RED HAT SUMMIT

BOSTON, MA
JUNE 23-26, 2015

Performance Analysis and Tuning – Part 1

D. John Shakshober (Shak) - Sr Consulting Eng / Director Performance Engineering

Larry Woodman - Senior Consulting Engineer / Kernel VM

Jeremy Eder - Principal Performance Engineering

Bill Gray - Principal Performance Engineer

Agenda: Performance Analysis Tuning Part I

- **Part I**
  - **RHEL Evolution 5->6->7 – out-of-the-box tuned for Clouds - “tuned”**
  - **NonUniform Memory Access (NUMA)**
  - **Process Scheduler, Numa awareness, tunables**
  - **Transparent Hugepages, Static Hugepages 4K/2MB/1GB**
  - **Cgroups – the basis of Linux Containers / Atomic**
- Part II
  - RHEL Atomic / Host, Tuning Optimized for Enterprise
  - Network Performance and Latency-performance
  - Disk and Filesystem IO - Throughput-performance
  - System Performance/Tools – perf, tuna, systemtap, performance-co-pilot
- **Performance Birds of the Feather (BoF) Wed 6-8 Room 206**

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

RH Cloud Suites

RHEV – out-of-the-box

virt-host/guest

RHEL OSP – blueprints

Tuned, Numa pining
NIC - jumbo SR-IOV

RHEL Atomic Host/Atomic Enterprise

RH OpenShift v3

Cloud Forms

RHEL Performance Workload Coverage

(bare metal, KVM virt w/ RHEV and/or OSP, LXC Kube/OSEand Industry Standard Benchmarks)

Benchmarks – code path coverage

- CPU – linpack, lmbench
- Memory – lmbench, McCalpin STREAM
- Disk IO – iozone, fio – SCSI, FC, iSCSI
- Filesystems – iozone, ext3/4, xfs, gfs2, gluster
- Networks – netperf – 10/40Gbit, Infiniband/RoCE, Bypass
- Bare Metal, RHEL6/7 KVM
- White box AMD/Intel, with our OEM partners

Application Performance

- Linpack MPI, HPC workloads
- AIM 7 – shared, filesystem, db, compute
- Database: DB2, Oracle 11/12, Sybase 15.x , MySQL, MariaDB, Postgrs, MongoDB
- OLTP – TPC-C, TPC-VMS
- DSS – TPC-H/xDS
- Big Data – TPCx-HS, Bigbench
- SPEC cpu, jbb, sfs, virt, cloud
- SAP – SLCS, SD
- STAC = FSI (STAC-N)
- SAS mixed Analytic, SAS grid (gfs2)

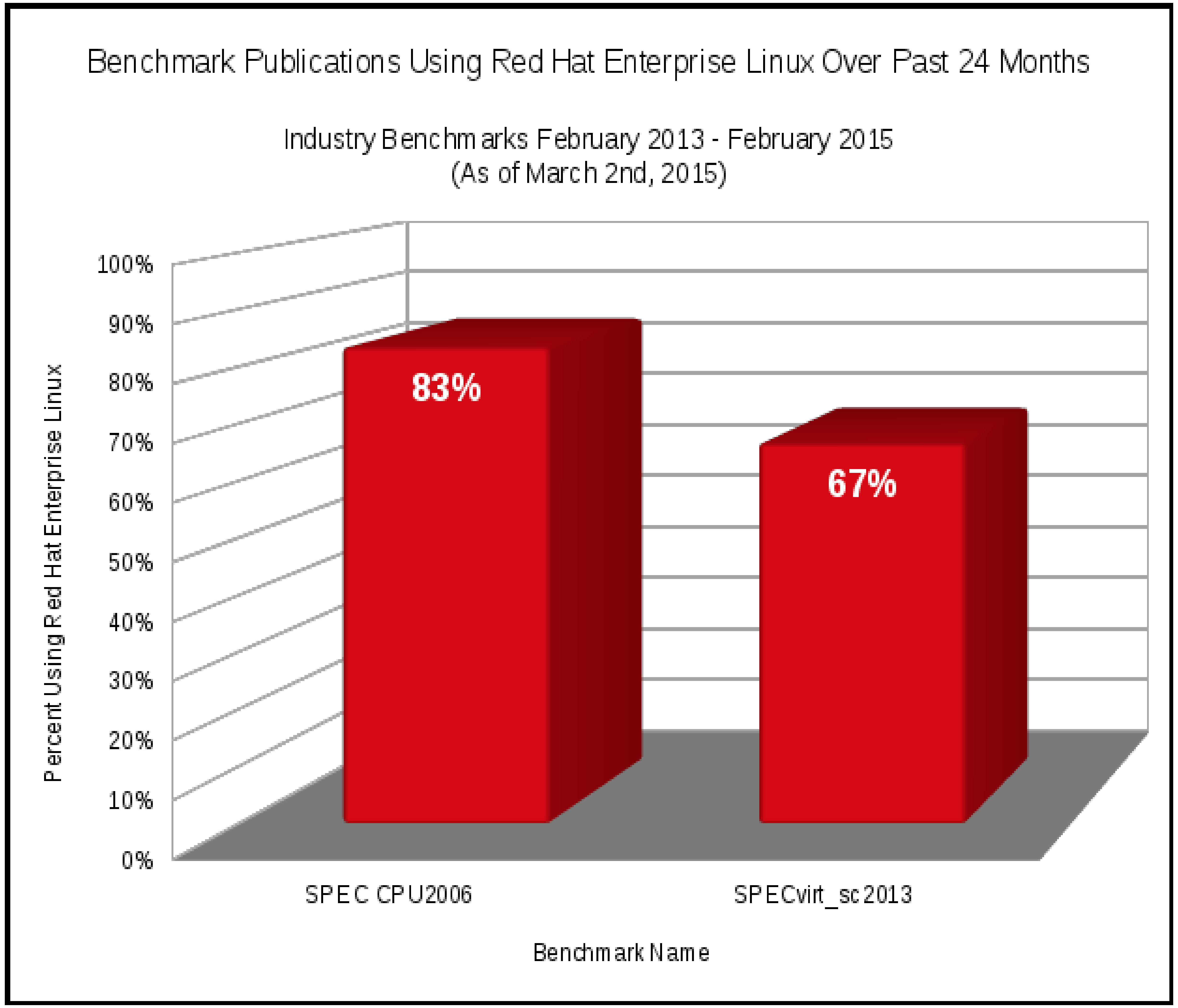
Red Hat / Intel Haswell EX Top Benchmark Results

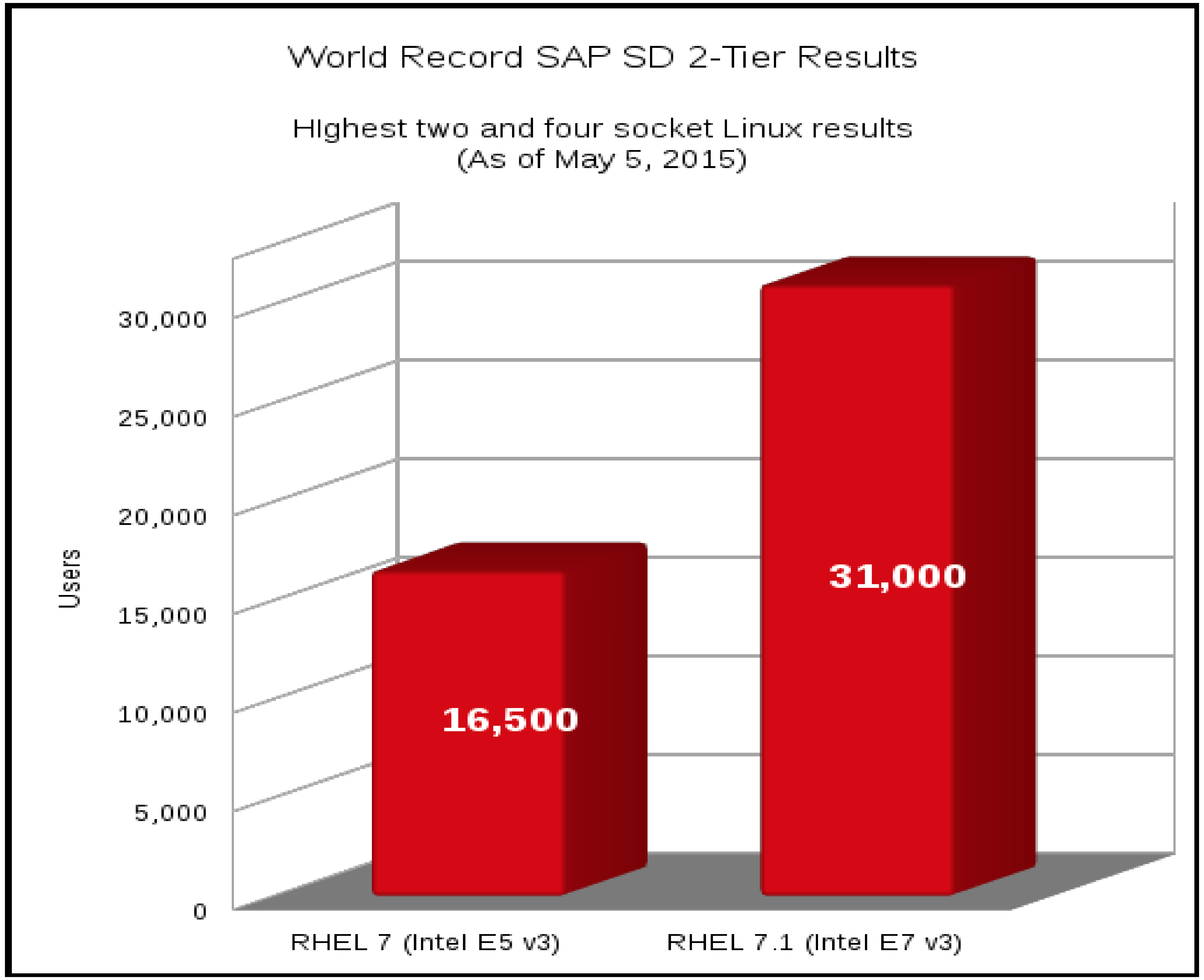
Source: http://www.intel.com/content/www/us/en/benchmarks/server/xeon-e7-v3/xeon-e7-v3-world-record.html

Significance	OEM Platform	Benchmark	OS
4-socket world record (Linux)	Dell PowerEdge R930 + HP ProLiant DL580 G9	SAP Sales & Distribution (2-Tier) on Linux	RHEL 7.1
Overall world record	HP ProLiant DL580 G9	SPECfp_base2006	RHEL7.1
2-socket world record	Fujitsu PRIMEQUEST 2800E2	SPECint_rate_base2006	RHEL 7.1
8-socket world record	Fujitsu PRIMEQUEST 2800E2	SPECint_rate_base2006	RHEL 6.6
8-socket world record (x86)	Huawei FusionServer RH8100 V3	SPECfp_rate_base2006	RHEL 7
4-socket record	Lenovo System x3850 X6	SPECvirt_sc2013	RHEL6.6

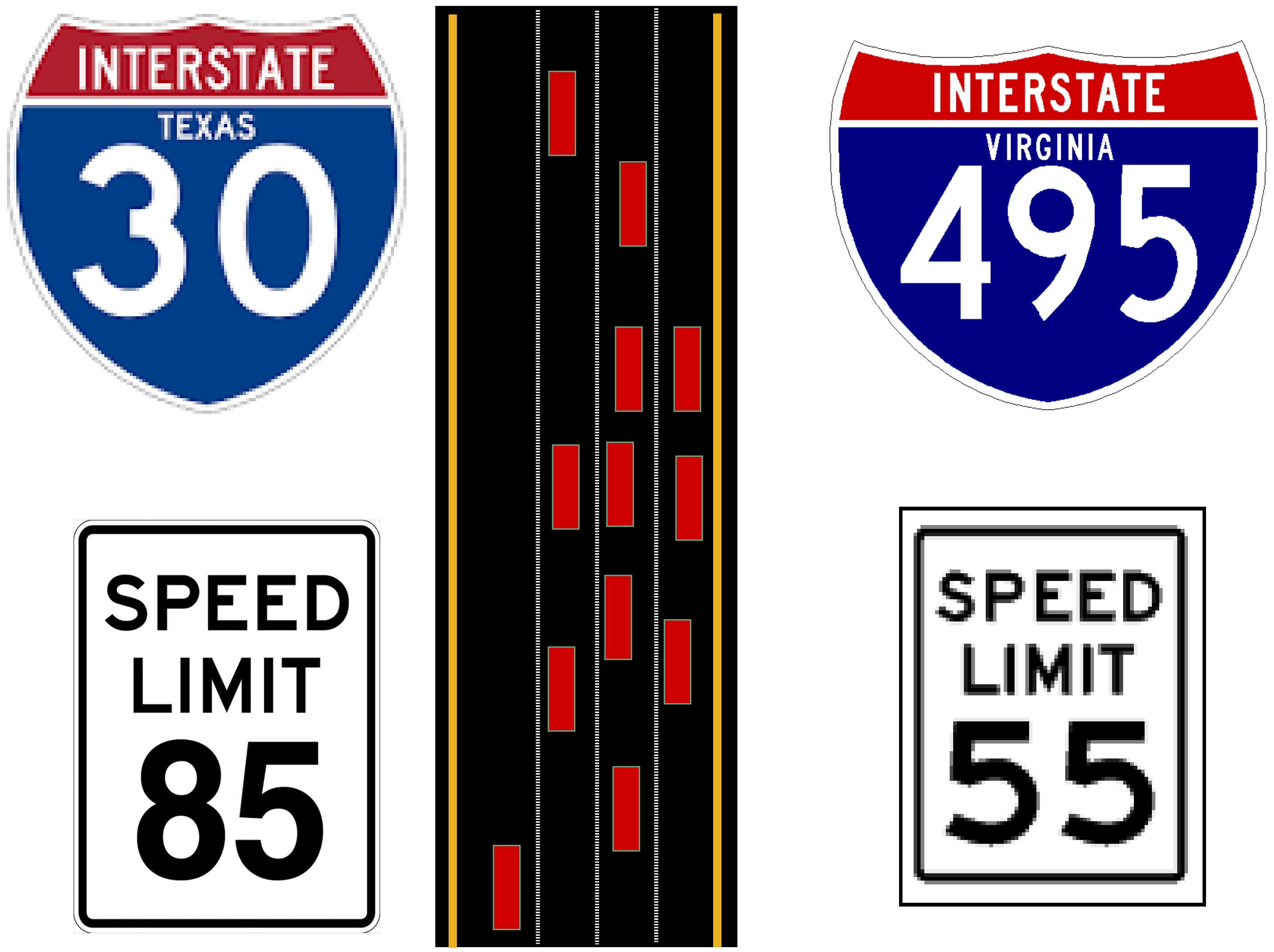
RHEL / Intel Benchmark Haswell EX

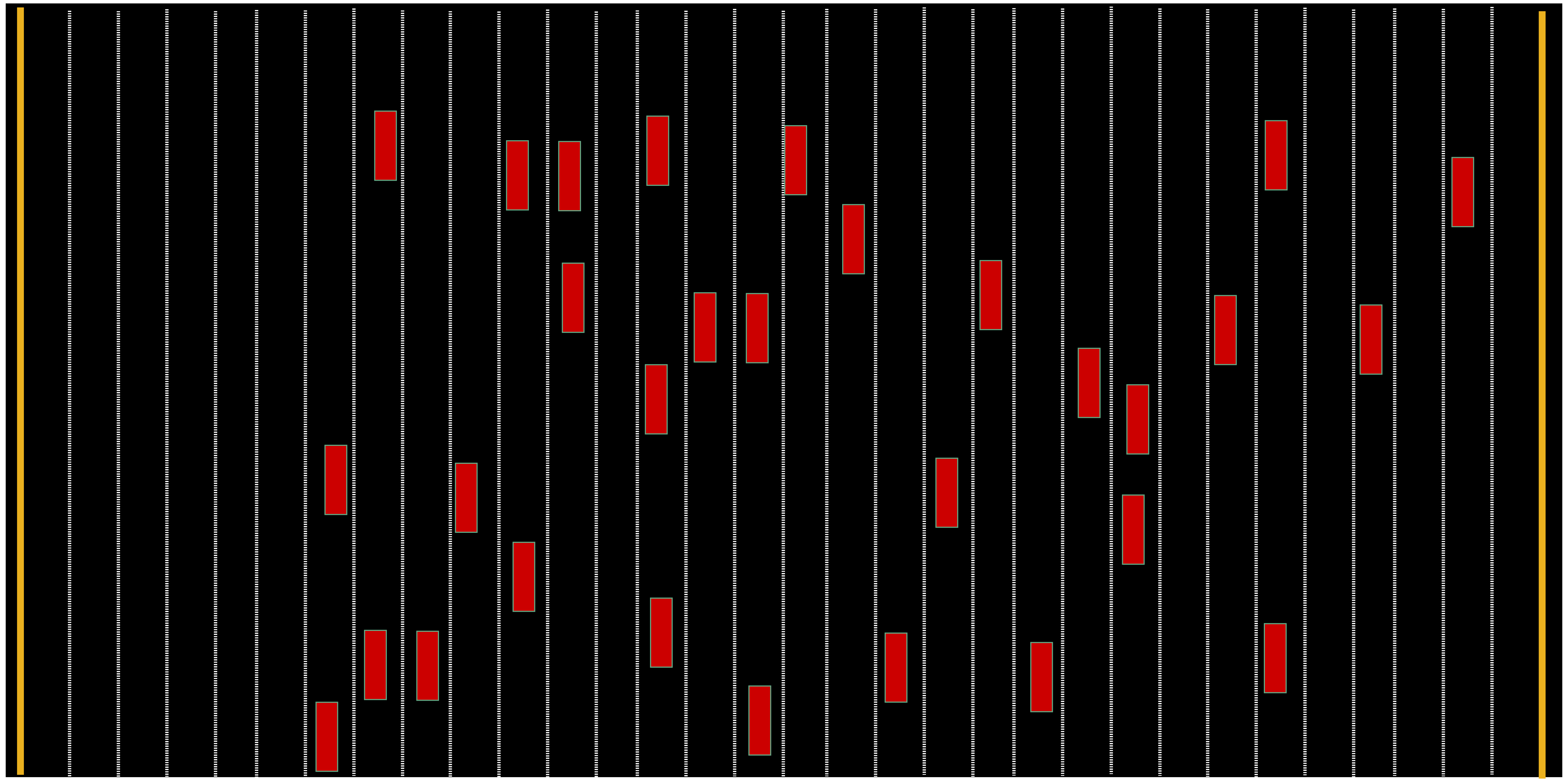
(http://rhelblog.redhat.com/2015/05/06/red-hat-delivers-leading-application-performance-with-the-latest-intel-xeon-processors/





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**

RED HAT SUMMIT

BOSTON, MA
JUNE 23-26, 2015

Tuned for RHEL Platforms
Overview and What's New

Tuned: Updates for RHEL7

- Re-written for maintainability and extensibility.
  - Configuration is now consolidated into a single tuned.conf file
  - Optional hook/callout capability
  - Adds concept of Inheritance (just like httpd.conf)

  - Profiles updated for RHEL7 features and characteristics
  - Added bash-completion :-)

Tuned: Your Custom Profiles

Tuned Profile Examples

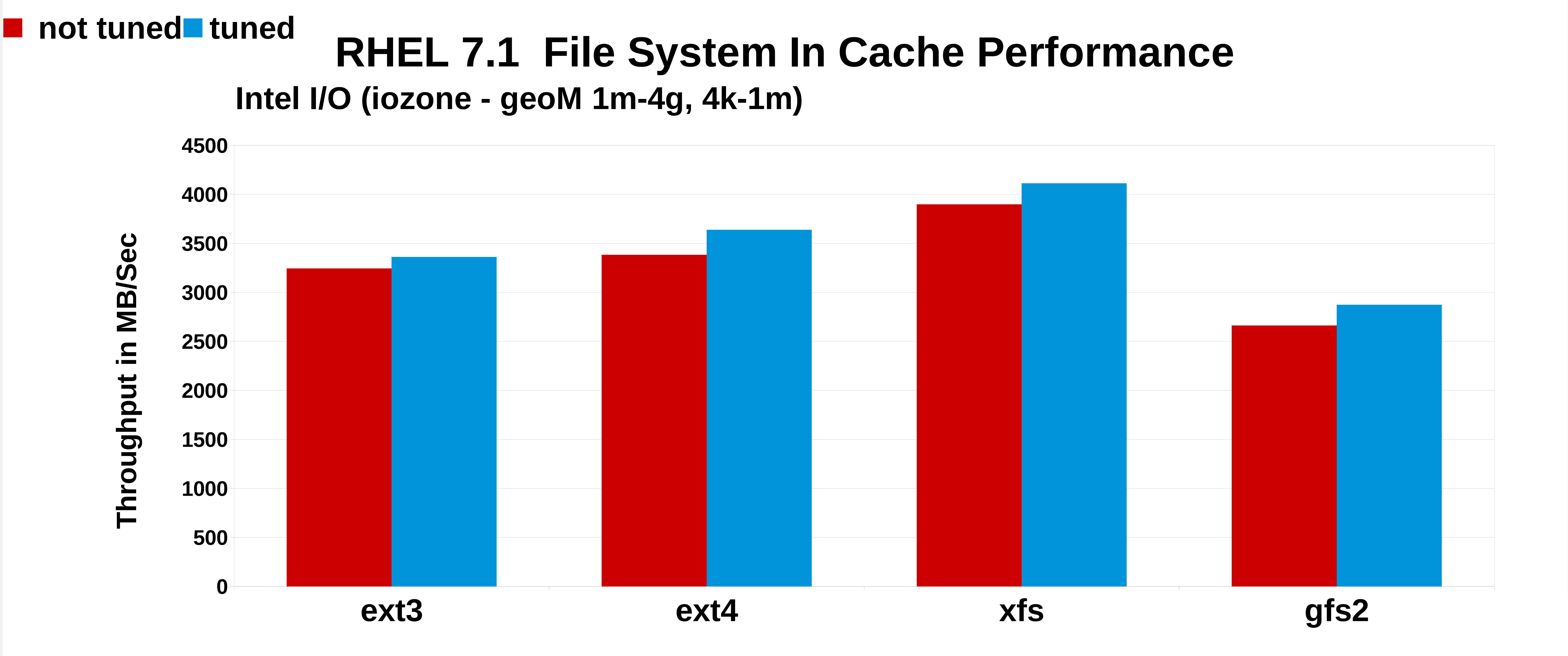
throughput-performance

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

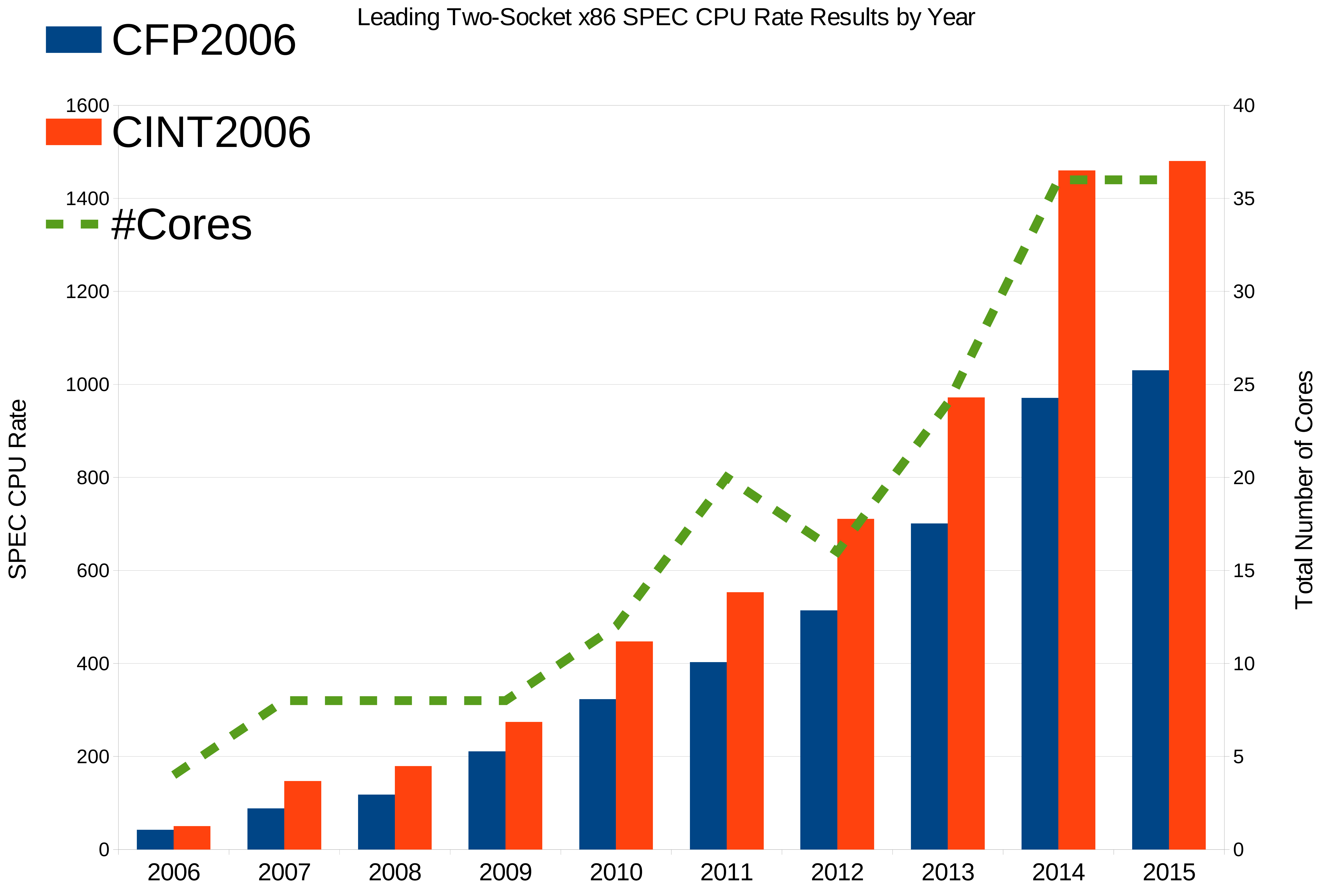
Tuned: Storage Performance Boost: throughput-performance (default in RHEL7)



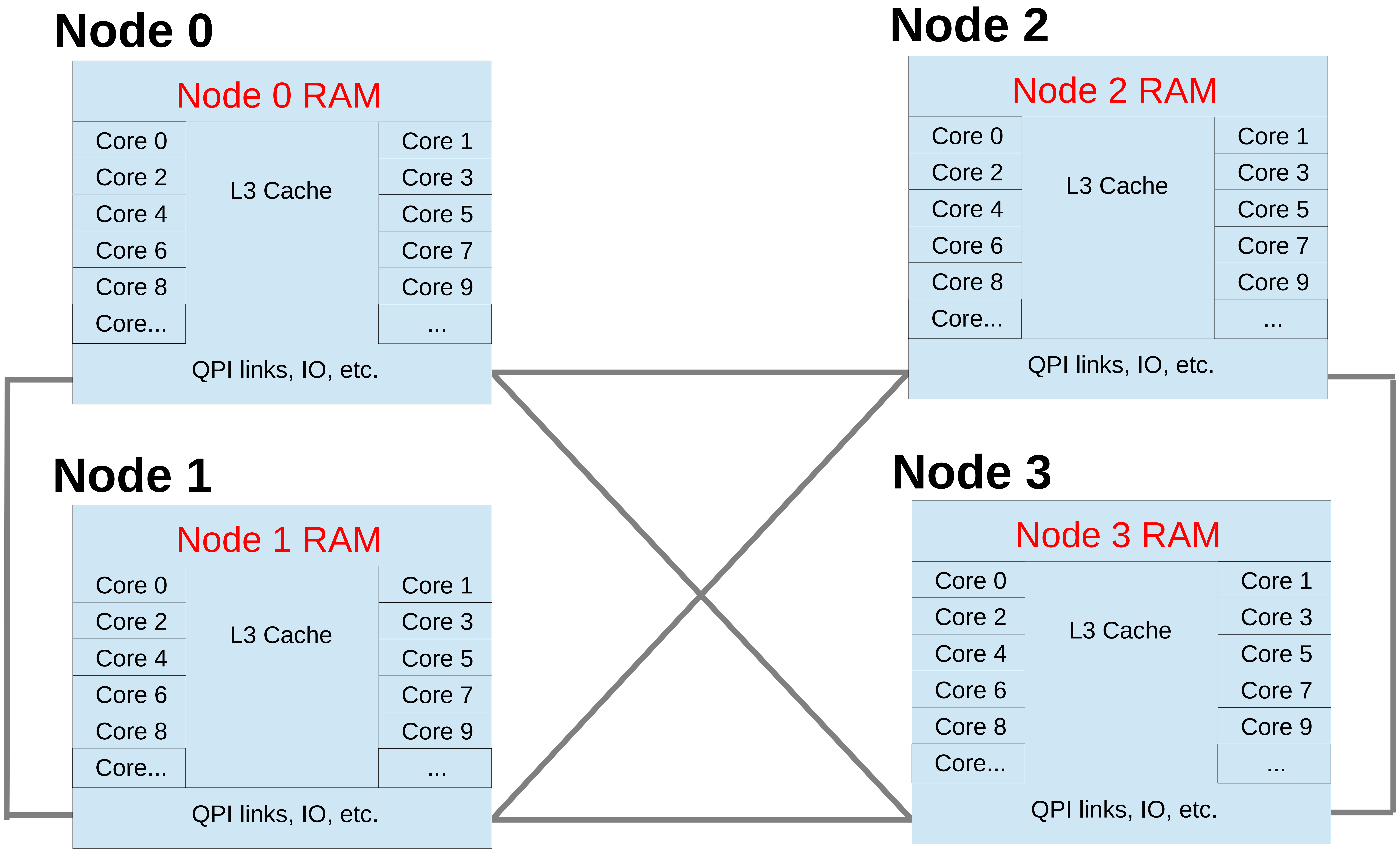
RHEL 6/7 Non-Uniform Memory (NUMA)

Two-Socket SPEC CPU 2006 Rate History

- 2P int rate up 30x / 10 yrs
- Results track # Cores
- Scaling helped by NUMA topology which enables amazing RAM bandwidth (4 channels, 68 GB/s)
- 9 / 10 of recent leading x86 results achieved on Red Hat Enterprise Linux



Typical Four-Node NUMA System



What is NUMA: Non-Uniform Memory Access?

- Making bigger systems more scalable by distributing system memory near individual CPUs....
- Access to local memory is fast, more latency for remote memory
- Practically all multi-socket systems have NUMA
  - Most servers have 1 NUMA node / socket
  - Some AMD systems have 2 NUMA nodes / socket
- Sometimes optimal performance still requires manual tuning.
- Red Hat has been increasingly automating NUMA management!

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
```

```
# 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
```

Visualize CPUs via lstopo (hwloc-gui rpm)

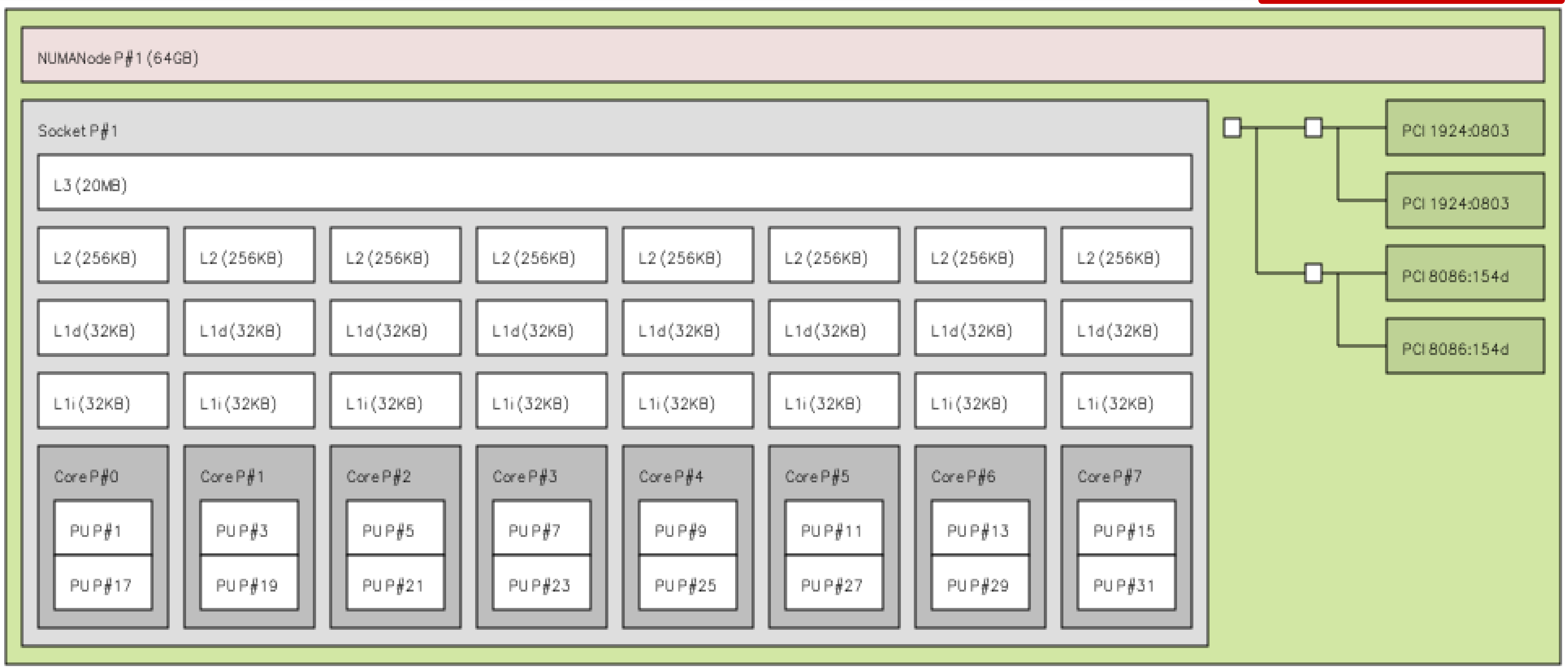
```
# lstopo
```

PCIe

NUMA

CACHE

HT



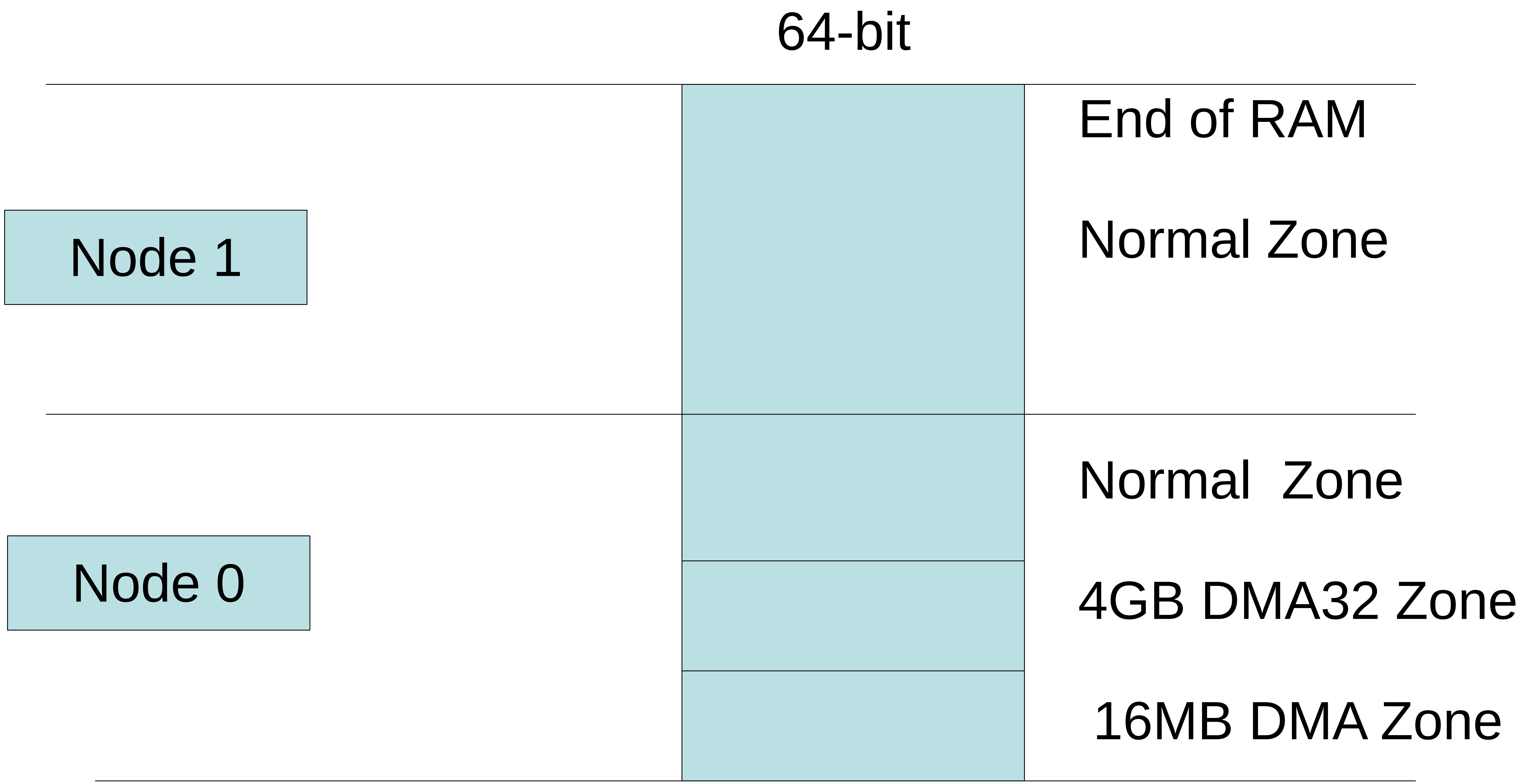
Tips for Good NUMA Performance

- Never disable NUMA in the BIOS. Keep interleave memory OFF (which should be the system BIOS default)
  - Else OS will see only 1-NUMA node!!!
- Understand basic operation and implications of NUMA
  - (e.g. per-node resources)
- Know your workload resource consumption attributes and access patterns. If possible, size parallel jobs to fit in NUMA nodes.
- Be aware of your system hardware NUMA topology.
- Use appropriate tuning if necessary for good performance.

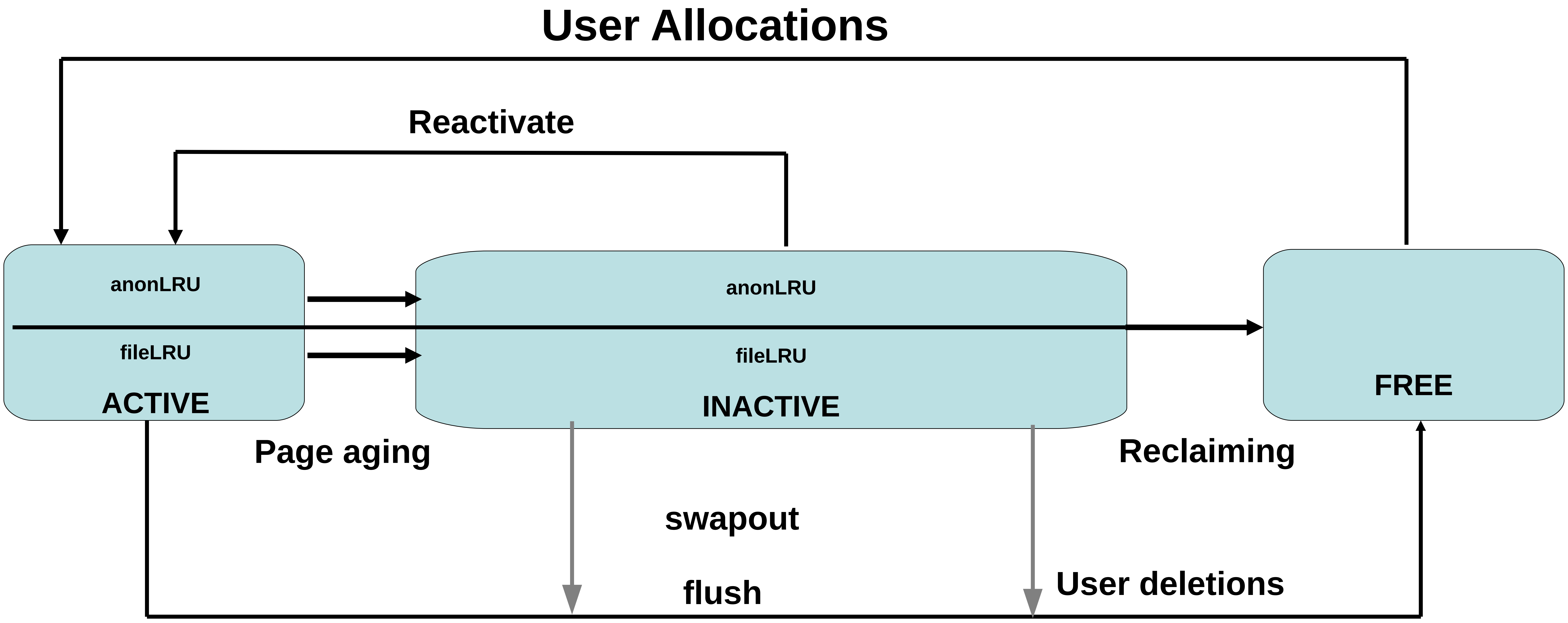
Per NUMA-Node Resources

- CPUs, Caches, Memory
- Interrupt processing, IO / DMA capacity
- Memory zones (DMA & Normal zones)
- Page reclamation kernel thread (kswapd#)
- Lots of other kernel threads
- May need to check resource status per node (e.g. numastat -cm)
  - Because some resources are per node, you can have a node-local resource shortage even though overall system resources look OK!

NUMA Nodes and Zones



Per Node / Zone split LRU Paging Dynamics



Interaction between VM Tunables and NUMA

- Dependent on NUMA:
  - Reclaim Ratios
    - /proc/sys/vm/swappiness
    - /proc/sys/vm/min_free_kbytes

- Independent of NUMA:
  - Reclaim Ratios
    - /proc/sys/vm/vfs_cache_pressure

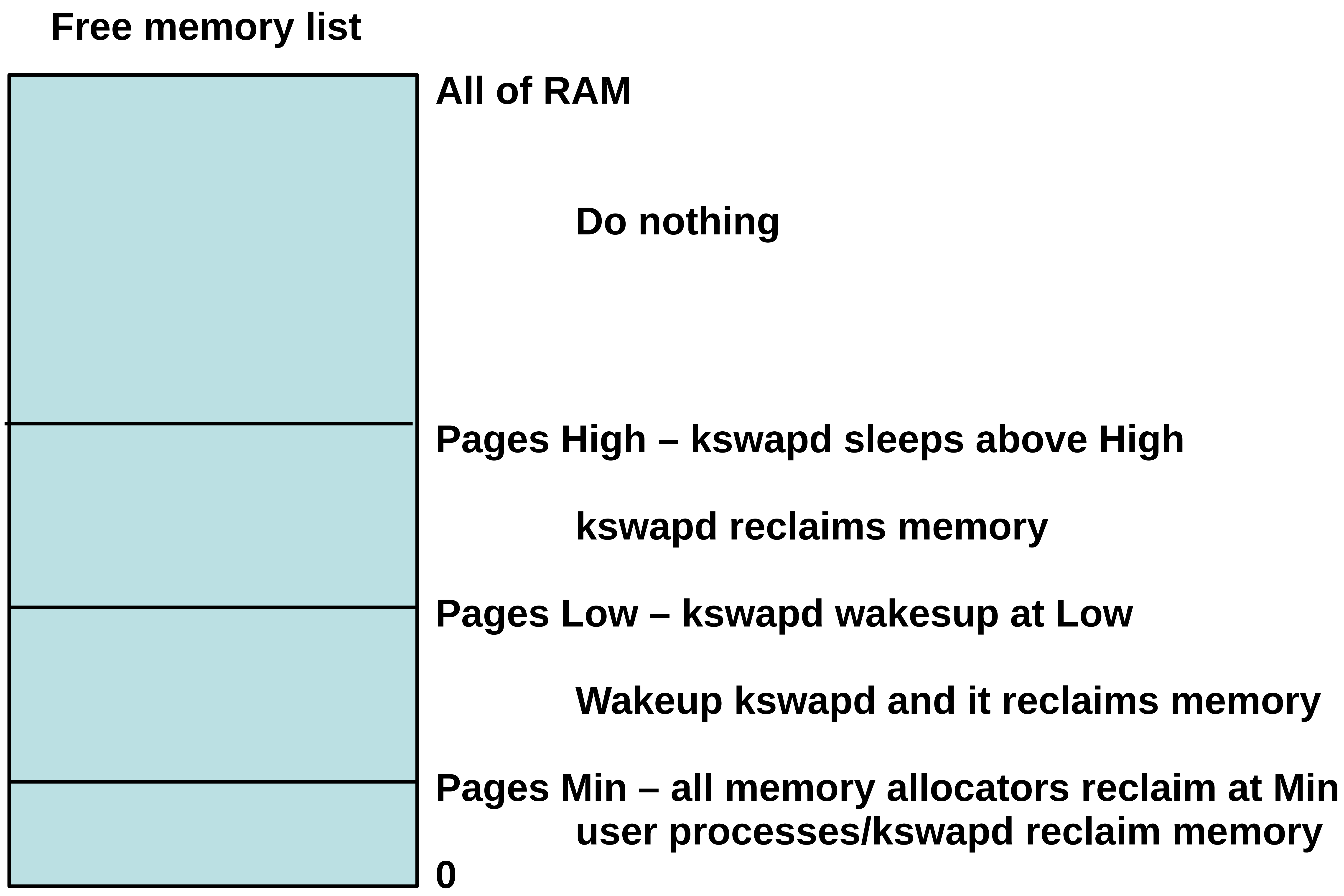
  - Writeback Parameters
    - /proc/sys/vm/dirty_background_ratio
    - /proc/sys/vm/dirty_ratio

  - 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

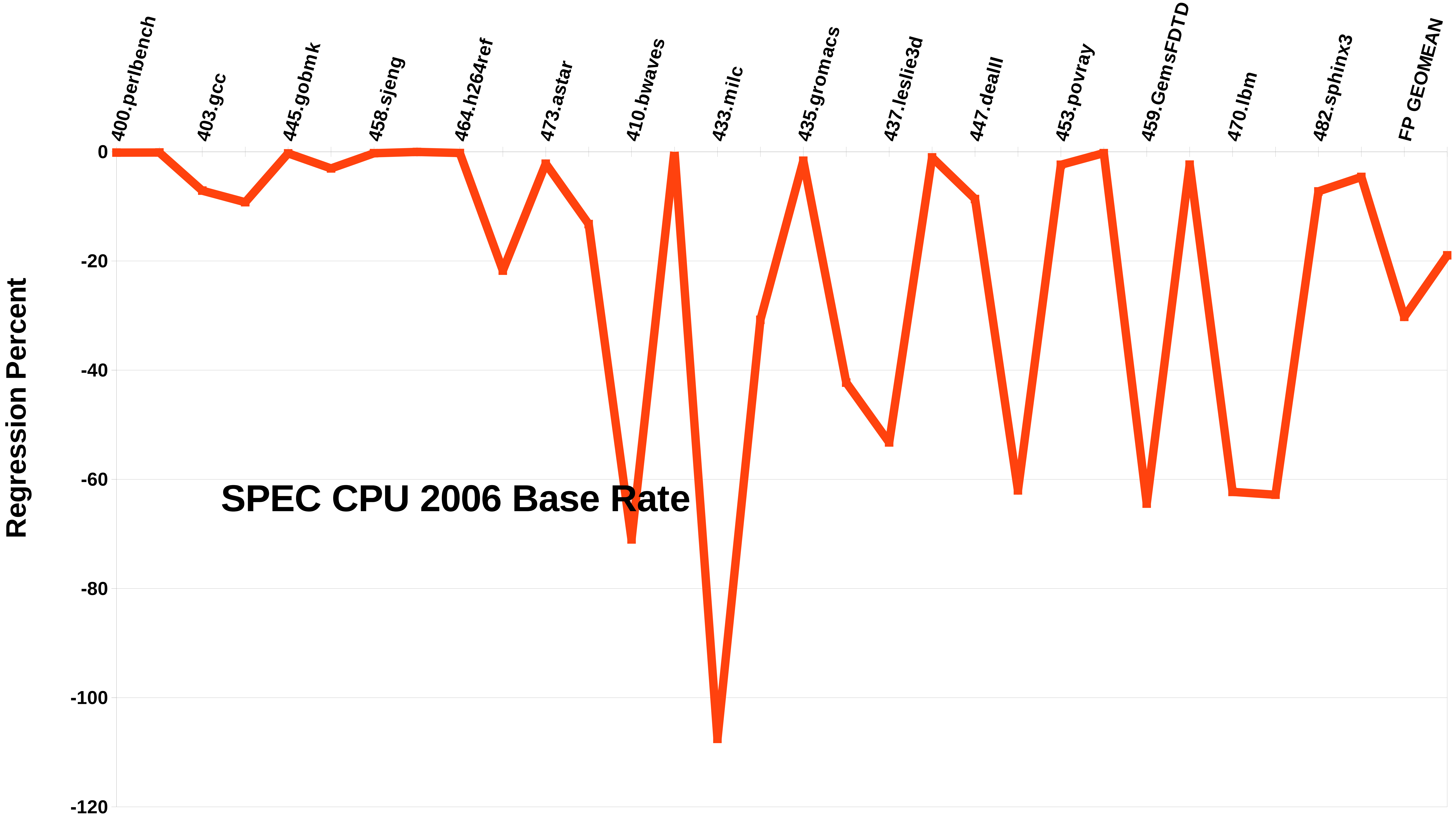
- Controls NUMA specific memory allocation policy
- When set and node memory is exhausted:
  - Reclaim memory from local node rather than allocating from next node
  - Slower initial allocation, higher NUMA hit ratio
- When clear and node memory is exhausted:
  - Allocate from all nodes before reclaiming memory
  - Faster initial allocation, higher NUMA miss ratio

zone_reclaim_mode (continued)

- To see current setting: cat /proc/sys/vm/zone_reclaim_mode
- Turn ON: echo 1 > /proc/sys/vm/zone_reclaim_mode
- Turn OFF: echo 0 > /proc/sys/vm/zone_reclaim_mode
- 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
- This setting can make a big difference in NUMA performance!

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!!)



zone_reclaim_mode (continued)

- Is NUMA data locality more or less important than cache?
- For file servers or workloads that benefit from having their data cached, zone_reclaim_mode should be left disabled as the caching effect is likely to be more important than data locality.
- zone_reclaim may be enabled if it's known that the workload is partitioned such that each partition fits within a NUMA node and that accessing remote memory would cause a measurable performance reduction.
- Need to know workload resource attributes...

Know Your Workload and Resource Attributes

- Dedicated system or Server consolidation / replication
  - Large monolithic process (e.g. large in-memory database)
    - Workload consumes most of the system resources
    - Resource access patterns are global and unpredictable
  - Multiple processes using mostly local data (e.g. virtual guests)
    - Multiple workloads / threads consuming fractional subsets of system resources
    - Resource access patterns can be private, localized or contained
    - Ideally, these workloads / threads can be sized to fit within NUMA nodes!
- Leave zone_reclaim_mode OFF (and consider interleaved memory policy) for global, unpredictable accesses.
- Align CPUs, Memory, and Devices for workloads that can be localized to minimize latency, and isolated to avoid interference!

NUMA Management Checklist

Checklist	Tool
☐ Research NUMA Topology	☑ lscpu, lstopo, numactl --hardware
☐ Consider I/O devices and IRQ	☑ irqbalance, PCI Bus
☐ Virtualization?	☑ libvirt numatune
☐ Plan Resource Allocations	☑ NUMA nodes per workload
☐ Group Tasks and Resources	☑ numactl, cgroups
	☑ numad, kernel NUMA balancing
☐ Monitor NUMA memory	☑ numastat -cm <workload>
☐ Monitor NUMA CPUs	☑ top (then press '2', or maybe '3')

Numactl

- The numactl command can launch commands with **static** NUMA memory and execution thread alignment
  - # numactl -m <NODES> -N <NODES> <Workload>
- Can specify devices of interest to process instead of explicit node list
- Numactl can interleave memory for large monolithic workloads
  - # numactl --interleave=all <Workload>

```
# numactl  -m 6-7 -N 6-7   numactl --show
policy: bind
preferred node: 6
physcpubind: 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79
cpubind: 6 7
nodebind: 6 7
membind: 6 7

# numactl  -m netdev:ens6f2 -N netdev:ens6f2   numactl --show
policy: bind
preferred node: 2
physcpubind: 20 21 22 23 24 25 26 27 28 29
cpubind: 2
nodebind: 2
membind: 2

# numactl  -m file:/data -N file:/data   numactl --show
policy: bind
preferred node: 0
physcpubind: 0 1 2 3 4 5 6 7 8 9
cpubind: 0
nodebind: 0
membind: 0

# numactl  --interleave=4-7  -N 4-7   numactl --show
policy: interleave
preferred node: 5 (interleave next)
interleavemask: 4 5 6 7
interleavenode: 5
physcpubind: 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59
60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79
cpubind: 4 5 6 7
nodebind: 4 5 6 7
membind: 0 1 2 3 4 5 6 7
```

Numastat

- Enhanced by Red Hat (since Red Hat Enterprise Linux 6.4) with helpful and informative new memory display features.
- Numastat shows per-NUMA-node memory statistics for processes and the operating system.
- By default, numastat displays per-node kernel memory allocator hit and miss statistics.
- Any command line arguments to numastat will invoke enhanced behavior to show per-node distribution of memory.

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

Cgroup cpusets

- Another way of manually grouping and aligning a set of tasks, CPUs and associated memory
- Uses normal cgroup hierarchy of resource partitioning
- memory_migrate will cause memory to move
- Must enter TIDs separately

```
# mount  -t cgroup  -o cpuset  cpuset  /sys/fs/cgroup/cpuset
# cd /sys/fs/cgroup/cpuset

# mkdir my_cpuset
# cd my_cpuset

# echo 30-39 > cpuset.cpus
# echo 3 > cpuset.mems
# echo 1 > cpuset.memory_migrate

# echo <tid 1> tasks
# echo <tid 2> tasks
# echo <tid 3> tasks
# echo <tid 4> tasks
```

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
```

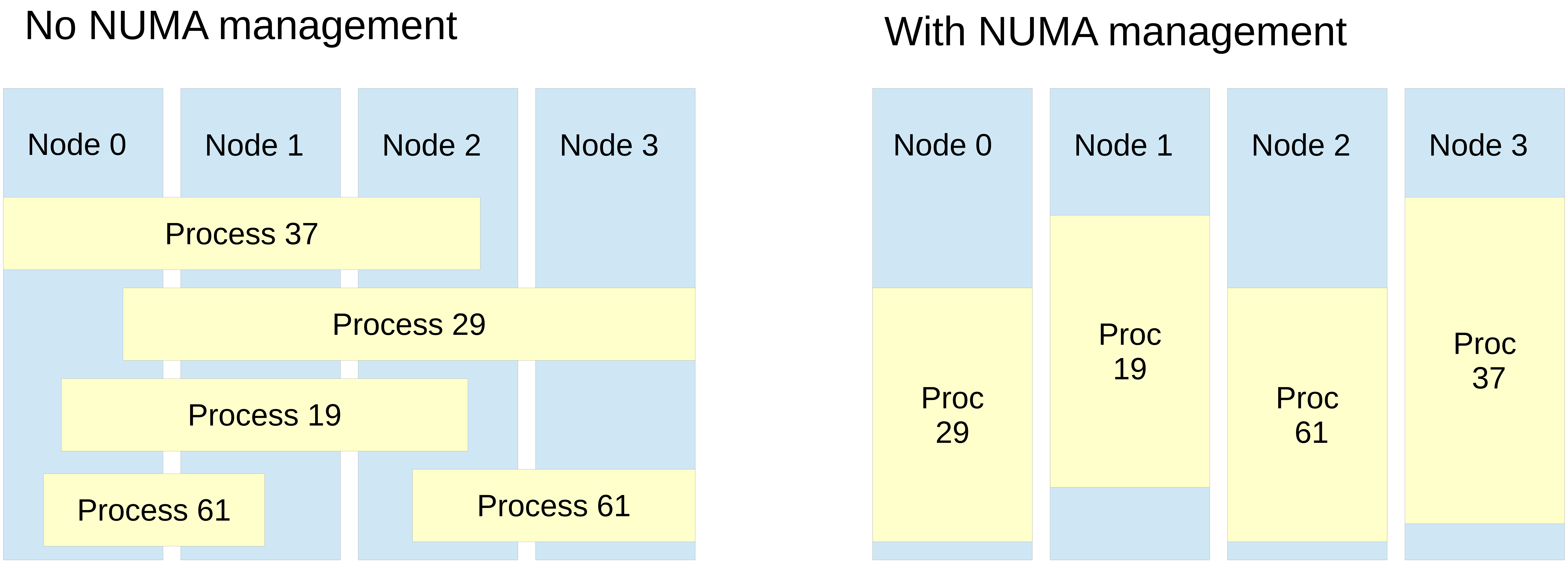
Incorrect NUMA bindings

```
# 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
```

KSM: Kernel Samepage Merging

- Ksmd allows oversubscription of resources by sharing memory pages between guest instances. Can save significant memory when running many similar guests.
- However, this is a **performance** talk....
  - Don't oversubscribe your resources if you want best performance!
- If you must, and multiple guests can fit in a single NUMA node, you might get some memory savings – without giving up NUMA isolation – by turning off ksm merging across NUMA nodes
  - # echo 0 > /sys/kernel/mm/merge_across_nodes
- Turn ksmd off: # echo 'KSM_ENABLED=0' > /etc/default/qemu-kvm

Numad and kernel NUMA balance align process memory and CPU threads within NUMA nodes



Automate NUMA with “numad” in RHEL6.4+

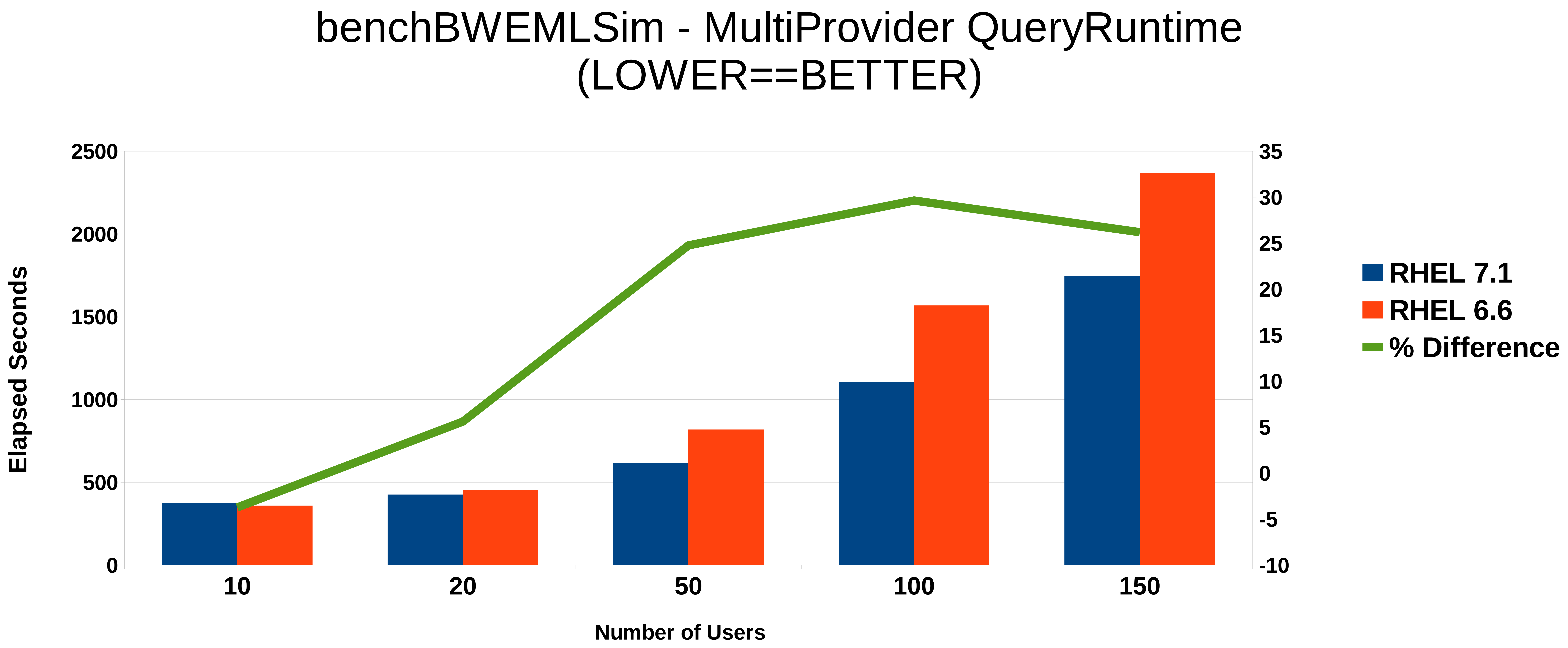
- An optional user-level CPU-and-memory-affinity management daemon to automatically improve NUMA performance
- Allocates CPU and NUMA memory resources to localize and isolate significant processes (e.g. KVM guests)
- Dynamically adjusts placement as loads change
- Maintains specified target utilization of node resources
  - Adjust default 85% with “-u <n>” to change node resource margin
- Pre-placement feature can be used by libvirt placement='auto'
  - <vcpu placement='auto'>2</vcpu>
  - <numatune> <memory mode='strict' placement='auto'/> </numatune>

Automate with RHEL7+ kernel NUMA balancing

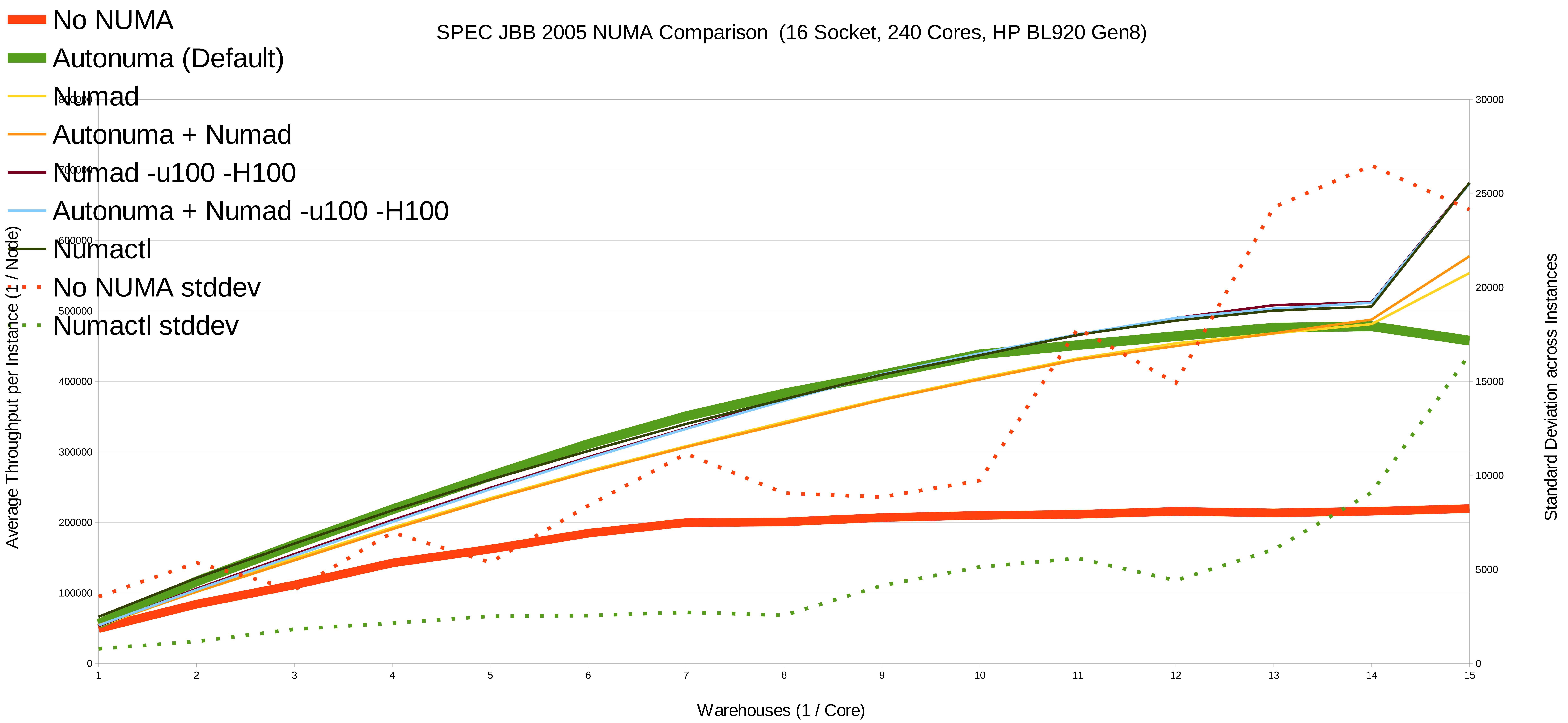
- Periodically unmaps pages to see where memory is used
  - This sampling approach efficiently ignores unused memory.
- Moves task threads to NUMA nodes with their memory **and** moves accessed memory to NUMA nodes where threads are executing
- Lazy page migration efficiently moves memory in the background
- Much better than numad at fine grain (thread-level) control
- Enabled and active by default in Red Hat Enterprise Linux 7+
- Turn off: echo 0 > /proc/sys/kernel/numa_balancing
- Other tunables in /proc/sys/kernel/numa*, e.g. can adjust numa_balancing_scan_delay_ms to ignore short-lived processes. Normally don't need to change these.

RHEL 6.6 vs RHEL 7.1 SAP HANA Performance

25% gain due to Auto NUMA balancing (kernel.numa_balancing = 1)



NUMA Alignment Makes JBB 2005 2x Faster



Summary - Red Hat Enterprise Linux Automates NUMA Management!

- With Red Hat Enterprise Linux 6.4+, careful use of numad can significantly improve performance and automate NUMA management on systems with server consolidation or replicated parallel workloads.
- With Red Hat Enterprise Linux 7+, most users will get good NUMA system memory management for most applications out of the box!
- Automated NUMA management is especially valuable in dynamic server environments with changing workload conditions.

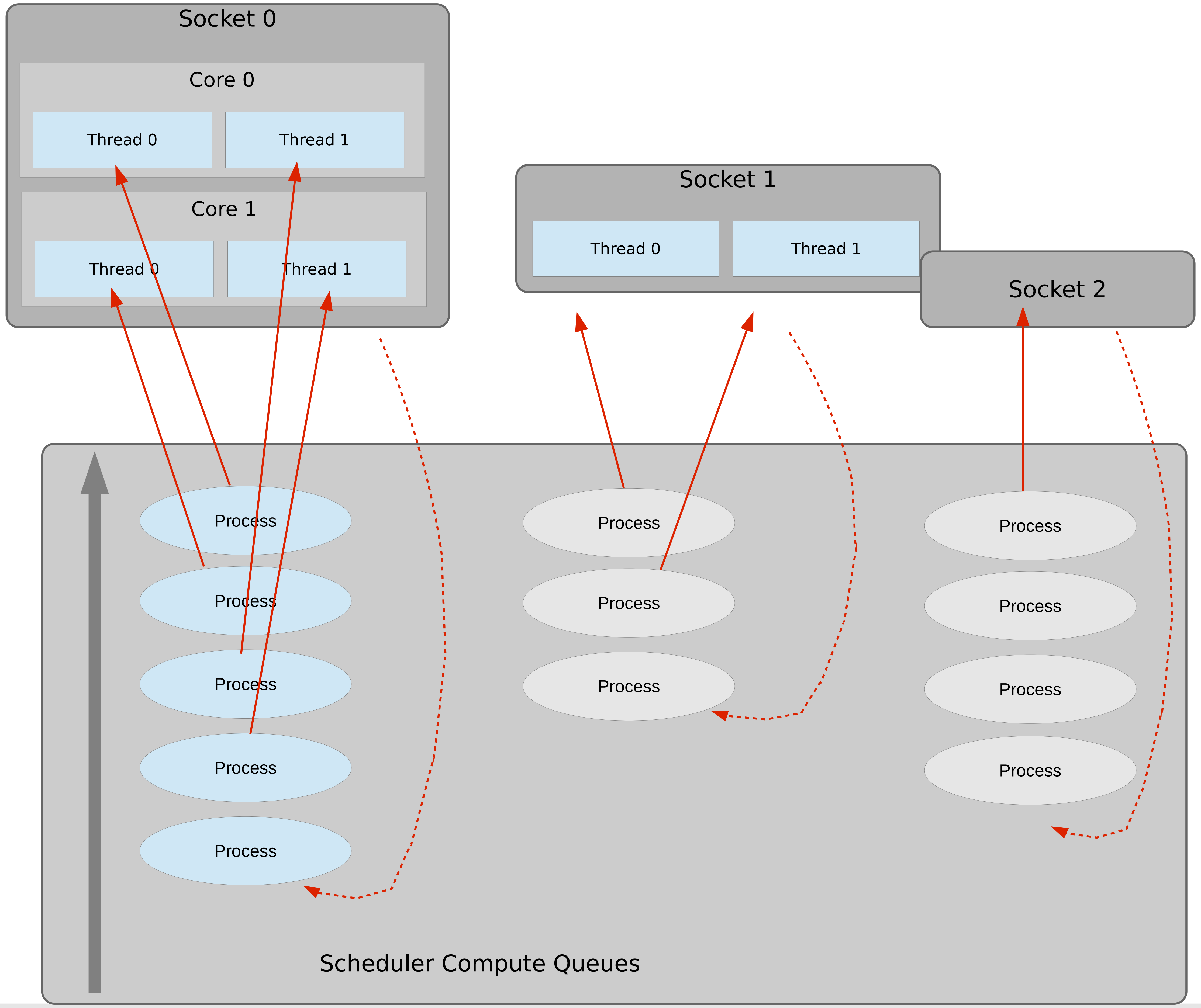
Red Hat Enterprise Linux Scheduler

RHEL Scheduler Tunables

Implements multiple red/black trees as run queues for sockets and cores (as opposed to one run queue per processor or per system)

RHEL tunables

- sched_min_granularity_ns
- sched_wakeup_granularity_ns
- sched_migration_cost
- sched_child_runs_first
- sched_latency_ns



Finer Grained Scheduler Tuning

- RHEL6/7 Tuned-adm will increase quantum on par with RHEL5
  - echo 10000000 > /proc/sys/kernel/sched_min_granularity_ns
    - Minimal preemption granularity for CPU bound tasks. See sched_latency_ns for details. The default value is 4000000 (ns).
  - echo 15000000 > /proc/sys/kernel/sched_wakeup_granularity_ns
    - The wake-up preemption granularity.
    - Increasing this variable reduces wake-up preemption, reducing disturbance of compute bound tasks.
    - Decreasing it improves wake-up latency and throughput for latency critical tasks, particularly when a short duty cycle load component must compete with CPU bound components. The default value is 5000000 (ns).

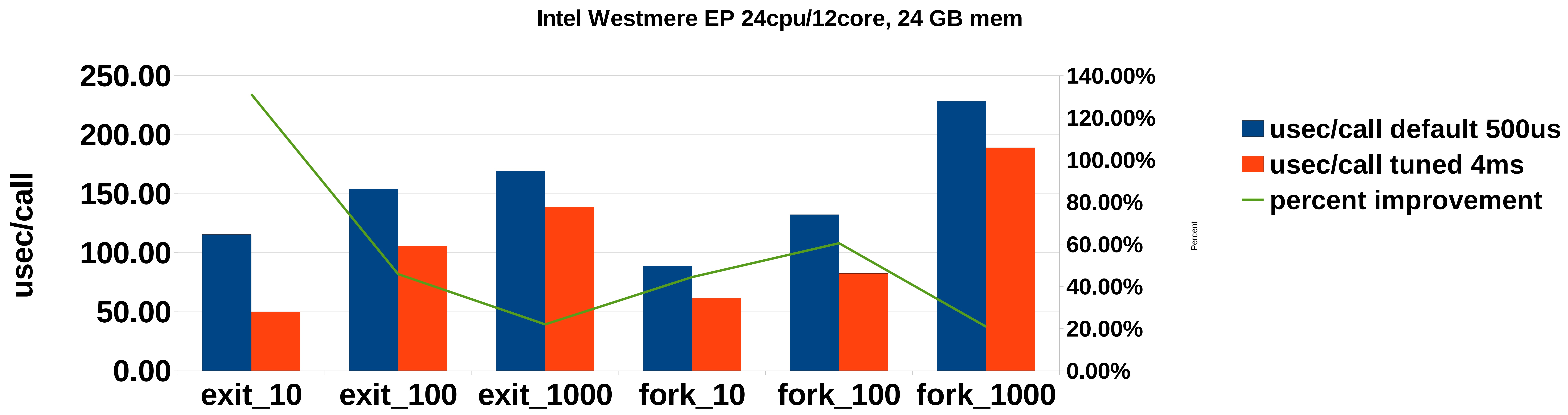
Load Balancing

- Scheduler tries to keep all CPUs busy by moving tasks form overloaded CPUs to idle CPUs
- Detect using “perf stat”, look for excessive “migrations”
- ***/proc/sys/kernel/sched_migration_cost***
  - Amount of time after the last execution that a task is considered to be “cache hot” in migration decisions. A “hot” task is less likely to be migrated, so increasing this variable reduces task migrations. The default value is 500000 (ns).
  - If the CPU idle time is higher than expected when there are runnable processes, try reducing this value. If tasks bounce between CPUs or nodes too often, try increasing it.
- Rule of thumb – increase by **2-10x** to reduce load balancing (tuned does this)
- Use 10x on large systems when many CGROUPs are actively used (ex: RHEV/ KVM/RHOS)

fork() behavior

sched_child_runs_first
- Controls whether parent or child runs first
- Default is 0: parent continues before children run.
- Default is different than RHEL5

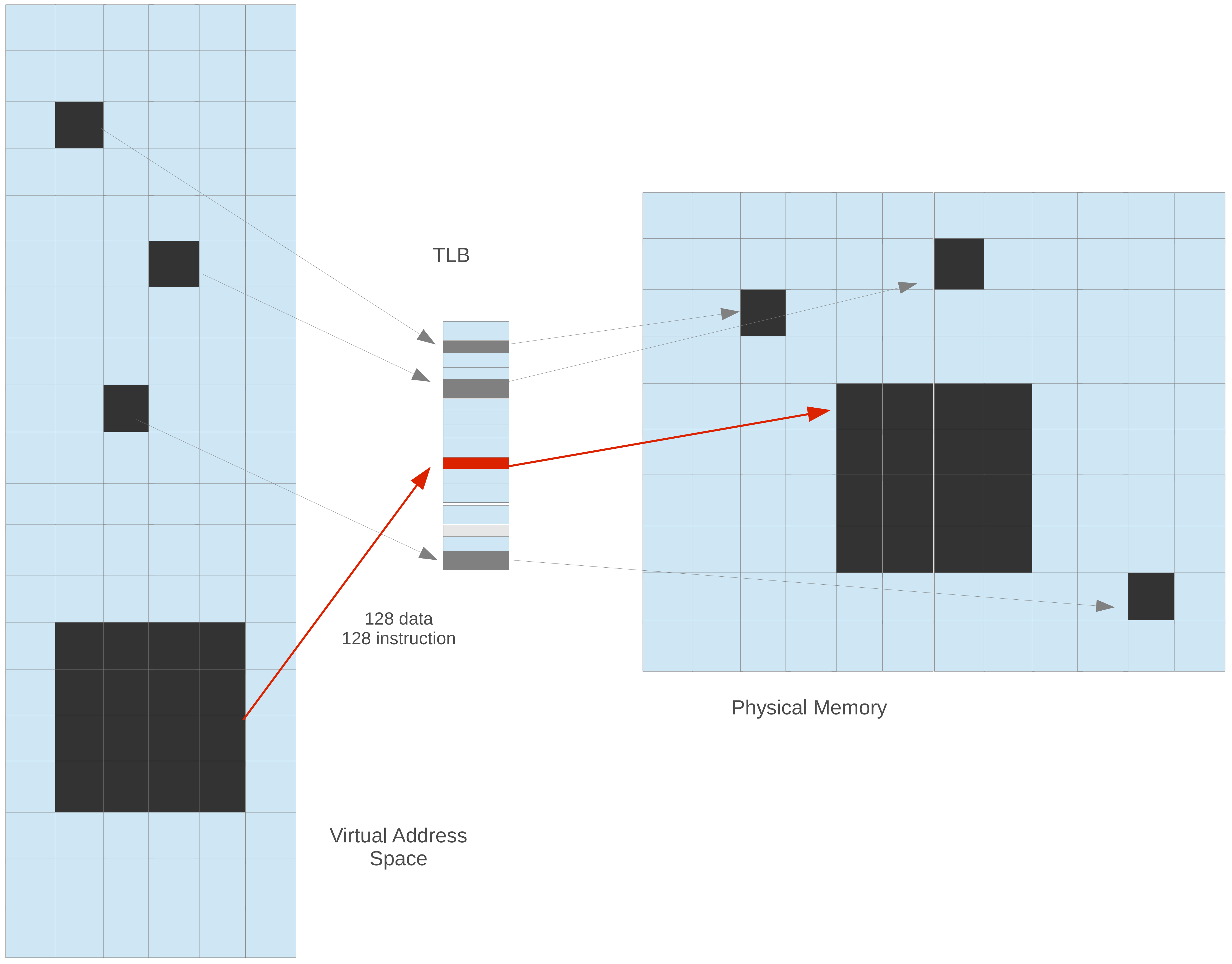
RHEL6 Effect of sched_migration cost on fork/exit



Red Hat Enterprise Linux Page Sizes

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



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
```

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
```

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
```

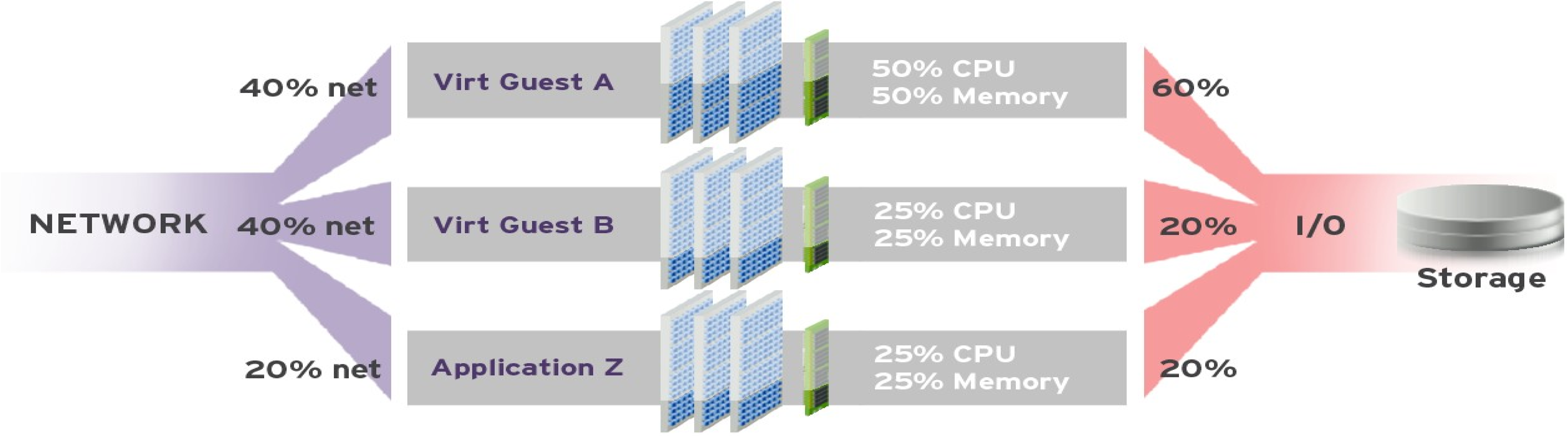
SPEEDUP 12.4/7.0 = 1.77x, 56%

Red Hat Enterprise Linux Cgroups

Resource Management using cgroups

Ability to manage large system resources effectively

- Control Group (Cgroups) for CPU/Memory/Network/Disk
- Benefit: guarantee Quality of Service & dynamic resource allocation
- Ideal for managing any multi-application environment
  - From back-ups to the Cloud



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**

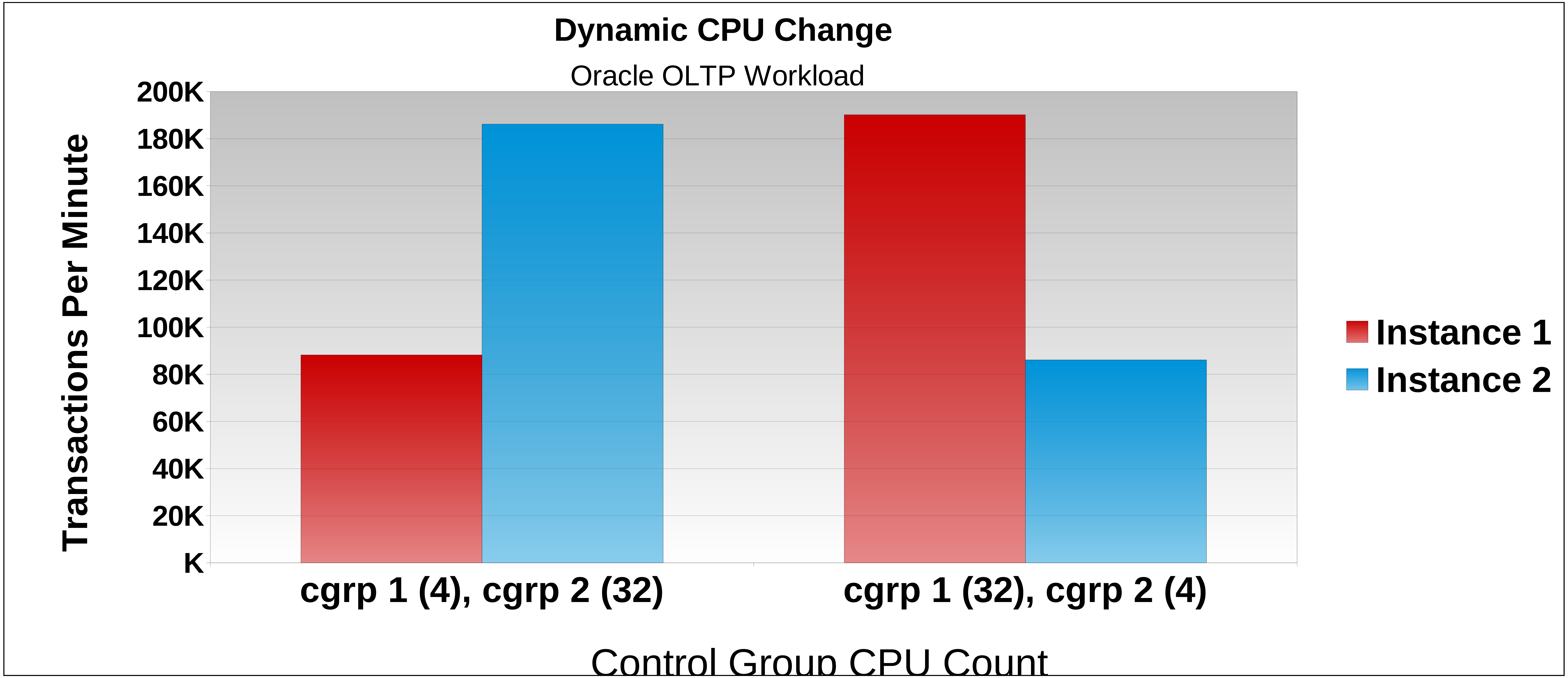
cpu.shares throttled

 # 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 OOMkills

```
# mkdir -p /sys/fs/cgroup/memory/test
# echo 1G > /sys/fs/cgroup/memory/test/memory.limit_in_bytes
# echo 2G > /sys/fs/cgroup/memory/test/memory.memsw.limit_in_bytes
# echo $$ > /sys/fs/cgroup/memory/test/tasks

# ./memory 16G
size = 10485760000
touching 2560000 pages
Killed
# vmstat 1
...
 0  0   52224 1640116      0 3676924    0      0      0      0   202  487  0  0 100  0  0
 1  0   52224 1640116      0 3676924    0      0      0      0   162  316  0  0 100  0  0
 0  1 248532 587268        0 3676948   32 196312     32 196372   912  974  1  4 88   7  0
 0  1 406228 586572        0 3677308    0 157696      0 157704   624  696  0  1 87  11  0
 0  1 568532 585928        0 3676864    0 162304      0 162312   722 1039  0  2 87  11  0
 0  1 729300 584744        0 3676840    0 160768      0 160776   719 1161  0  2 87  11  0
 1  0 885972 585404        0 3677008    0 156844      0 156852   754 1225  0  2 88  10  0
 0  1 1042644 587128       0 3676784    0 156500      0 156508   747 1146  0  2 86  12  0
 0  1 1169708 587396       0 3676748    0 127064      4 127836   702 1429  0  2 88  10  0
 0  0   86648 1607092      0 3677020  144      0    148      0   491 1151  0  1 97   1  0
```

Cgroup OOMkills (continued)

```
# vmstat 1
...
 0  0  52224 1640116      0 3676924    0     0      0      0  202  487  0  0 100  0  0
 1  0  52224 1640116      0 3676924    0     0      0      0  162  316  0  0 100  0  0
 0  1 248532 587268       0 3676948   32 196312    32 196372  912  974  1  4 88   7  0
 0  1 406228 586572       0 3677308    0 157696     0 157704  624  696  0  1 87  11  0
 0  1 568532 585928       0 3676864    0 162304     0 162312  722 1039  0  2 87  11  0
 0  1 729300 584744       0 3676840    0 160768     0 160776  719 1161  0  2 87  11  0
 1  0 885972 585404       0 3677008    0 156844     0 156852  754 1225  0  2 88  10  0
 0  1 1042644 587128      0 3676784    0 156500     0 156508  747 1146  0  2 86  12  0
 0  1 1169708 587396      0 3676748    0 127064     4 127836  702 1429  0  2 88  10  0
 0  0  86648 1607092      0 3677020  144     0   148      0  491 1151  0  1 97   1  0
...
```

```
# dmesg
...
[506858.413341] Task in /test killed as a result of limit of /test
[506858.413342] memory: usage 1048460kB, limit 1048576kB, failcnt 295377
[506858.413343] memory+swap: usage 2097152kB, limit 2097152kB, failcnt 74
[506858.413344] kmem: usage 0kB, limit 9007199254740991kB, failcnt 0
[506858.413345] Memory cgroup stats for /test: cache:0KB rss:1048460KB rss_huge:10240KB
mapped_file:0KB swap:1048692KB inactive_anon:524372KB active_anon:524084KB inactive_file:0KB
active_file:0KB unevictable:0KB
```

RHEL7 Performance Tuning Summary

- **Use “Tuned”, “NumaCTL”, “NumaD” in RHEL6 and RHEL7**
  - Transparent Hugepages for anon memory (monitor it)
  - Scheduler – Auto-Numa-Balance – Multi-instance, consider “NumaD”
  - Scheduler – tuned profiles, load balance
  - Cgroup infrastructure for RHEL6, Atomic/ Docker for RHEL7
- **Manually Tune**
  - NUMA – via numactl, monitor numastat -c pid
  - Huge Pages – static hugepages for pinned shared-memory
  - Managing VM, dirty ratio and swappiness tuning
  - Use cgroups for further resource management control

Performance Utility Summary

Supportability

- redhat-support-tool
- sos
- kdump
- perf
- psmisc
- strace
- sysstat
- systemtap
- trace-cmd
- Util-linux-ng
- pcp

NUMA

- hwloc
- Intel PCM
- numactl
- numad
- numatop (01.org)

Networking

- dropwatch
- ethtool
- netsniff-ng (EPEL6)
- tcpdump
- wireshark/tshark

Power/Tuning

- cpupowerutils (R6)
- kernel-tools (R7)
- powertop
- tuna
- tuned

Storage

- blktrace
- iotop
- iostat

RED HAT SUMMIT

LEARN. NETWORK.
EXPERIENCE OPEN SOURCE.

RED HAT SUMMIT

BOSTON, MA
JUNE 23-26, 2015

Performance Analysis and Tuning – Part 2

D. John Shakshober (Shak) - Sr Consulting Eng / Director Performance Engineering

Larry Woodman - Senior Consulting Engineer / Kernel VM

Jeremy Eder - Principal Performance Engineering

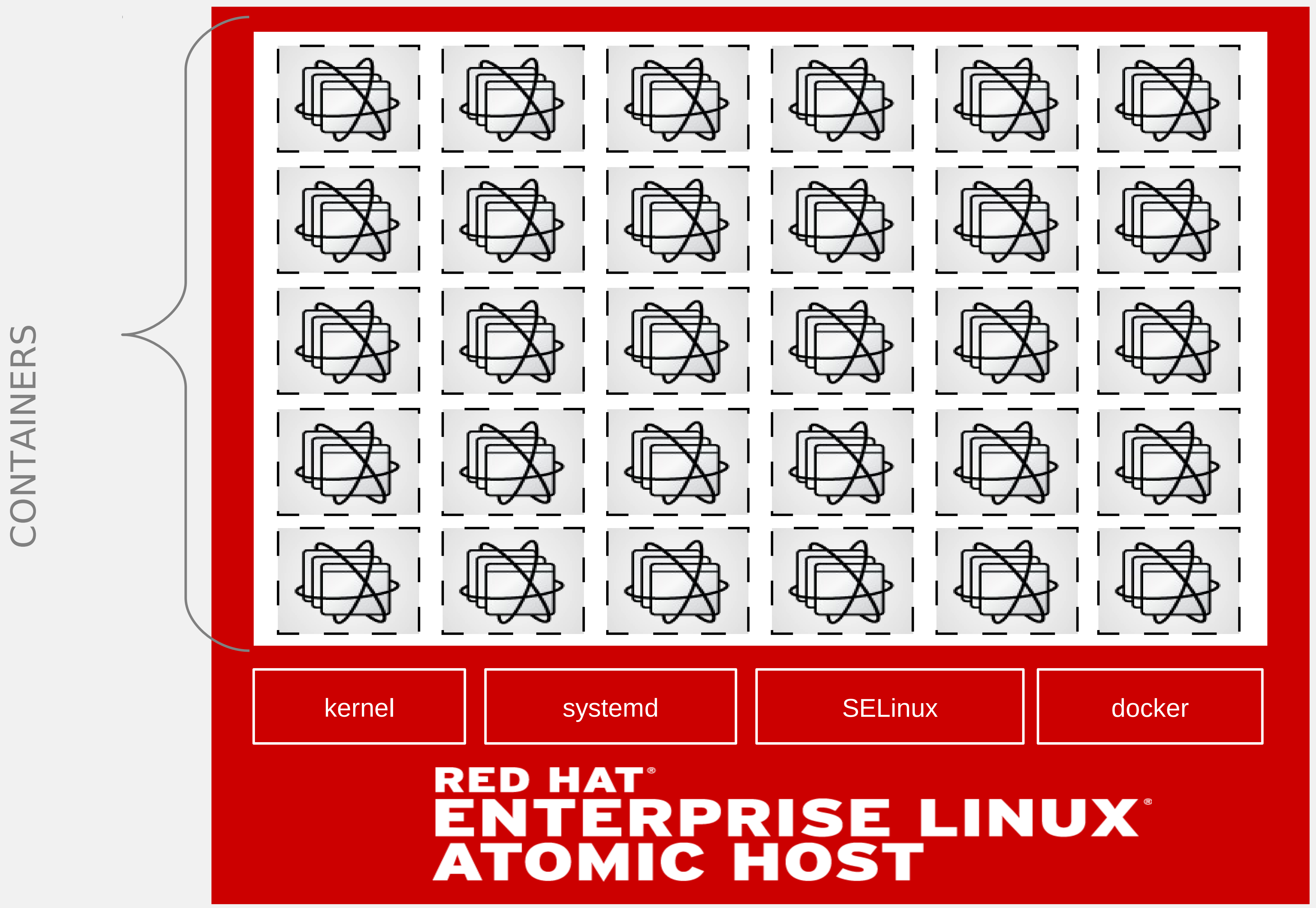
Bill Gray - Principal Performance Engineer

Agenda: Performance Analysis Tuning Part II

- Part I
  - RHEL Evolution 5->6->7 – out-of-the-box tuned for Clouds - “tuned”
  - NonUniform Memory Access (NUMA)
  - Cgroups – the basis of Linux Containers / Atomic
  - Process Scheduler, Numa awareness, tunables
  - Transparent Hugepages, Static Hugepages 4K/2MB/1GB
- **Part II**
  - **RHEL Atomic / Platform, Tuning Optimized for Enterprise**
  - **Network Performance and Latency-performance, Real Time**
  - **Disk and Filesystem IO - Throughput-performance**
  - **Cloud Performance Topics OpenShift, OpenStack - NFV**
- **Performance Birds of the Feather (BoF) Wed 6-8 Room 206**

RED HAT® ENTERPRISE LINUX® ATOMIC HOST

RED HAT ENTERPRISE LINUX ATOMIC HOST



MINIMAL, SECURE FOOTPRINT

- Minimal host provides “just enough” to support apps.

RAPID PROVISIONING

- Apps can be provisioned and started in milliseconds.

SIMPLIFIED MAINTENANCE

- Atomic updates are quick, reliable, and can be rolled back.

[1] Red Hat Enterprise Linux Atomic Host is not generally available. Visit http://www.redhat.com/about/news/press-archive/2014/4/linux-container-innovations for additional information.

Atomic Tuned Profile Inheritance

Parents

- **throughput-performance**

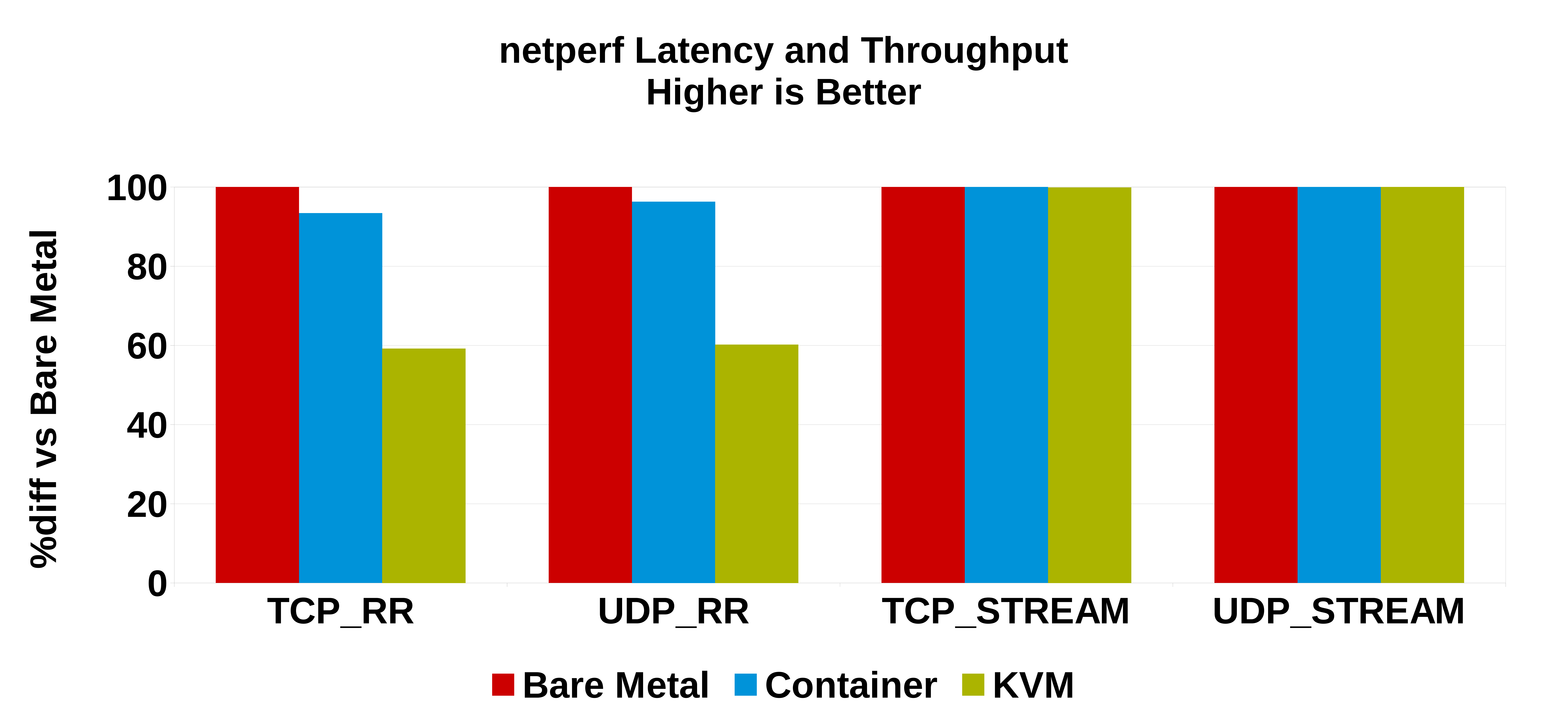
Children

- **atomic-host**
- **virtual-guest**

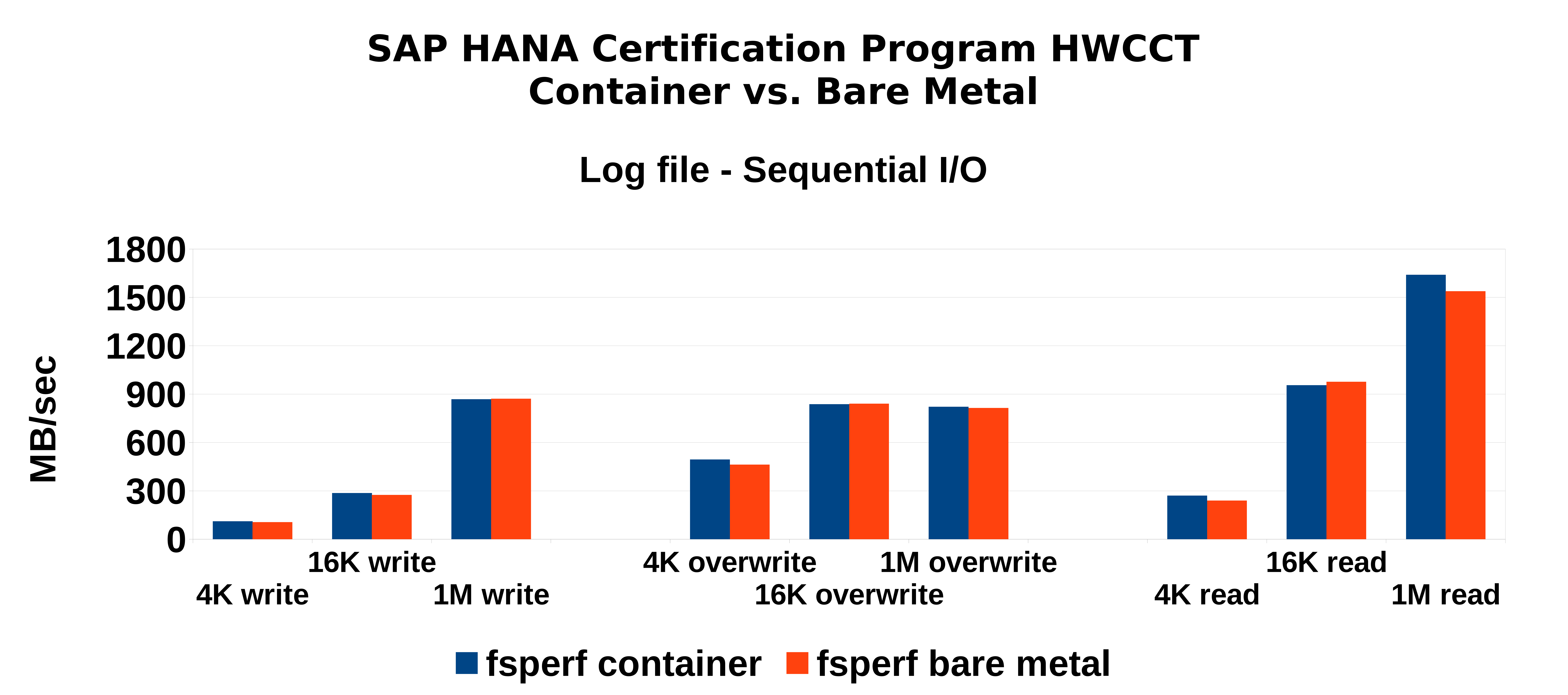
Children/Grandchildren

- **atomic-guest**

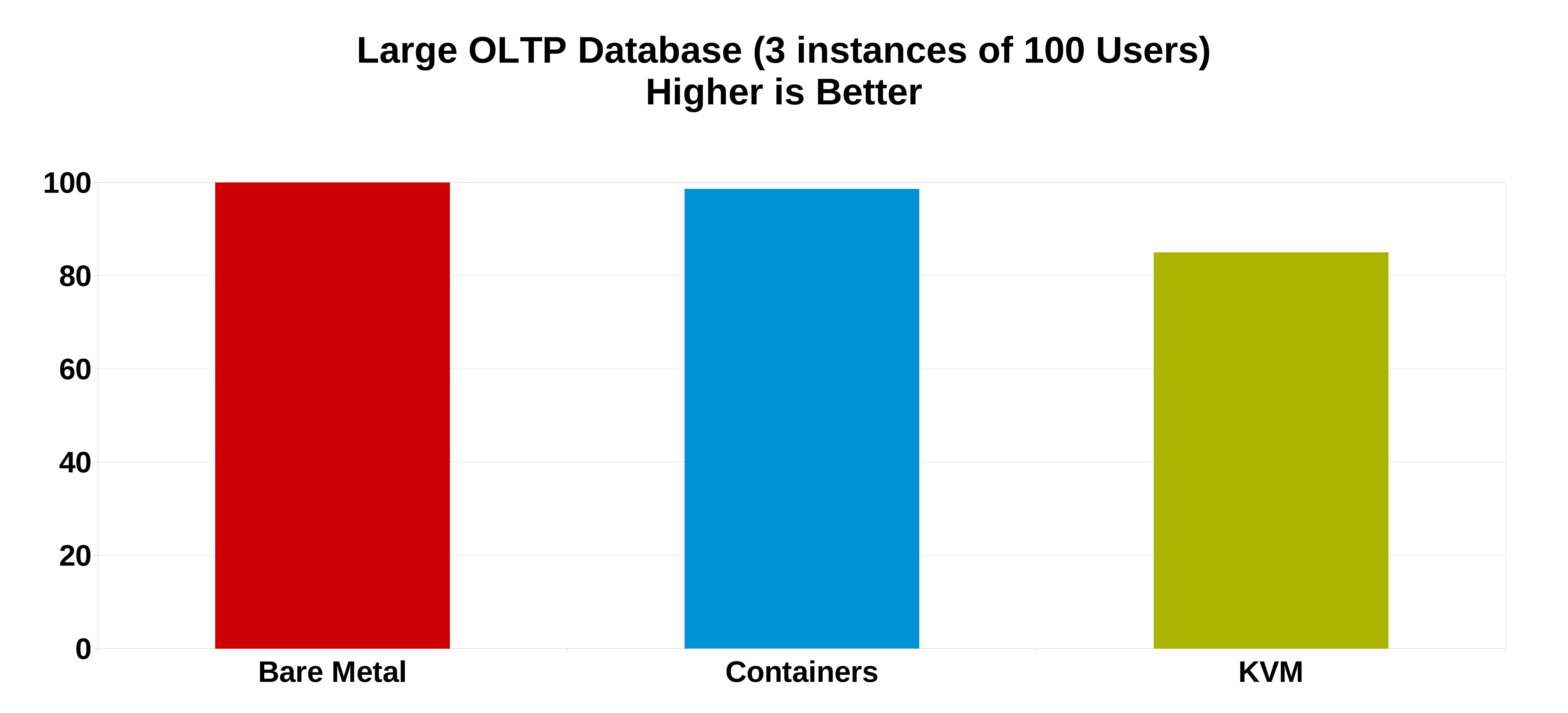
Network Latency and Throughput



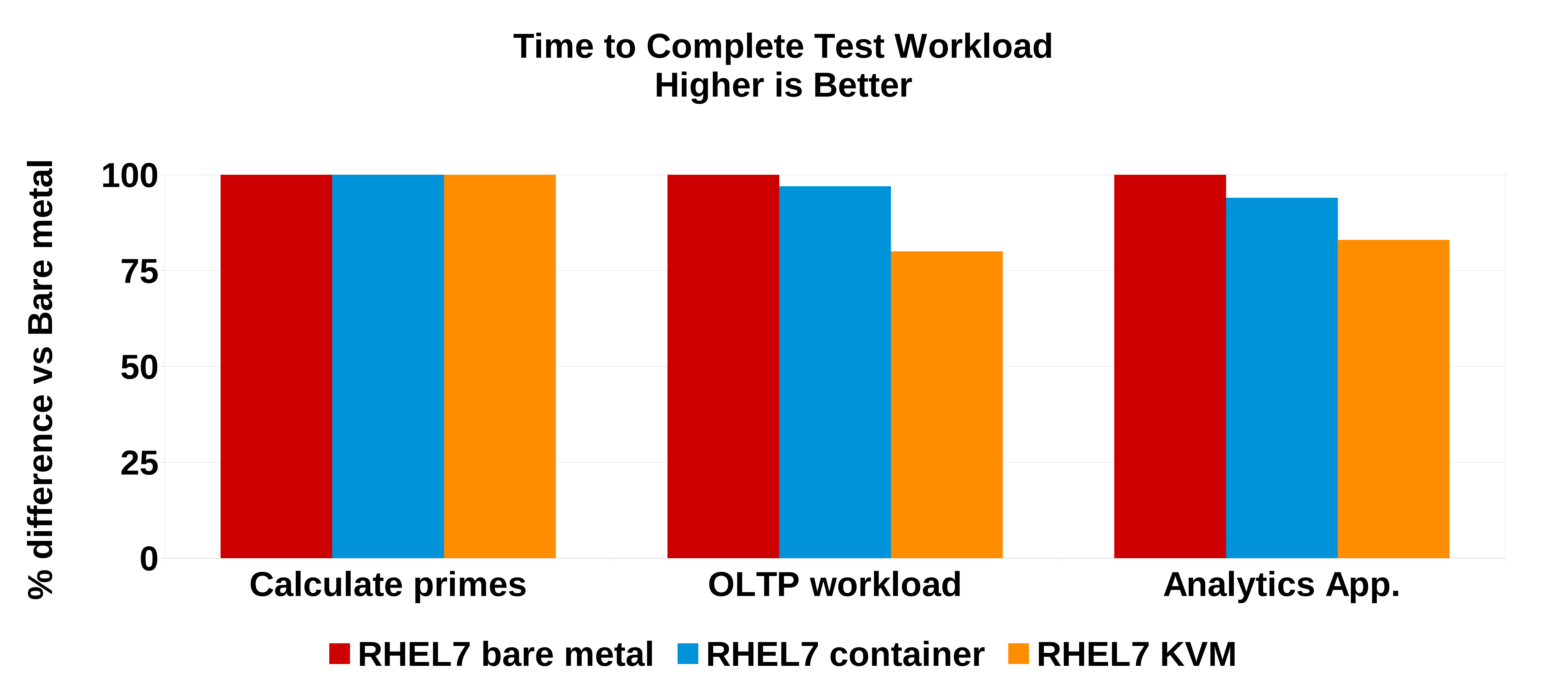
SAP Hana Test Suite in a container



Large OLTP Database, BM vs Container vs KVM



Container performance across multiple workloads



Network Performance
NFV
Realtime

Visualize CPUs via lstopo (hwloc-gui rpm)

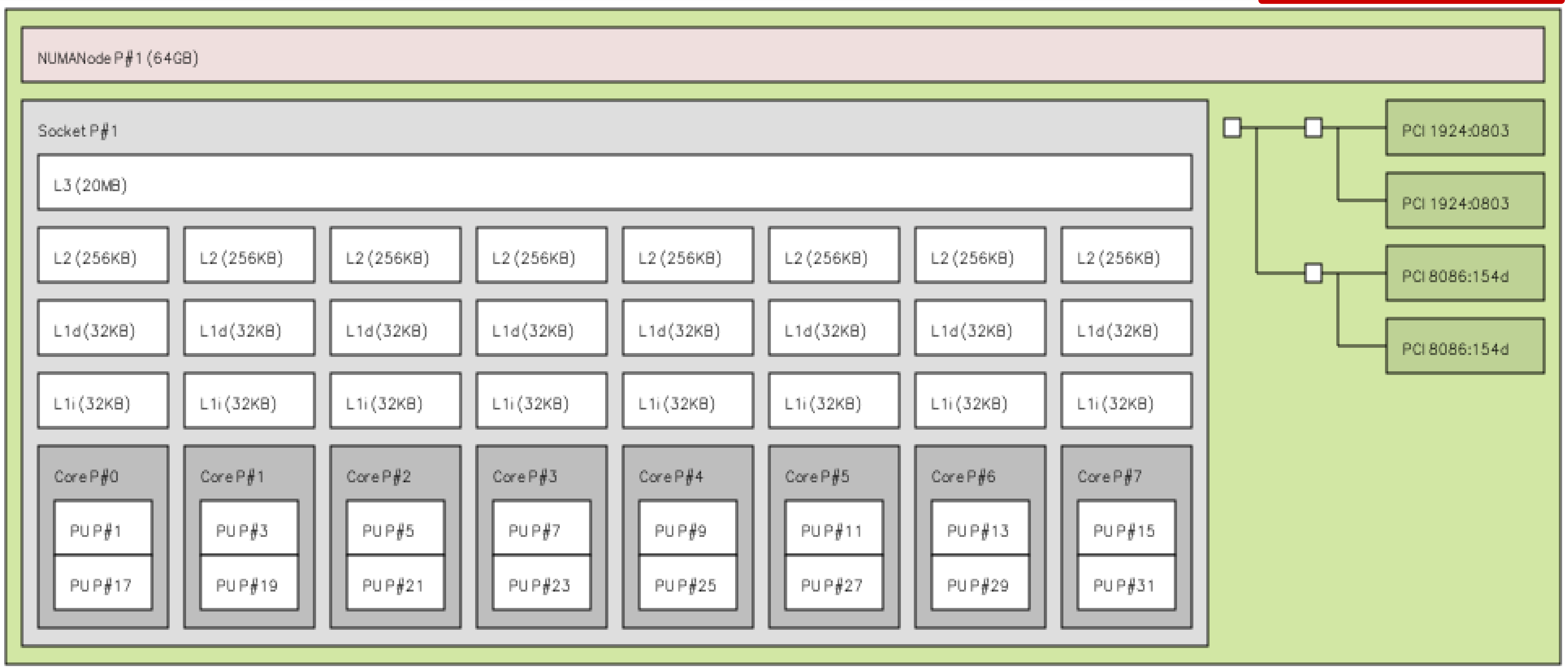
```
# lstopo
```

PCIe

NUMA

CACHE

HT



Realtime, Realtime KVM/NFV Tuned Profiles

Parents

latency-performance

Children

network-latency

Children/Grandchildren

realtime

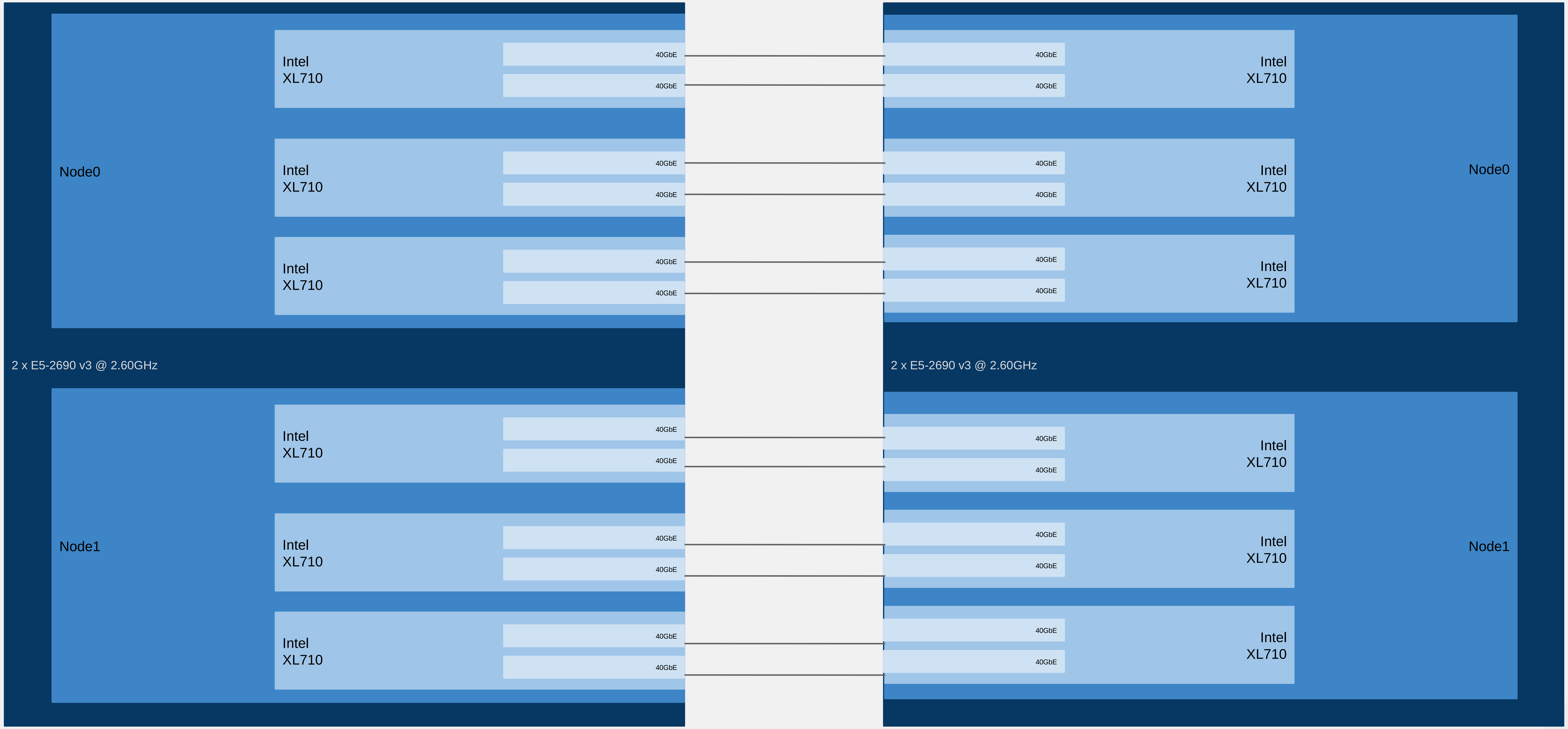
realtime-virtual-host

realtime-virtual-guest

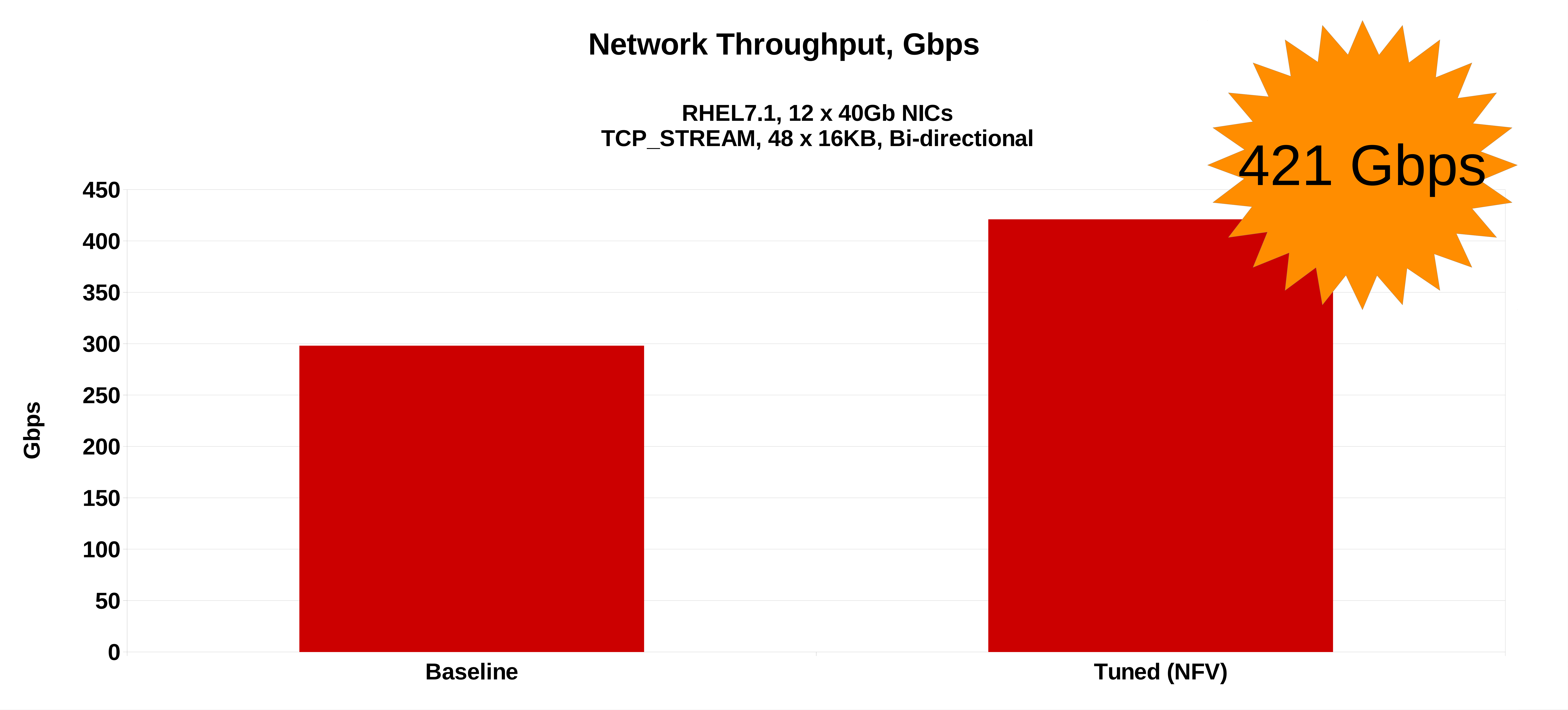
Networking Latency Performance – System setup

- Evaluate the 2 new tuned profiles for networking
- Disable unnecessary services, runlevel 3
  - Follow vendor guidelines for BIOS Tuning
  - Logical cores? Power Management? Turbo?
- In the OS, consider
  - Disabling filesystem journal
  - SSD/Memory Storage
  - Reducing writeback thresholds if your app does disk I/O
  - NIC Offloads favor throughput

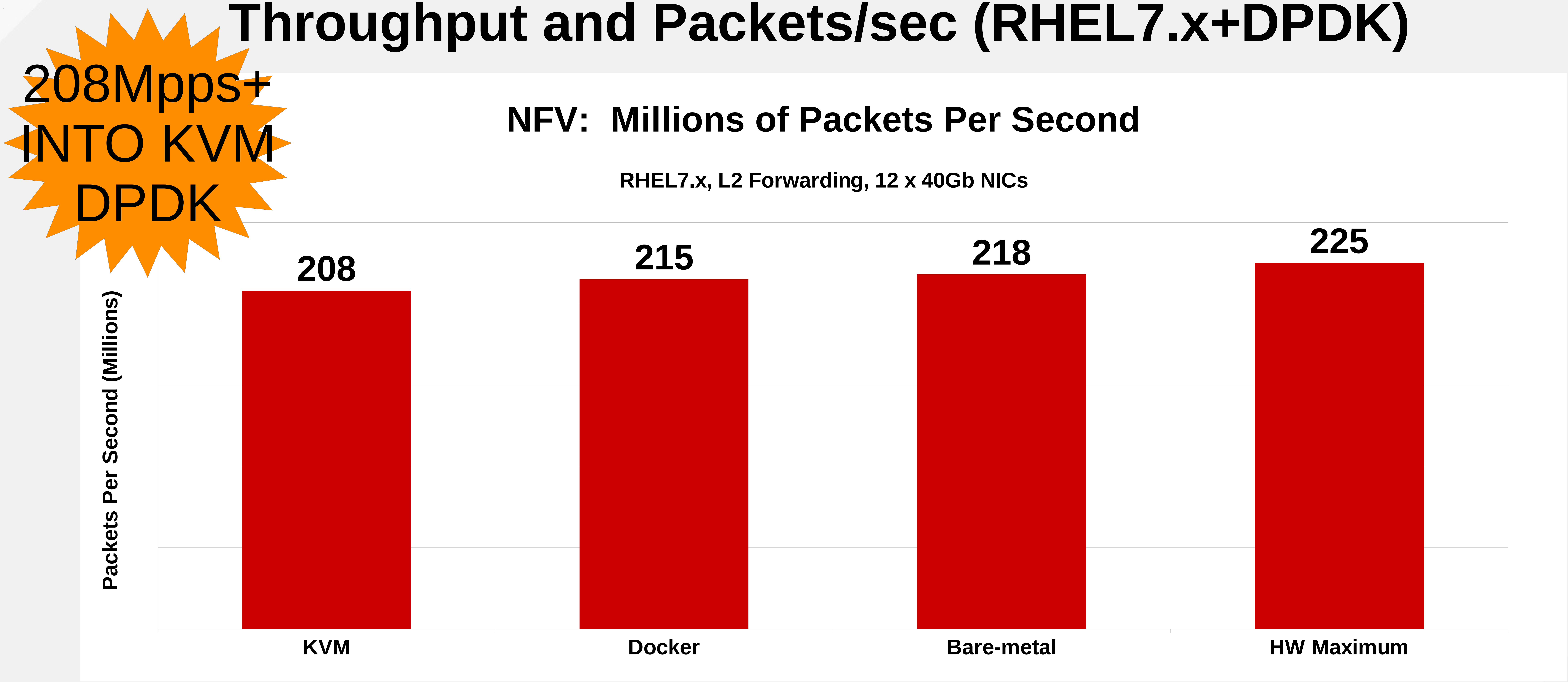
RHEL 7.x Network Performance
Intel Haswell EP, 12-40Gb ports (6 cards)



40G Network Data/Tuned Networks



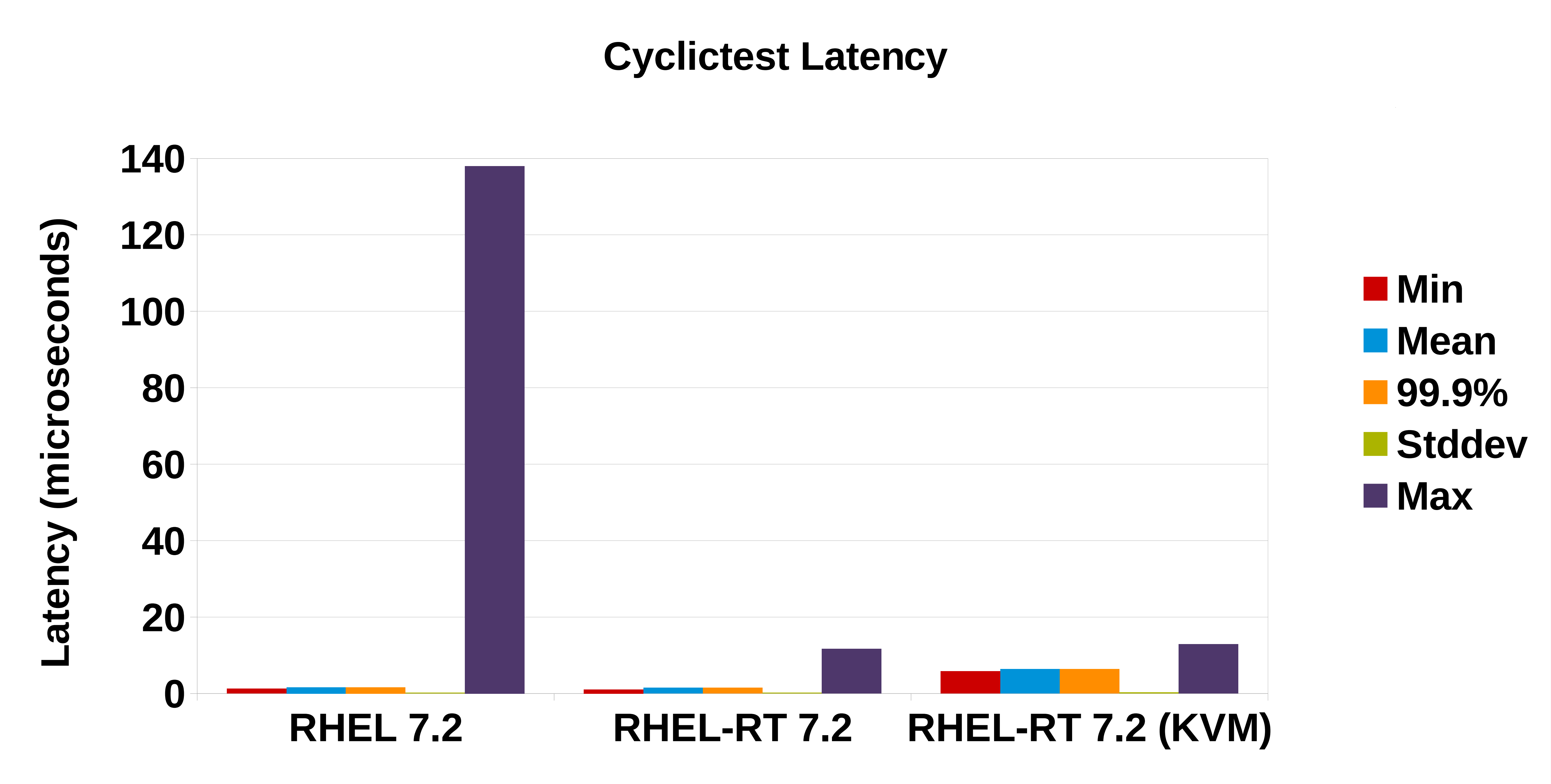
Network Function Virtualization (NFV) Throughput and Packets/sec (RHEL7.x+DPDK)



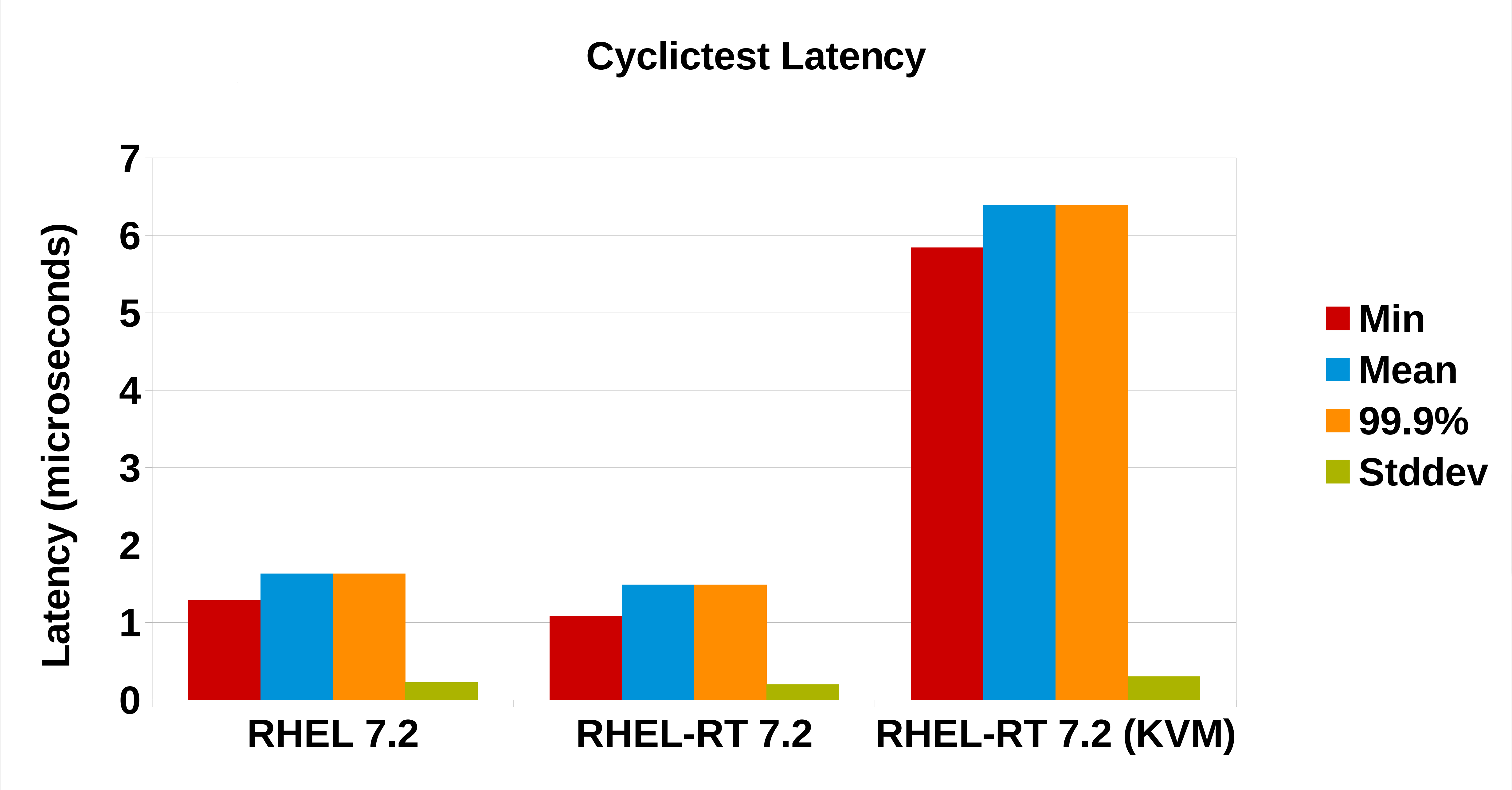
421 Gbps
Kernel

208Mpps+
INTO KVM
DPDK

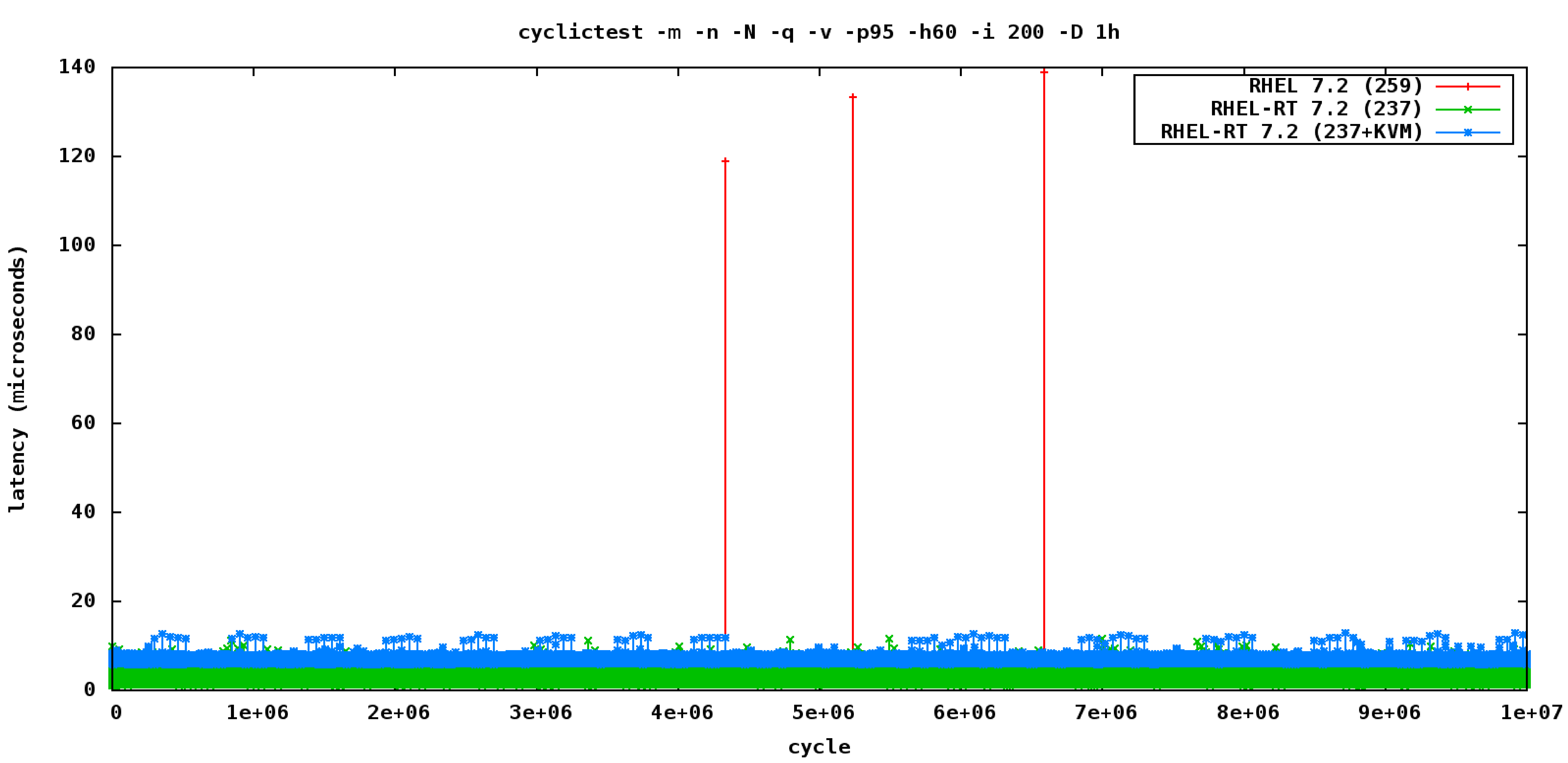
Scheduler Latency (cyclictest)



Remove maxes to zoom in

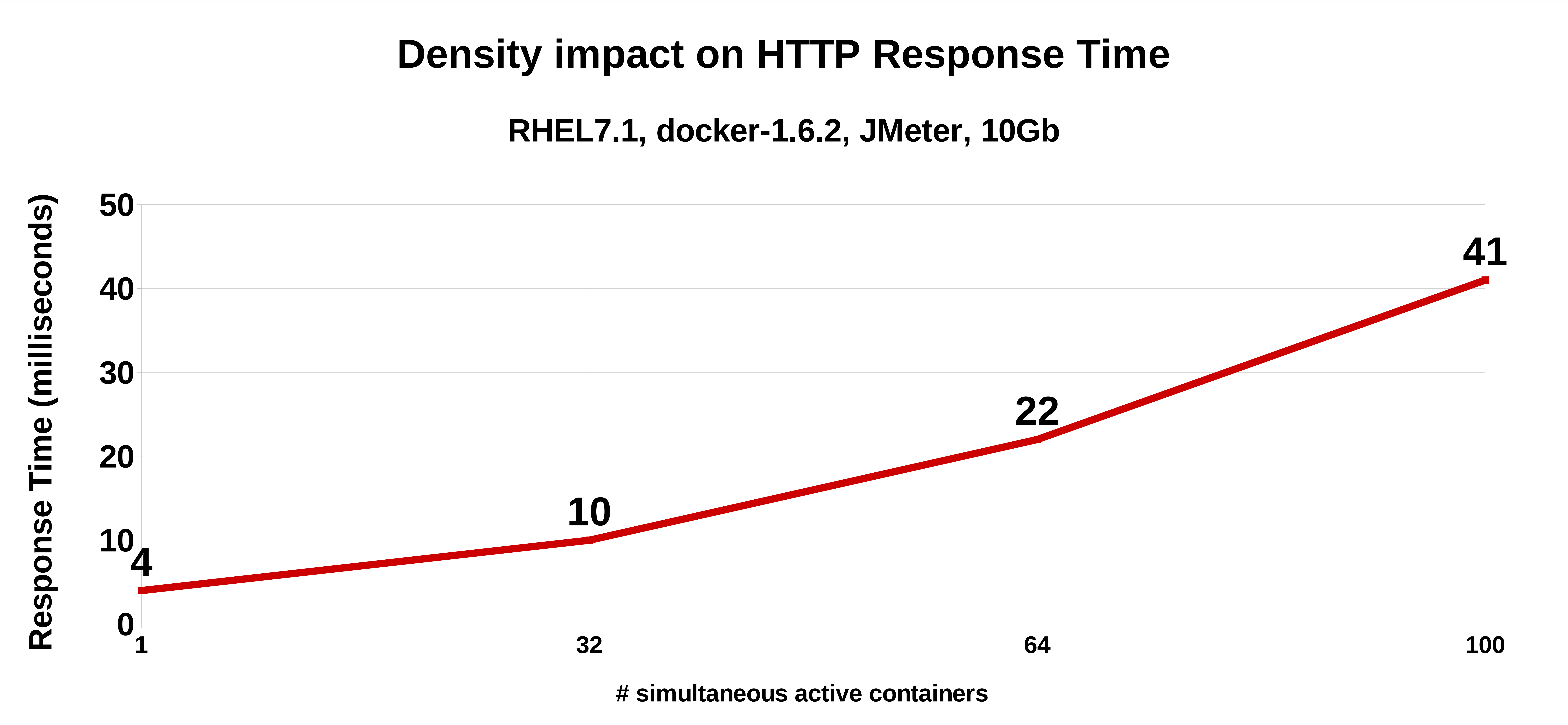


Realtime Scheduler Latency Jitter Plot

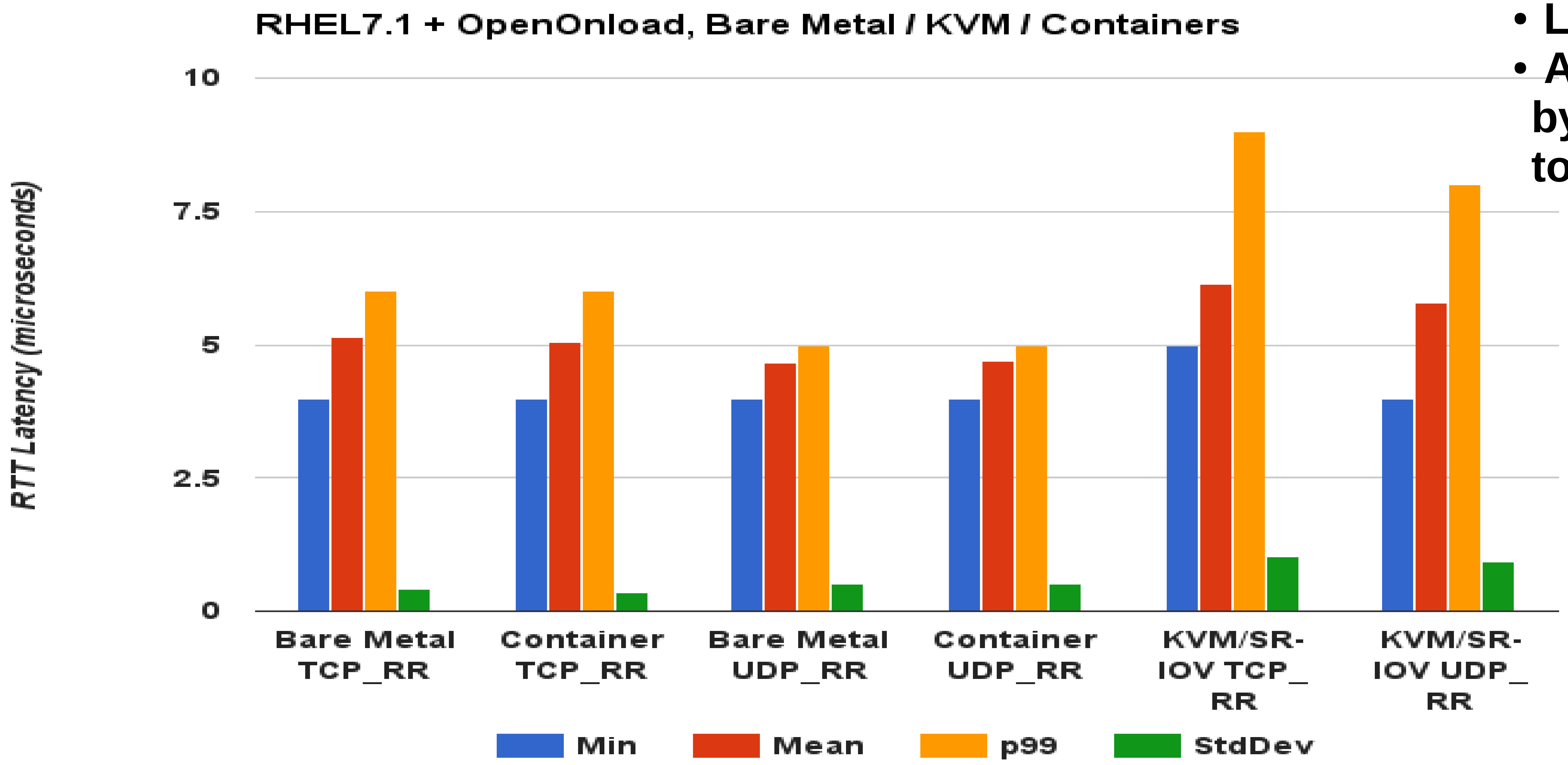


10 Million Samples

OpenShift JMeter



RHEL7.1 + Solarflare OpenOnload Bare Metal / KVM / Containers



- Lower is better
- Alternative kernel-bypass mechanism to DPDK

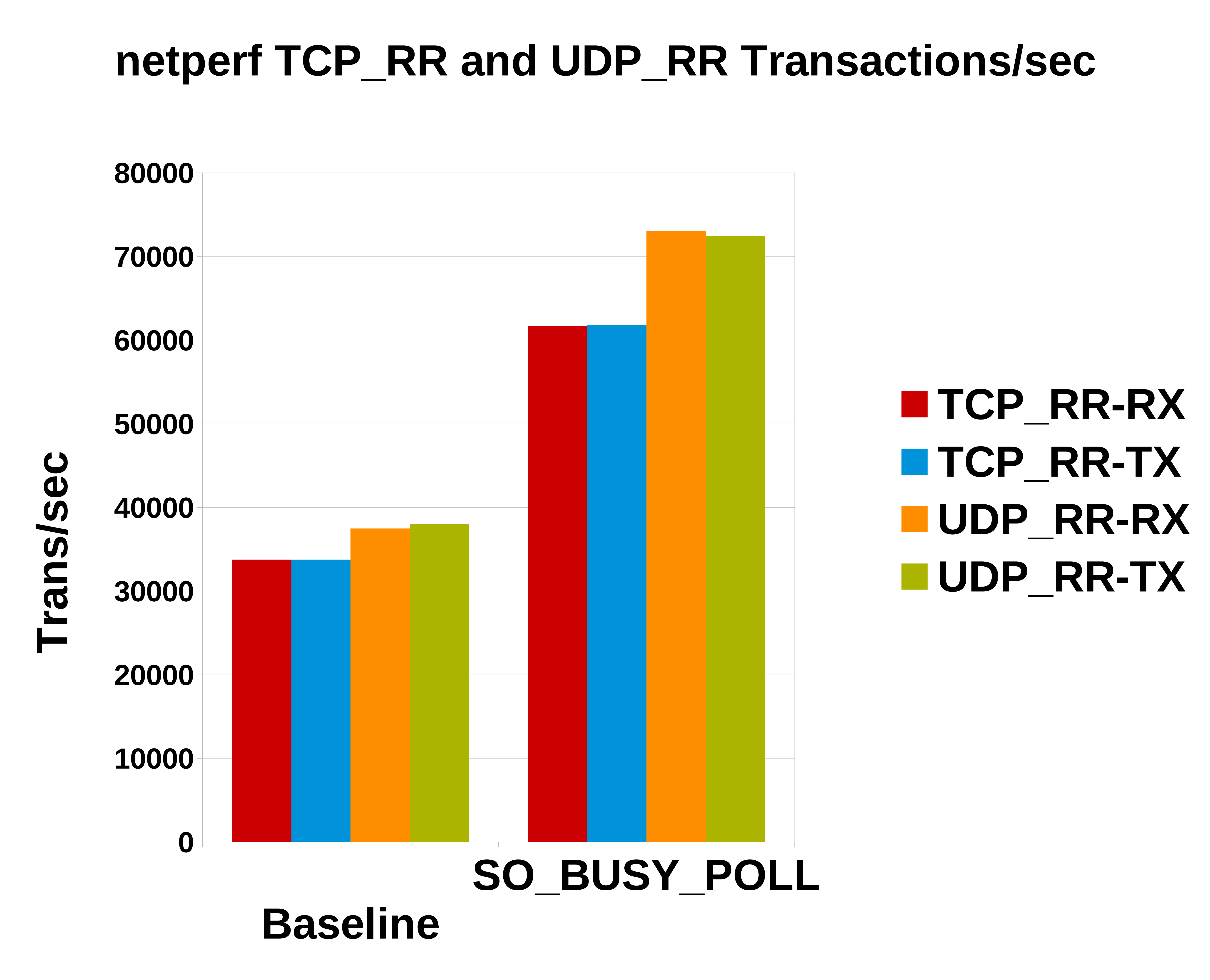
RHEL7 nohz_full

- 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)

RHEL7 BUSY_POLL Socket Options

- Socket-layer code polls receive queue of NIC
- Replaces interrupts and NAPI
- Retains full capabilities of kernel network stack



Turbostat: Idle States and Frequencies on Intel CPUs

```
# tuned-adm profile throughput-performance
# turbostat sleep 5
 Bzy_MHz TSC_MHz      SMI  CPU%c1  CPU%c3  CPU%c6
    1866    2600        0    0.22    0.01   99.71
```

```
# tuned-adm profile network-latency
# turbostat sleep 5
 Bzy_MHz TSC_MHz      SMI  CPU%c1  CPU%c3  CPU%c6
    3108    2600        0   99.99    0.00    0.00
```

Disk I/O in RHEL

I/O Tuning – Understanding I/O Elevators

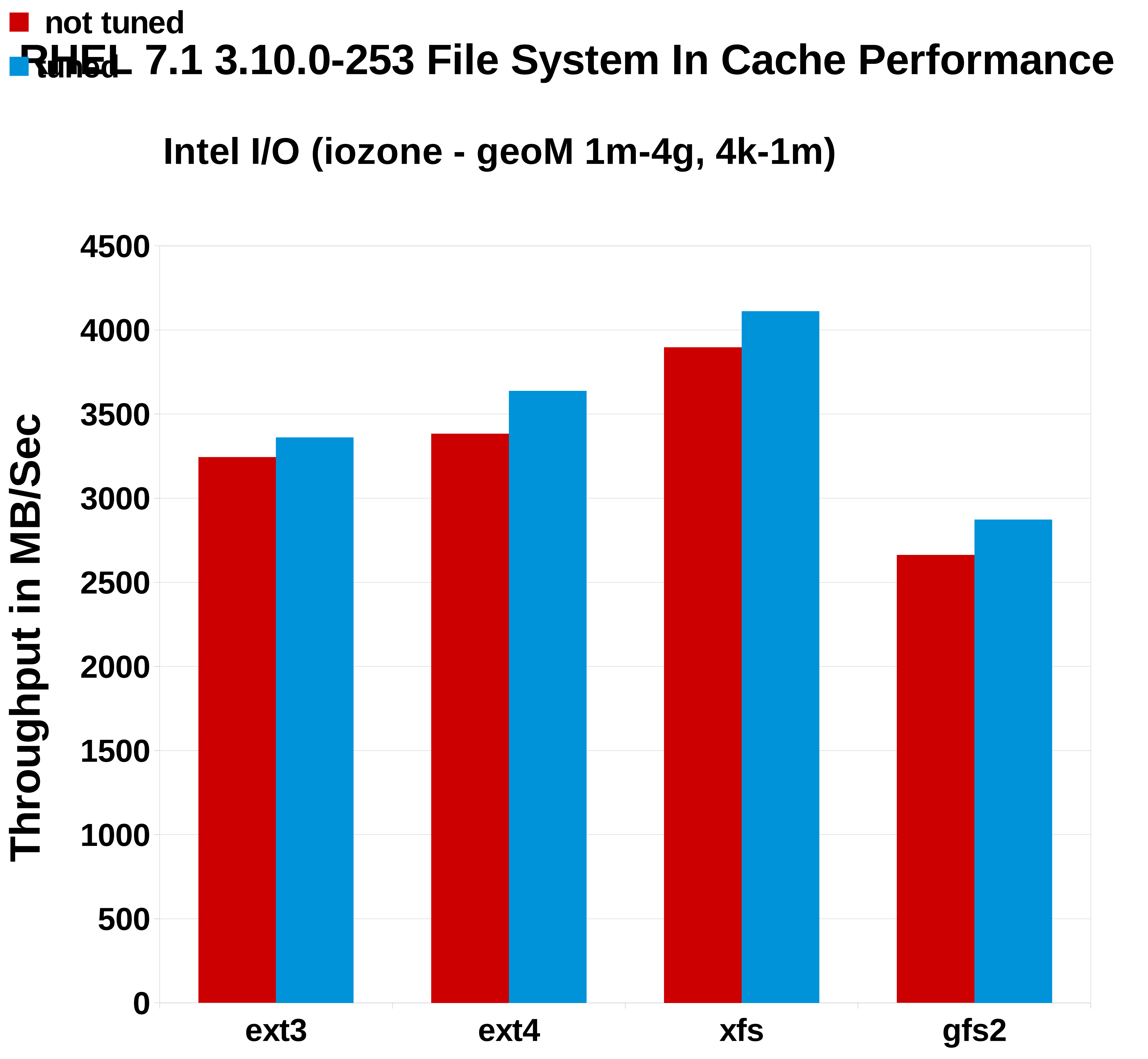
- Deadline – new RHEL7 default for all profiles
  - Two queues per device, one for read and one for writes
  - I/Os dispatched based on time spent in queue
- CFQ – used for system disks off SATA/SAS controllers
  - Per process queue
  - Each process queue gets fixed time slice (based on process priority)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

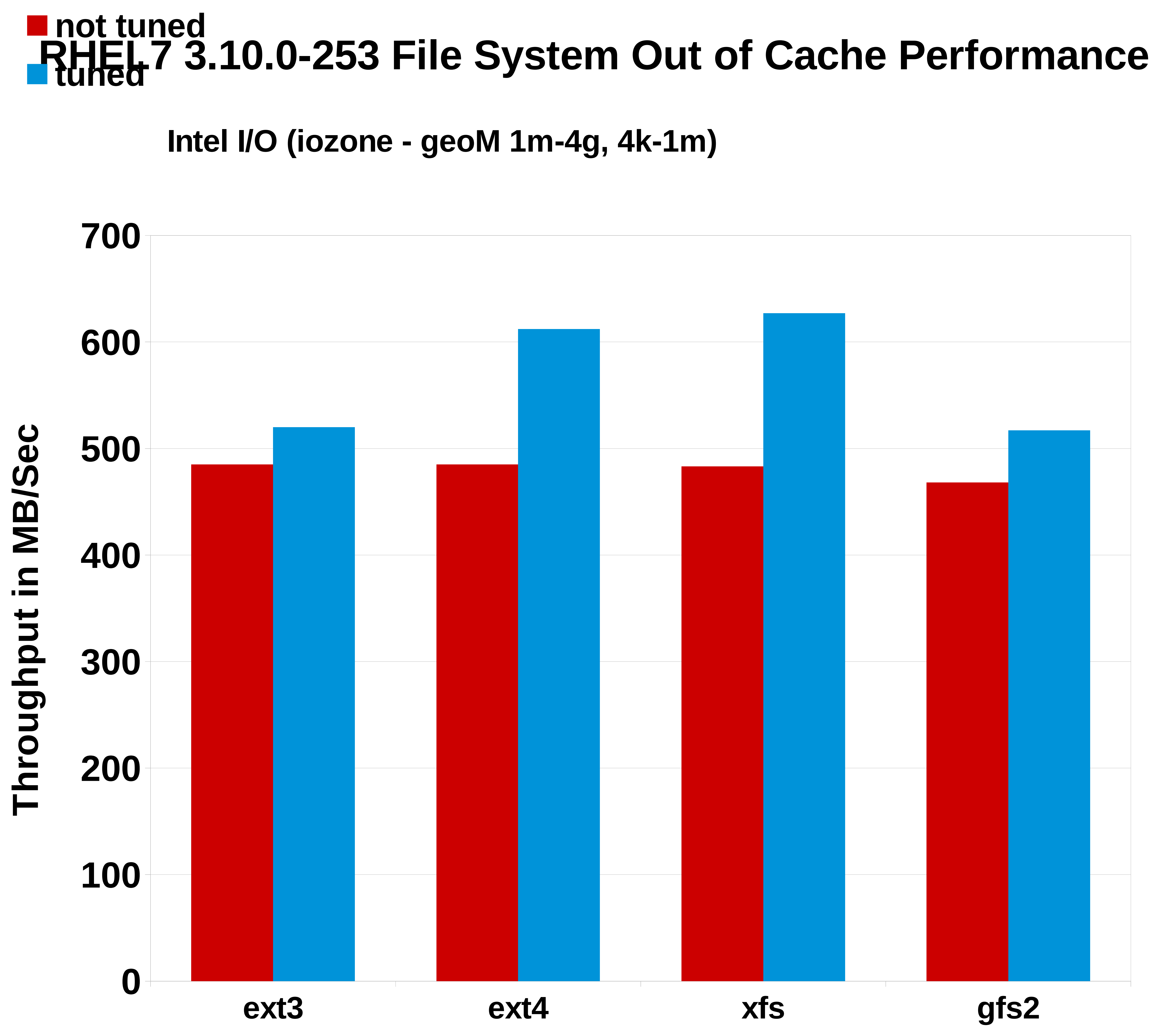
Tuned: Profile throughput-performance (RHEL7 default)

throughput-performance

governor=performance
energy_perf_bias=performance
min_perf_pct=100
readahead=4096
kernel.sched_min_granularity_ns = 10000000
kernel.sched_wakeup_granularity_ns = 15000000
vm.dirty_background_ratio = 10
vm.swappiness=10

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





SAS Application on Standalone Systems

RHEL 7 limits

xfs **most** recommended

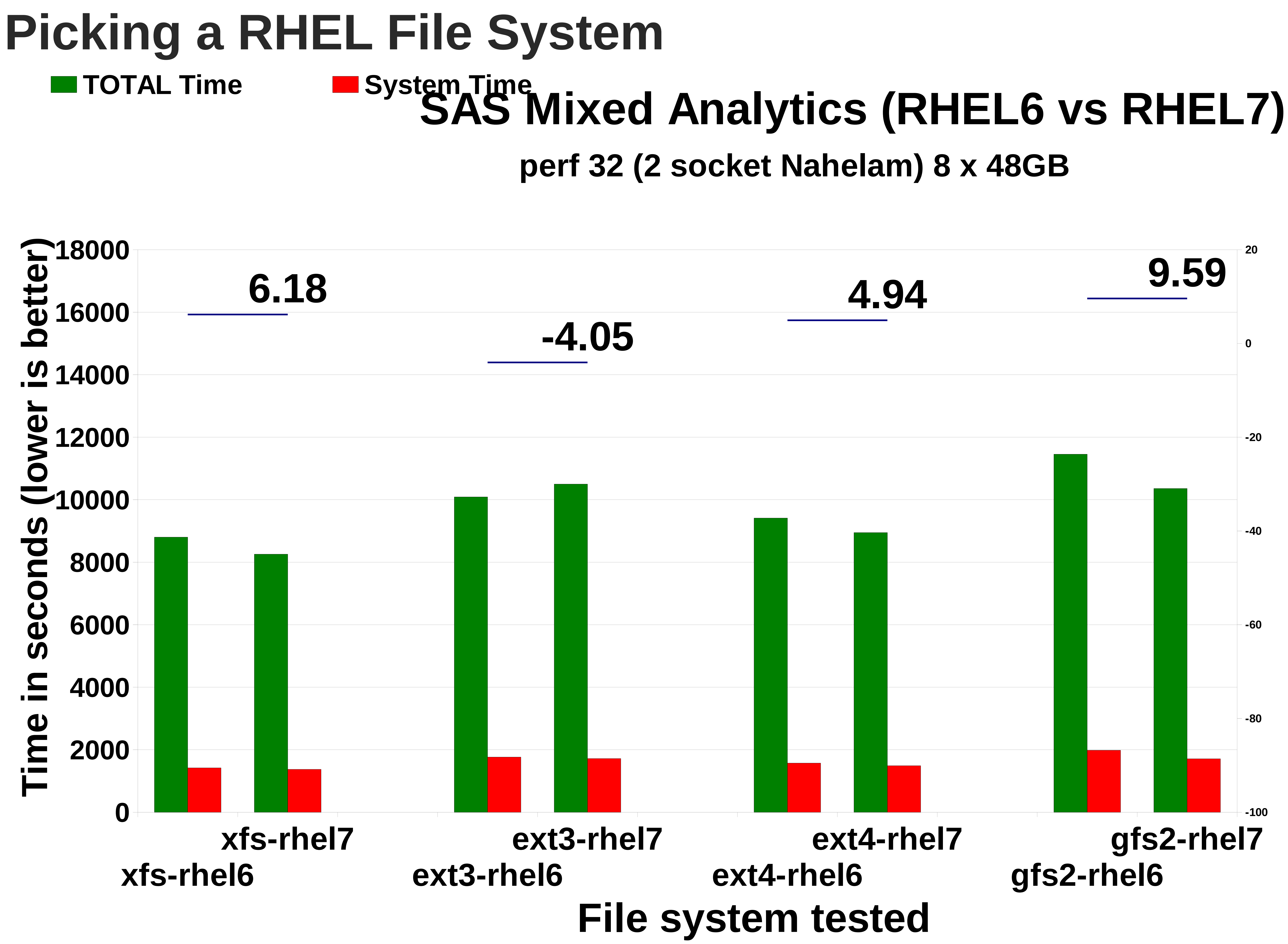
- Max file system size 500TB
- Max file size 100 TB
- Best performing

ext4 recommended

- Max file system size 50 TB
- Max file size 16 TB

ext3 not recommended

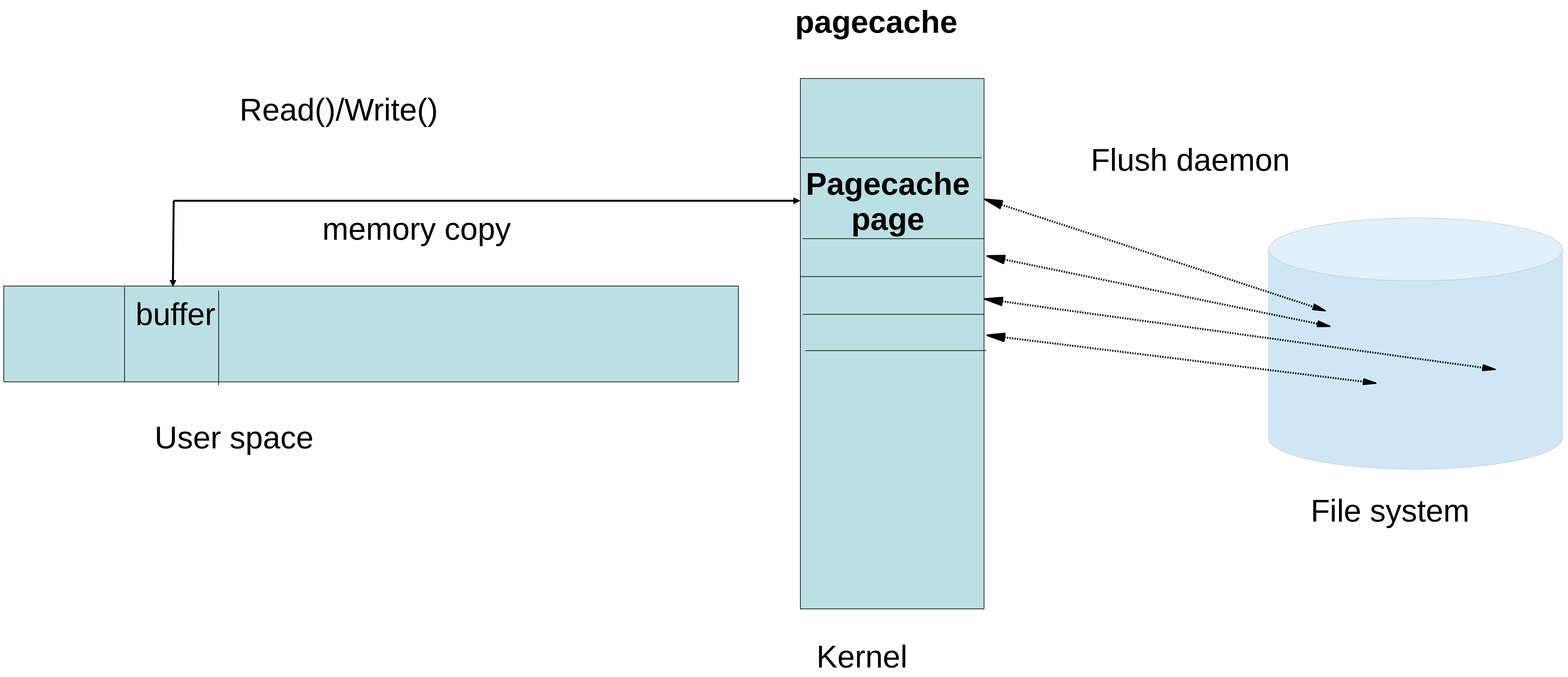
- Max file system size 16TB
- Max file size 2TB



Tuning Memory – Flushing Caches

- Drop unused Cache – to control pagecache dynamically
  - ✔Frees most pagecache memory
  - ✔File cache
  - ✗If the DB uses cache, may notice slowdown
- NOTE: Use for benchmark environments.
- **Free pagecache**
  - **# sync;** echo 1 > /proc/sys/vm/drop_caches
- **Free slabcache**
  - # sync; echo 2 > /proc/sys/vm/drop_caches
- **Free pagecache and slabcache**
  - # sync; echo 3 > /proc/sys/vm/drop_caches

Per file system flush daemon



Virtual Memory Manager (VM) Tunables

- **Reclaim Ratios**
  - /proc/sys/vm/swappiness
  - /proc/sys/vm/vfs_cache_pressure
  - /proc/sys/vm/min_free_kbytes
- **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.
- 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 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

RED HAT SUMMIT

BOSTON, MA
JUNE 23-26, 2015

RHEL Performance in Cloud

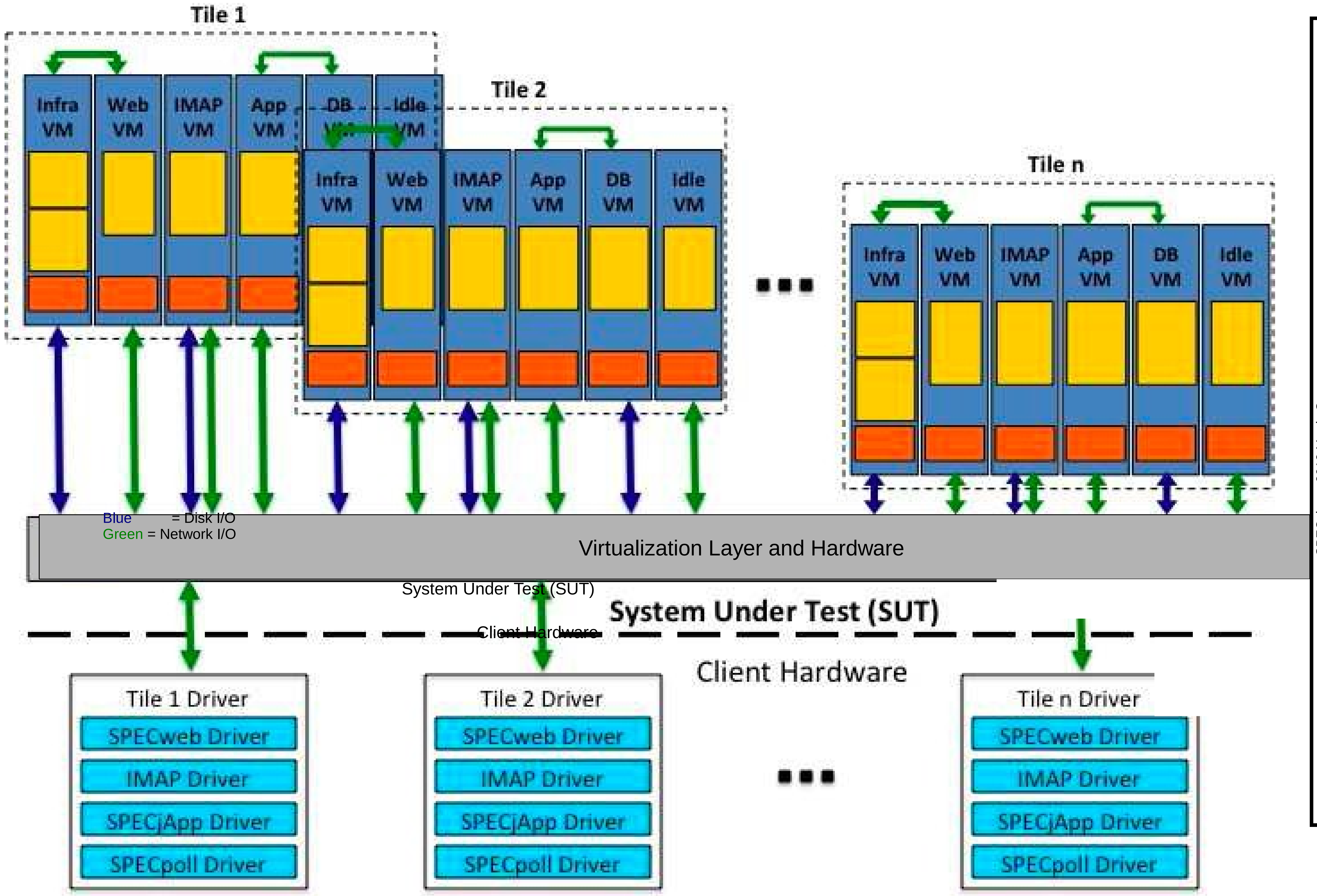
RHEL Platforms (RHEV/ OpenStack)

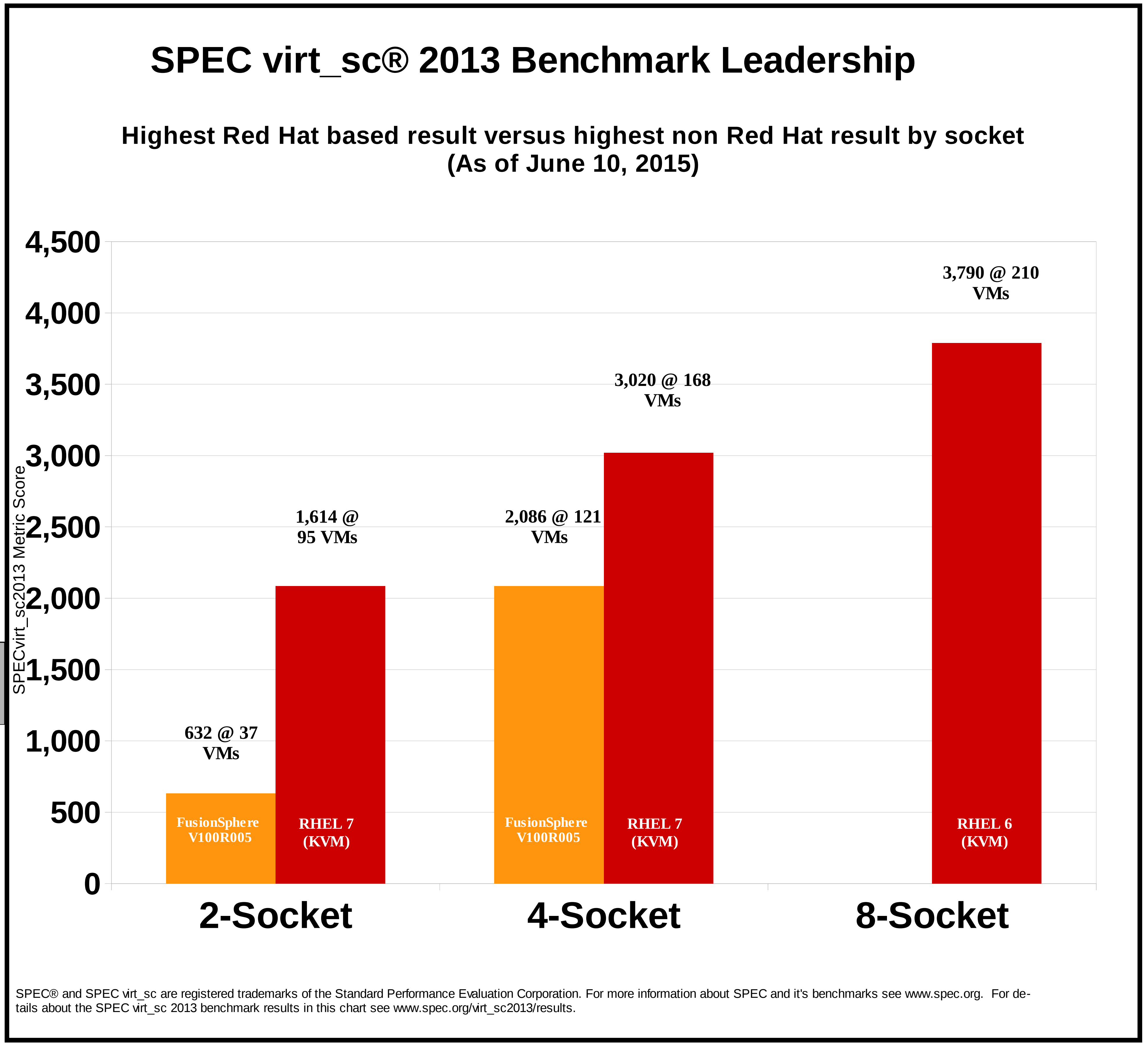
- **RHEV**
  - KVM Performance
    - SPECvirt leadership
      - Vcpu ping
      - NUMA binding
      - Hugepages 2MB + 1GB
    - Low Latency SR-IOV
    - High Throughput via
      - DPDK

- **RH OpenStack Platform**
  - Control Plane
    - Keystone
    - Database / HA
    - Messaging / HA
    - Ceilometer
  - Data Plane
    - Nova
    - Neutron / HA
    - Cinder/ Swift

- **OpenShift**
  - V3 LXC / containers
- **RH Storage**
  - Gluster file w/ RHEV /OSP
  - Ceph Block w Cinder
    - Block (librados)
    - w/ SSD block storage

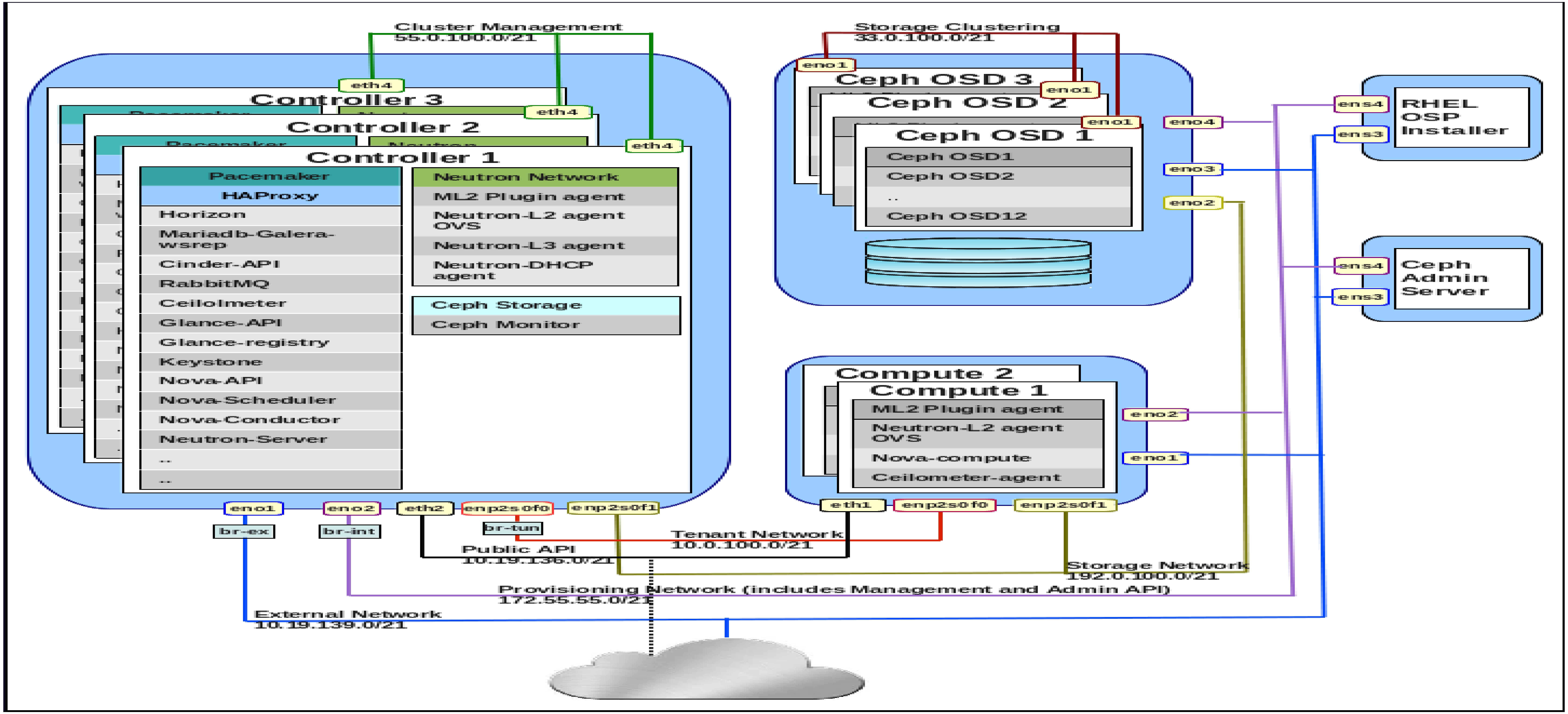
SPECvirt_sc2013: *RHEL 6/7 and KVM Post Industry Leading Results*





http://www.spec.org/virt_sc2013/results/

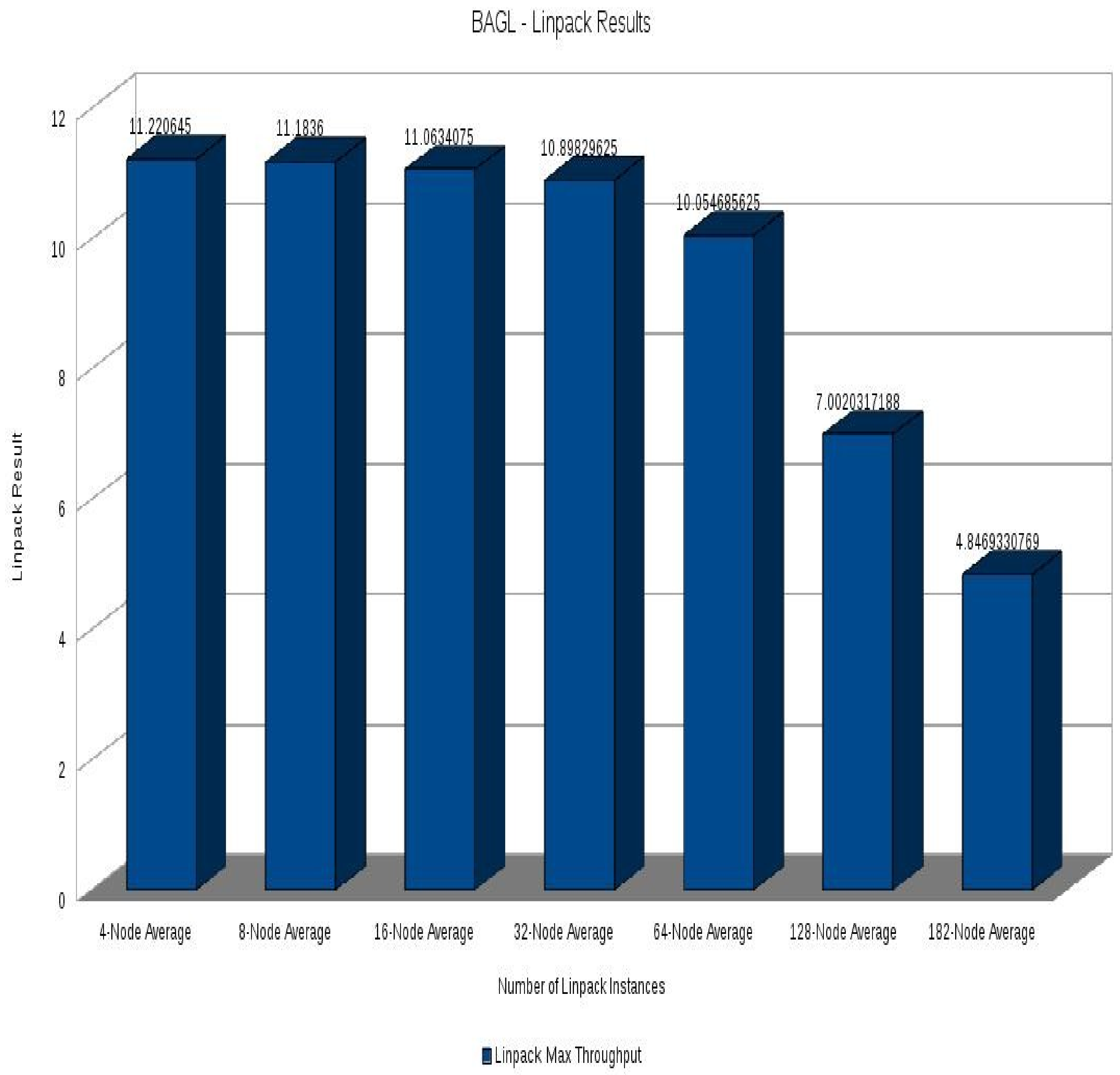
RHEL OSP 5/6 – Architecture - https://access.redhat.com/articles/1321163



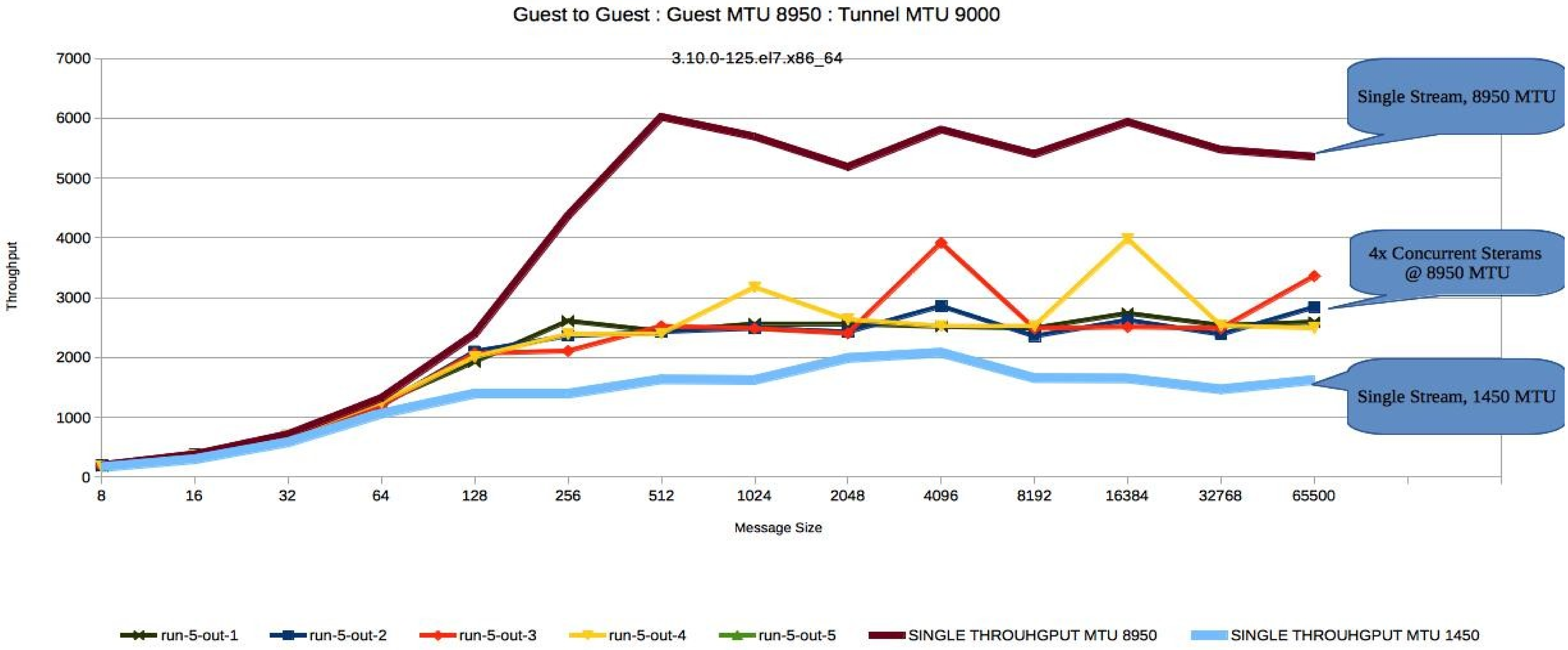
Performance Tuning RHEL OSP5/ R7

General tuning:

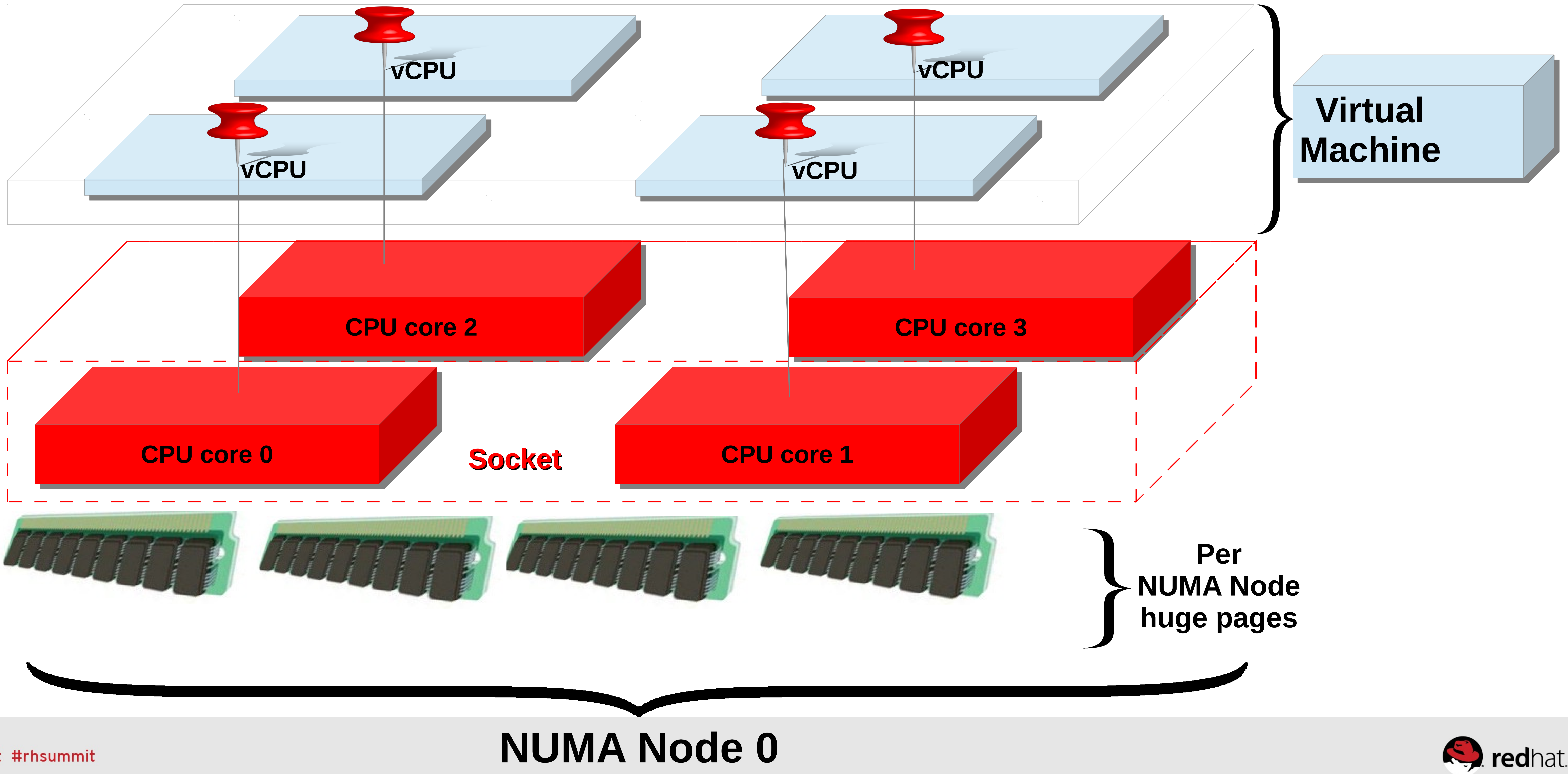
- **Disable BIOS power**
  - switch to OS controlled/prtg
- **Tuned-adm**
  - Default for OSP 4/5 has been “throughput-performance”
  - NFV - latency sensitive loads should consider
    - Alter cstate to contant 1 through the latency profiles
    - R6 - profile latency-performance
    - R7 - profile network-latency



Neutron Performance / Network Performance / VxLAN OVS

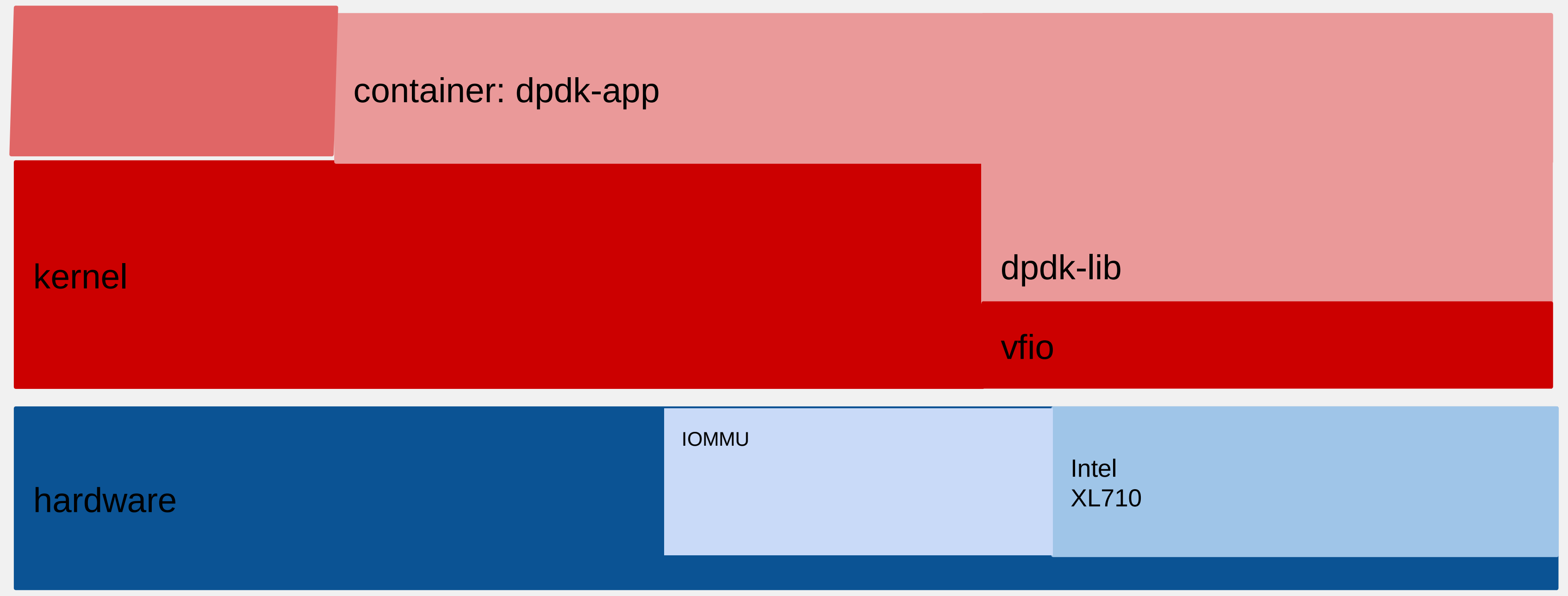


NUMA Pinning and Topology Awareness – RHEL OSP 6



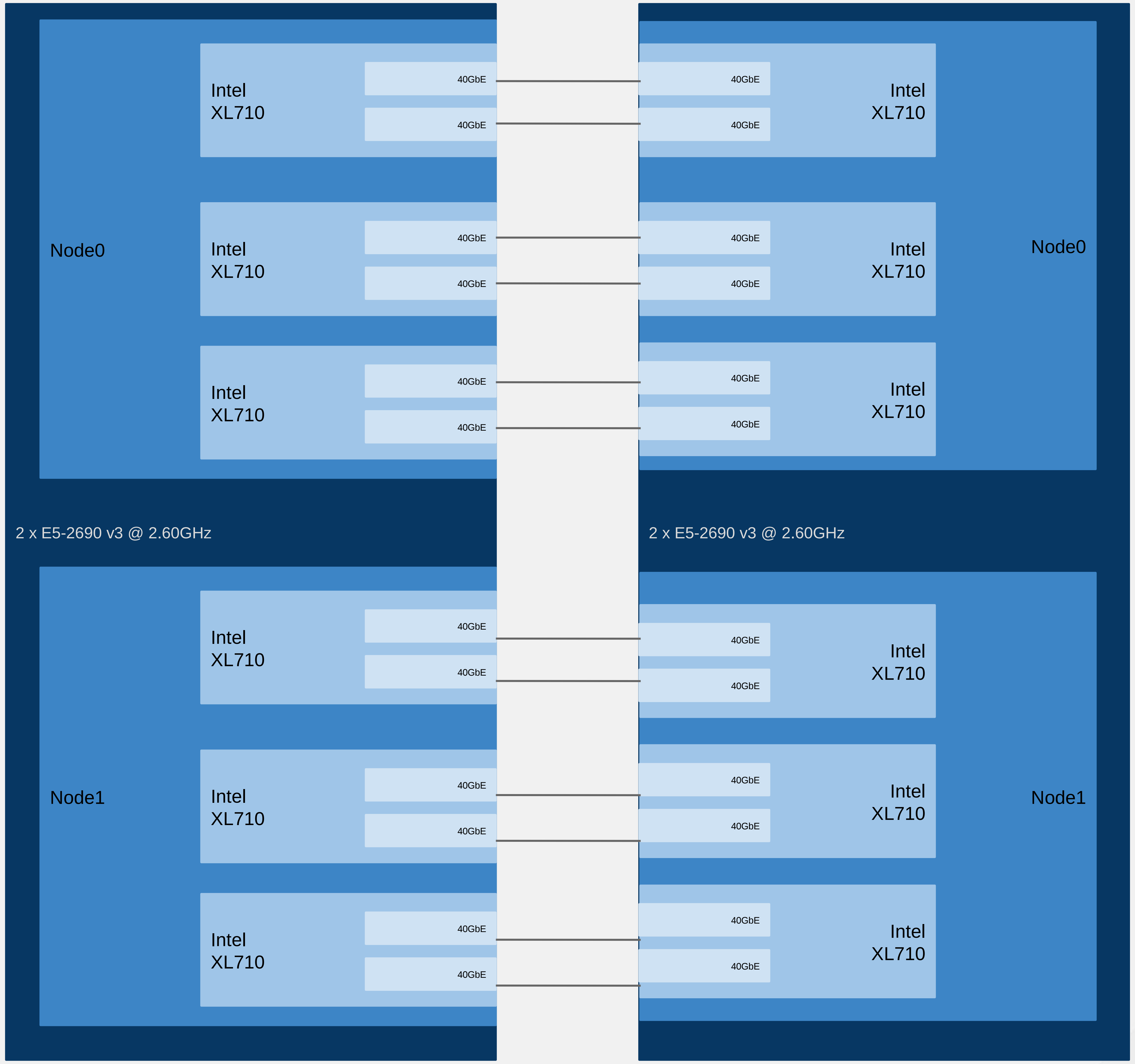
RHEL 7.x w/ OSP / Network - DPDK OVS

Configurations: BM / Atomic/KVM



- Boot options
  - CPU cstate=1
  - Reserve 1GB hugepages
  - isolate CPUs

- Current software versions tested:
  - dpdk-2.0.0-6
  - pktgen-dpdk-2.8.4
  - openvswitch-2.3.90-10031.gitf097013a.3



RHEL7.x Network Function Virtualization (NFV)

Throughput and Packets/sec @ 64Bytes (RHEL7.x+DPDK)

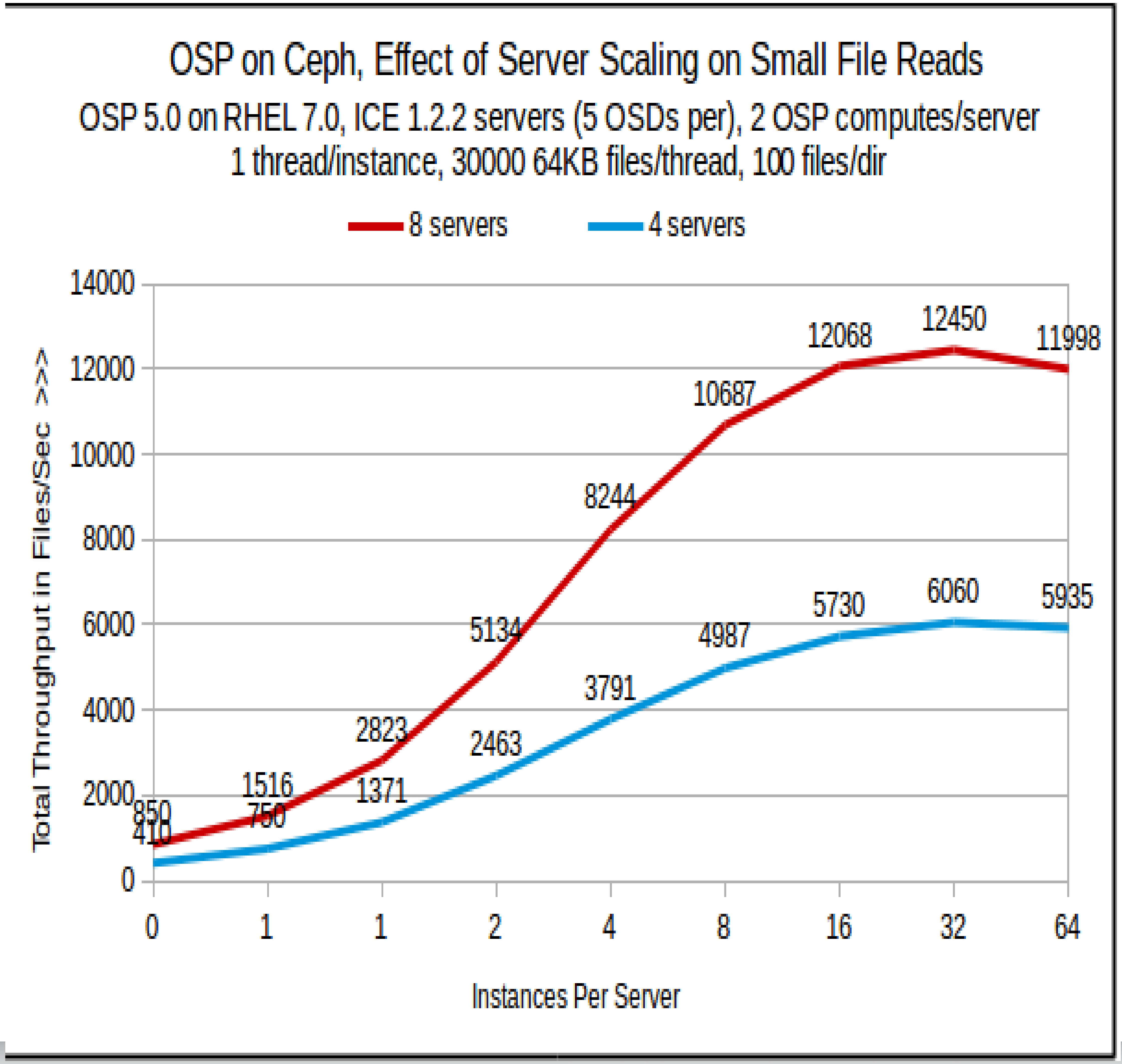
- Bare-Metal
  - DPDK application runs right on bare-metal, forwarding packets between port pair in all XL710 adapters
  - Two cores per adapter used
  - **218 Million packets per second processed**
- Atomic Containers
  - VFIO module loaded in host (bare-metal)
  - Docker container launched
  - Docker container includes only software to run DPDK app
  - Docker container given access to /dev/vfio devices
  - Two cores per adapter used, twelve cores total
  - **215 Million packets per second processed**
- KVM
  - Six VMs created, 1 per network adapter
  - Each VM configured for optimal performance
    - NUMA-node local I/O, CPU, and memory
    - VM memory backed with 1GB memory pages
  - Each VM assigned a network adapter
    - (2 physical functions)
    - **Under 5% performance impact using KVM**
  - **208 Million packets per second processed**

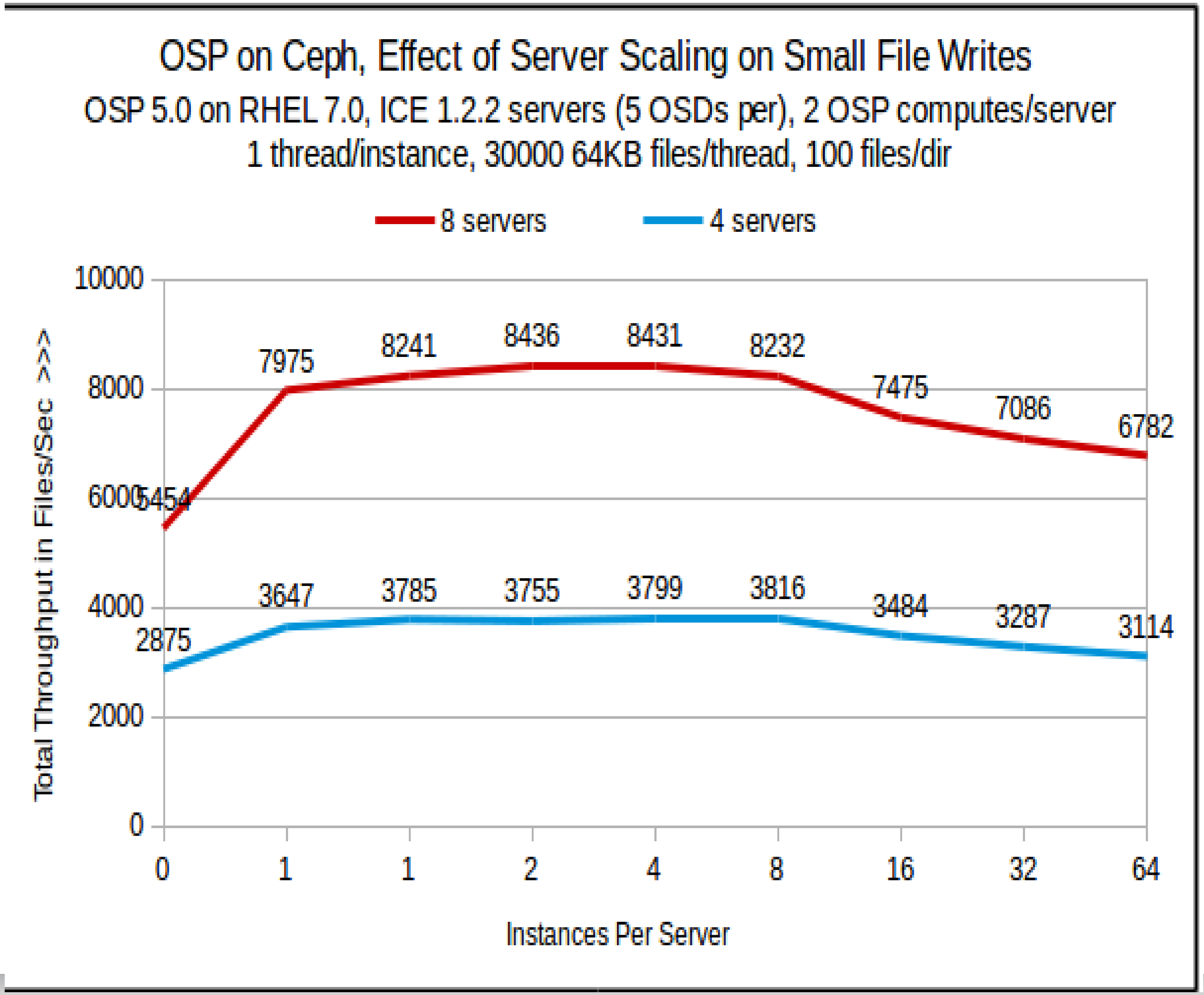
Haswell EP,, 48p Intel 6-40Gb	1-port Mpps	Total Mpps
RHEL 7.beta	18.1	218
RHEL w/ Atomic 12 containers-PT	17.9	215
RHEL w/ KVM 6 Vms - PT	17.3	208

RHEL RHS Tuning w/ RHEV/RHEL OSP (tuned)

- **Ceph and Gluster – (visit Summit talks)**
- XFS mkfs -n size=8192, mount inode64, noatime
- RHS server: **tuned-adm profile rhs-virtualization**
  - Increase in readahead, lower dirty ratio's
- KVM host: **tuned-adm profile virtual-host**
  - Better response time shrink guest block device queue
    - `/sys/block/vda/queue/nr_request (16 or 8)`
  - Best sequential read throughput, raise VM read-ahead
    - `/sys/block/vda/queue/read_ahead_kb (4096/8192)`

Ceph Block Perf – scale 4 to 8 ceph servers
https://access.redhat.com/articles/1321163





SELinux

- Run representative set of benchmarks
- A:B comparison (SELinux enabled/disabled)
- Provide % difference between runs
- ***Overhead 0-5%.***

Tests run:

- LINPACK, STREAMS, SPECJBB2005
- SPECJBB2015, IOZONE, Phoronix Apache Bench
- Oracle OLTP, Oracle OLTP+NFS, DB2

RHEL7 Performance Tuning Summary

- **Use “Tuned”, “NumaD” and “Tuna” in RHEL6 and RHEL7**
  - Power savings mode (performance), locked (latency)
  - Transparent Hugepages for anon memory (monitor it)
  - numabalance – Multi-instance, consider “NumaD”
  - Virtualization – virtio drivers, consider SR-IOV
- **Manually Tune**
  - NUMA – via numactl, monitor numastat -c pid
  - Huge Pages – static hugepages for pinned shared-memory
  - Managing VM, dirty ratio and swappiness tuning
  - Use cgroups for further resource management control

Upcoming Performance Talks

1) Wednesday, Jun 24, 4:50 PM: Performance tuning Red Hat Enterprise Linux Platform for databases, Ballroom A
2) Wednesday, Jun 24, 6:00 PM: Performance analysis & tuning: An interactive mixer, Room 202
3) Thursday, Jun 25, 10:40 AM: Red Hat Storage performance, Room 310
4) Thursday, Jnu 25, 4:50 PM: Performance of OpenStack Cinder on Ceph, Room 310
5) Thursday, Jun 25, 4:50 PM: Cloud Architecture and Performance, Room 313
6) Friday, Jun 26, 9:45 AM: Containers versus virtualization, 302

Performance Utility Summary

Supportability

- redhat-support-tool
- sos
- kdump
- perf
- strace
- sysstat
- systemtap
- trace-cmd
- util-linux-ng
- pcp

NUMA

- hwloc
- Intel PCM
- numactl
- numad
- numatop (01.org)

Power/Tuning

- kernel-tools
- powertop/cpupower
- tuna
- tuned

Networking

- ss
- dropwatch
- ethtool
- netsniff-ng (ifpps)
- tcpdump
- wireshark/tshark

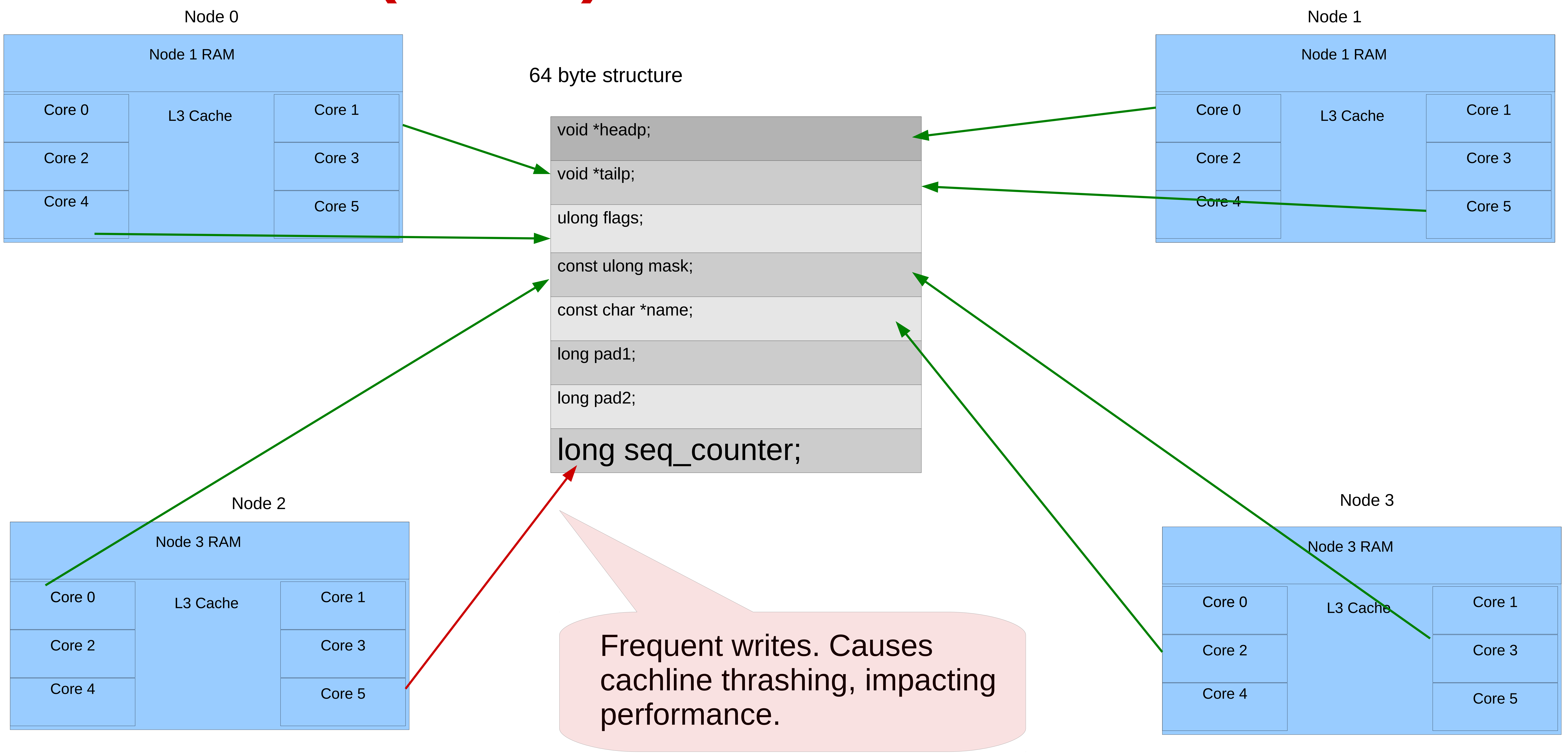
Storage

- blktrace
- iotop
- iostat

Helpful Links

- Official Red Hat Documentation
- Red Hat Low Latency Performance Tuning Guide
- Low Latency Performance Tuning for RHEL7
- How do I create my own tuned profile on RHEL7 ?
- RHEL7: Optimizing Memory System Performance

False cacheline sharing.
Add writer (in red) – slows down all readers.



RED HAT SUMMIT

LEARN. NETWORK.
EXPERIENCE OPEN SOURCE.