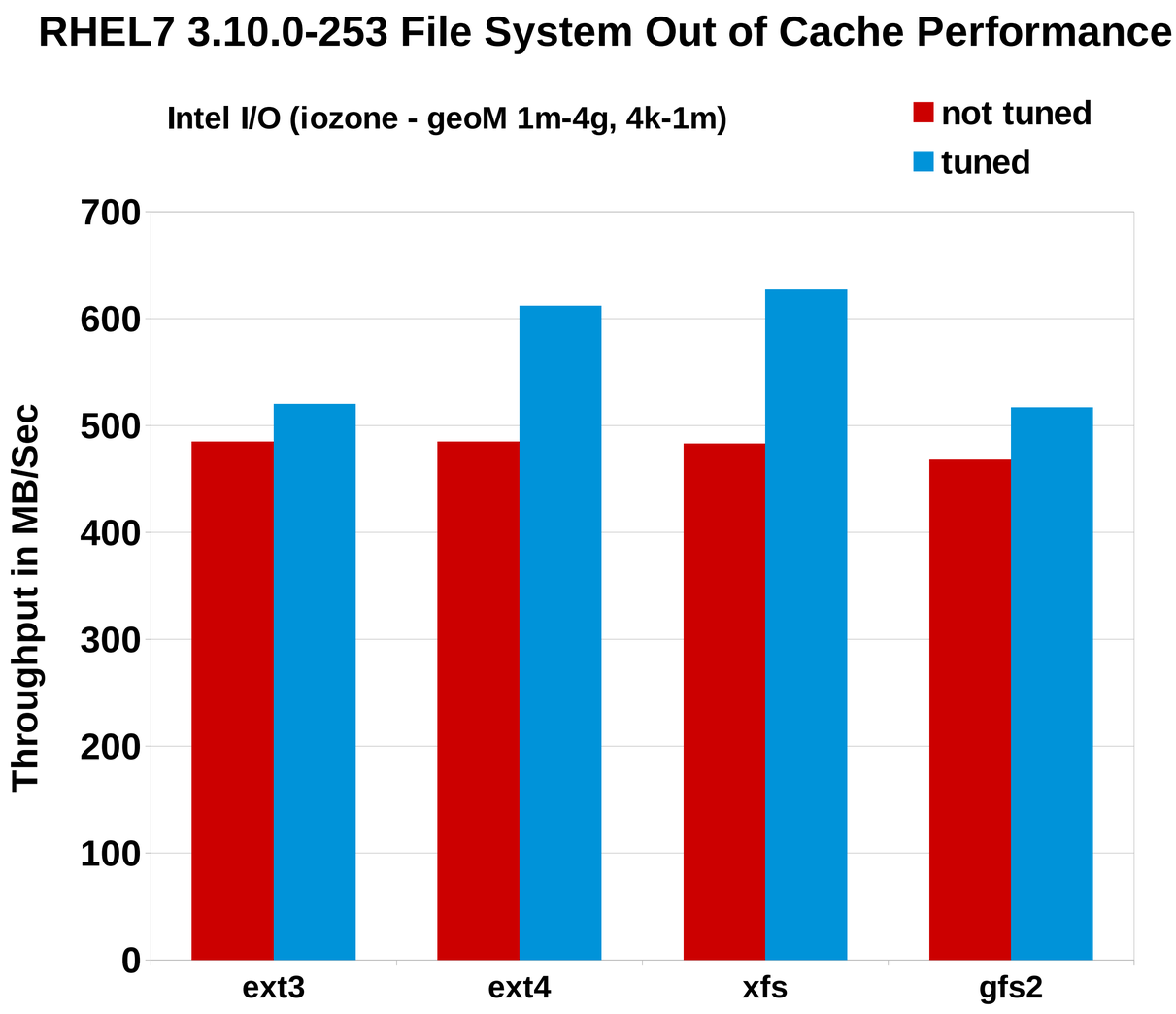


I/O Tuning – Understanding I/O Elevators

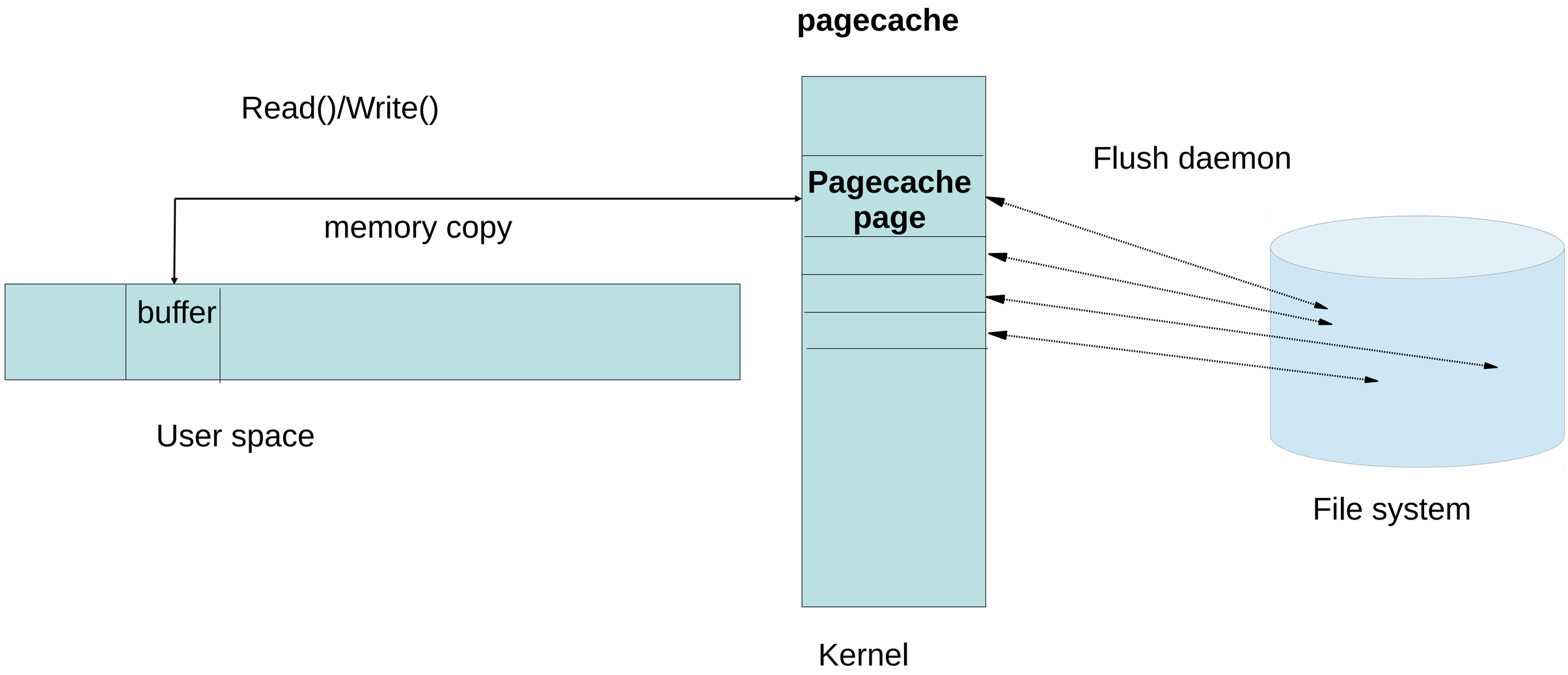
- Deadline – new RHEL7 default for all profiles
  - Two queues per device, one for read and one for writes
  - I/Os dispatched based on time spent in queue
- CFQ – used for system disks off SATA/SAS controllers
  - Per process queue
  - Each process queue gets fixed time slice (based on process priority)
- NOOP – used for high-end SSDs (Fusion IO etc)
  - FIFO
  - Simple I/O Merging
  - Lowest CPU Cost

Iozone Performance effect of “tuned” EXT4/XFS/GFS





Per file system flush daemon



Writeback and readahed Tunables

- **Writeback Parameters**
  - /proc/sys/vm/dirty_background_ratio
  - /proc/sys/vm/dirty_ratio
- **Readahead parameters**
  - /sys/block/<bdev>/queue/read_ahead_kb

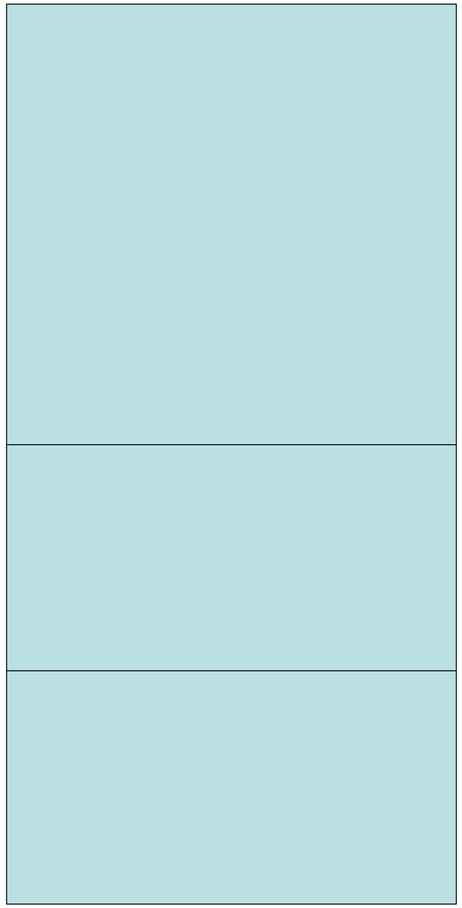
dirty_background_ratio/dirty_background_bytes

- Controls when dirty pagecache memory starts getting written back to storage.
- Default is 10%
- Lower
  - flushing starts earlier
  - less dirty pagecache and smaller IO streams
- Higher
  - flushing starts later
  - more dirty pagecache and larger IO streams
- **dirty_background_bytes over-rides when you want < 1%**

dirty_ratio/dirty_bytes

- Controls max dirty pagecache memory.
- Default is 20%
- Lower
  - Limits dirty pagecache earlier
  - less dirty pagecache and smaller IO streams
  - Lower latencies but lower throughput
- Higher
  - Limits dirty pagecache later
  - more dirty pagecache and larger IO streams
  - Higher throughput but higher latencies
- **dirty_bytes over-rides when you want < 1%**

dirty_ratio and dirty_background_ratio



100% of pagecache RAM dirty

flushd and write()'ng processes write dirty buffers

dirty_ratio(20% of RAM dirty) – processes start synchronous writes

flushd writes dirty buffers in background

dirty_background_ratio(10% of RAM dirty) – wakeup flushd

do_nothing

0% of pagecache RAM dirty

RHEL8 Kernel Features

Some RHEL8 kernel features

- PML5 – 5 level pagetable support for x86_64
  - 55-bits/32PB user virtual address space
  - 52-bits/4PB physical memory
- Cgroup V2
  - More closely parallels /proc/sys/...
- Memory mode NVDimm support
  - Faster/smaller DRAM caches larger/slower NVDIMMs
- THP/2MB page support for pagecache
  - Larger page sized for cached/mmap()'d files
- KASLR
  - Kernel address space is randomized at boot

Red Hat Performance Whitepapers

- Performance Tuning of Satellite 6.1 and Capsules https://access.redhat.com/articles/2356131
- OpenShift v3 Scaling, Performance and Capacity Planning https://access.redhat.com/articles/2191731
- Performance and Scaling your RHEL OSP 7 Cloud https://access.redhat.com/articles/2165131
- RHEL OSP 7: Cinder Volume Performance on RHCS 1.3 (Ceph) https://access.redhat.com/articles/2061493
- RHGS 3.1 Performance Brief (Gluster) https://access.redhat.com/articles/1982243

- Red Hat Performance Tuning Guide
- Red Hat Low Latency Tuning Guide
- Red Hat Virtualization Tuning Guide
- RHEL Blog / Developer Blog