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Performance Analysis & Tuning of Red Hat Enterprise Linux

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Agenda

Section 1 – System Overview

Section 2 - Analyzing System Performance

Section 3 - Tuning Red Hat Enterprise Linux

Section 4 – RHEL6 Tuning preview

Section 5 – Performance Analysis and Tuning Examples

References

Section 1 – System Overview

Processors

NUMA

Memory

I/O

Processors Supported/Tested

RHEL4

- x86 – 32
- x86_64 – 8, 64(LargeSMP)
- ia64 – 64, 512(SGI)

RHEL5

- x86 – 32
- x86_64 – 255
- ia64 – 64, 1024(SGI)

RHEL6

- x86 - 32
- x86_64 - 4096

Processor types

Uni-Processor

Symmetric Multi Processor

Multi-Core

Symmetric Multi-Thread(Hyper threaded)

Combinations

Processor types & locations

```
[root@intel-s3e36-01 node1]# cat /proc/cpuinfo
processor       : 0   <logical cpu #>

physical id     : 0   <socket #>

siblings        : 16 <logical cpus per socket>

core id         : 0   <core # in socket>

cpu cores       : 8   <physical cores per socket>


# cat /sys/devices/system/node/node*/cpulist
node0: 0-3
node1: 4-7
```


NUMA & Multi Core Support

Cpusets (2.6.12)

Enable CPU & Memory assignment to sets of tasks

Allow dynamic job placement on large systems

Numa-aware slab allocator (2.6.14)

Optimized locality & management of slab creation

Swap migration. (2.6.16)

Swap migration relocates physical pages between nodes in a NUMA system while the process is running – improves performance

Huge page support for NUMA (2.6.16)

Netfilter ip_tables: NUMA-aware allocation (2.6.16)

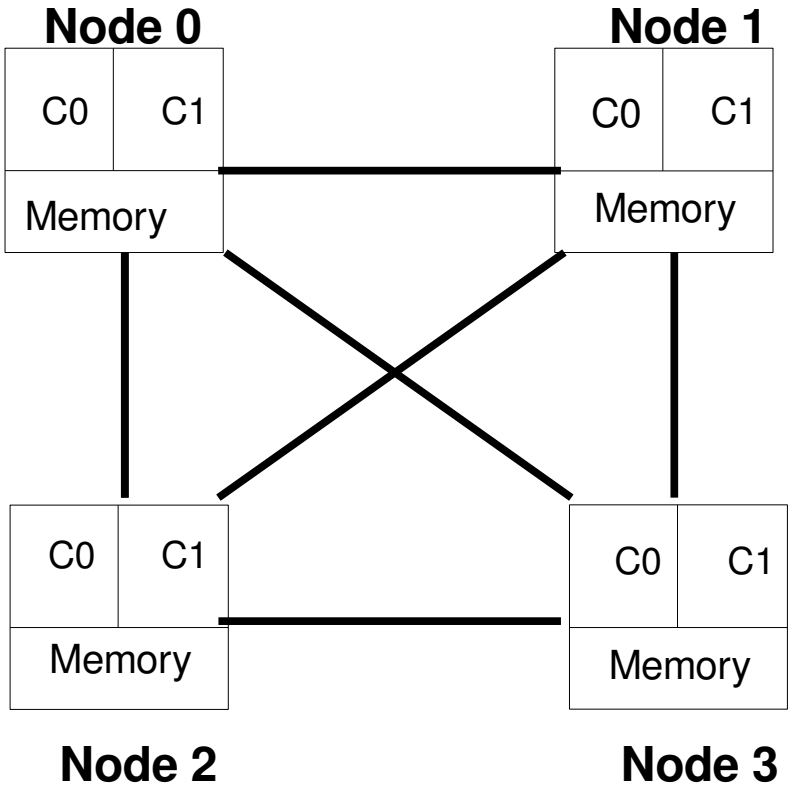
Multi-core

Scheduler improvements for shared-cache multi-core systems (2.6.17)

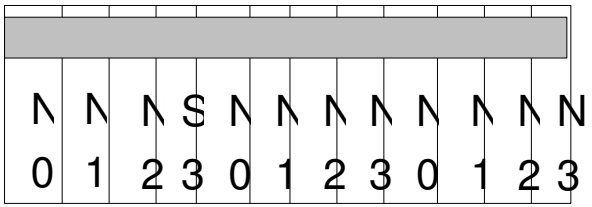
Scheduler power saving policy

Power consumption improvements through optimized task spreading

Typical NUMA System Layout

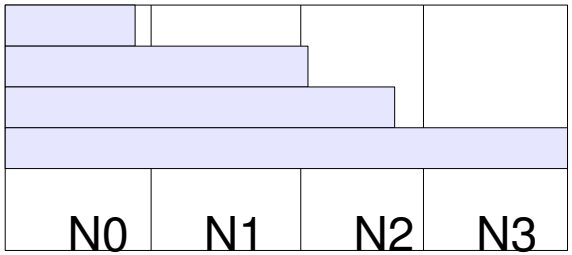


Process memory on N1C0



Interleaved (Non-NUMA)

Process memory on N1C0



Non-Interleaved (NUMA)

NUMA Support

RHEL4 NUMA Support

- NUMA aware memory allocation policy
- NUMA aware memory reclamation
- Multi-core support

RHEL5 NUMA Support

- RHEL4 NUMA support (taskset, numactl)
- NUMA aware scheduling
- NUMA-aware slab allocator
- NUMA-aware hugepages

Memory Management

Physical Memory(RAM) Management

Virtual Address Space Maps

Kernel Wired Memory

Reclaimable User Memory

Page Reclaim Dynamics

Physical Memory(RAM) Management

Physical Memory Layout

NUMA versus Non-NUMA(UMA)

NUMA Nodes

Zones

mem_map array

Page lists

- Free
- Active
- Inactive

Physical Memory Supported/Tested

RHEL4

- x86 – 4GB, 16GB, 64GB
- x86_64 – 512GB
- ia64 – 1TB

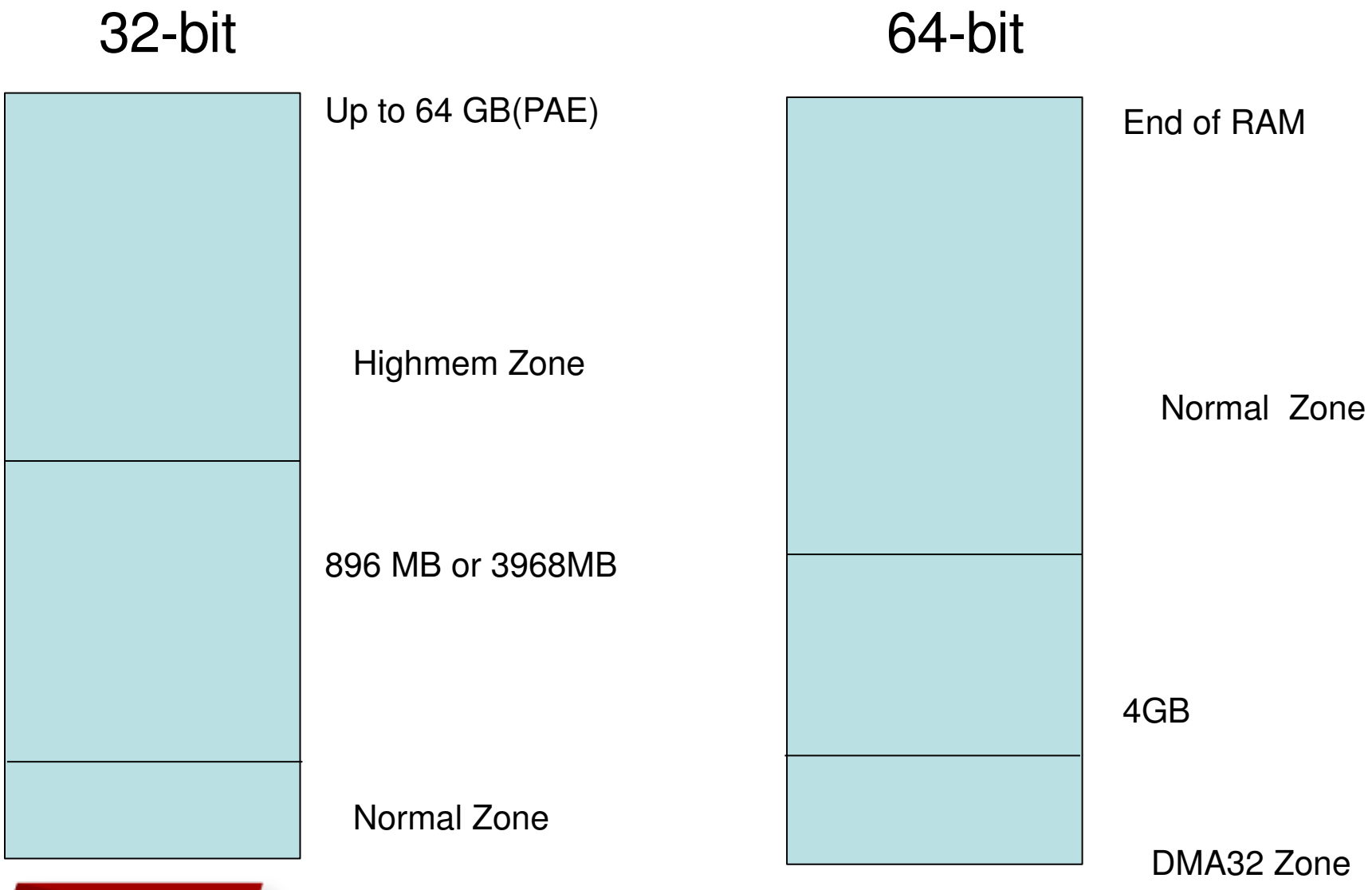
RHEL5

- x86 – 4GB, 16GB
- x86_64 – 1TB
- ia64 – 2TB

RHEL6

- x86 – 16GB
- x86_64 - 64TB/4TB

Memory Zones



Memory Zone Utilization(x86)

24bit I/O

Kernel Static

Kernel Dynamic

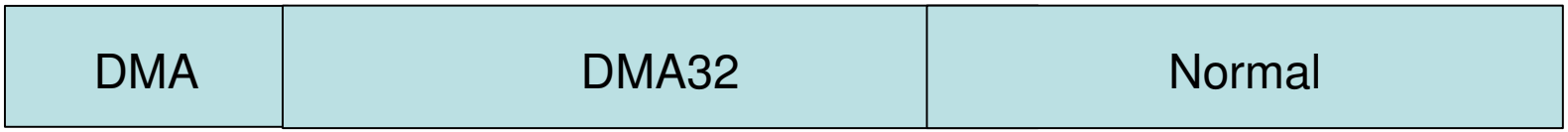
- slabcache
- bounce buffers
- driver allocations

User Overflow

User

- Anonymous
- Pagecache
- Pagetables

Memory Zone Utilization(x86_64)



24bit I/O

32bit I/O

Normal overflow

Kernel Static

Kernel Dynamic

- **slabcache**
- **bounce buffers**
- **driver allocations**

User

- **Anonymous**
- **Pagecache**
- **Pagetables**

Per-Zone Resources

RAM

mem_map

Page lists: free, active and inactive

Page allocation and reclamation

Page reclamation watermarks

mem_map

Kernel maintains a “page” struct for each 4KB(16KB on IA64 and 64KB for PPC64/RHEL5) page of RAM

mem_map is the global array of page structs

Page struct size(x86, x86_64):

32-bit = 32bytes

64-bit = 56bytes

Per-zone page lists

Active List - most recently referenced

- Anonymous-stack, heap, bss
- Pagecache-filesystem data/meta-data

Inactive List - least recently referenced

- Dirty-modified
- writeback in progress
- Clean-ready to free

Free

- Coalesced buddy allocator

Per zone Free list/buddy allocator lists

Kernel maintains per-zone free list

Buddy allocator coalesces free pages into larger physically contiguous pieces

DMA

1*4kB 4*8kB 6*16kB 4*32kB 3*64kB 1*128kB 1*256kB 1*512kB 0*1024kB 1*2048kB 2*4096kB = 11588kB)

Normal

217*4kB 207*8kB 1*16kB 1*32kB 0*64kB 1*128kB 1*256kB 1*512kB 0*1024kB 0*2048kB 0*4096kB = 3468kB)

HighMem

847*4kB 409*8kB 17*16kB 1*32kB 1*64kB 1*128kB 1*256kB 1*512kB 0*1024kB 0*2048kB 0*4096kB = 7924kB)

Memory allocation failures

Freelist exhaustion.

Freelist fragmentation.

Per NUMA-Node Resources

Memory zones(DMA & Normal zones)

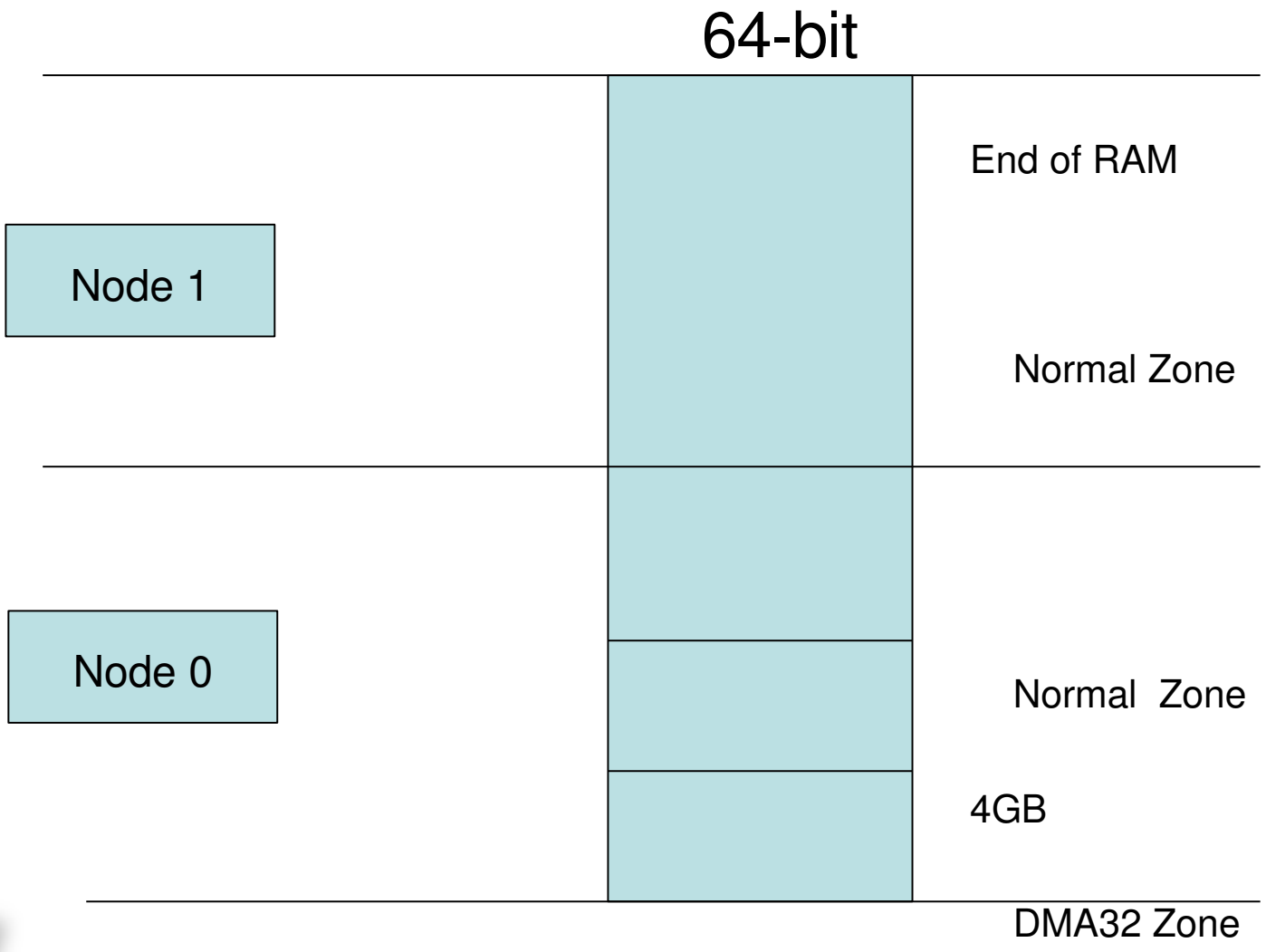
CPUs

IO/DMA capacity

Interrupt processing

Page reclamation kernel thread(kswapd#)

NUMA Nodes and Zones



Virtual Address Space Maps

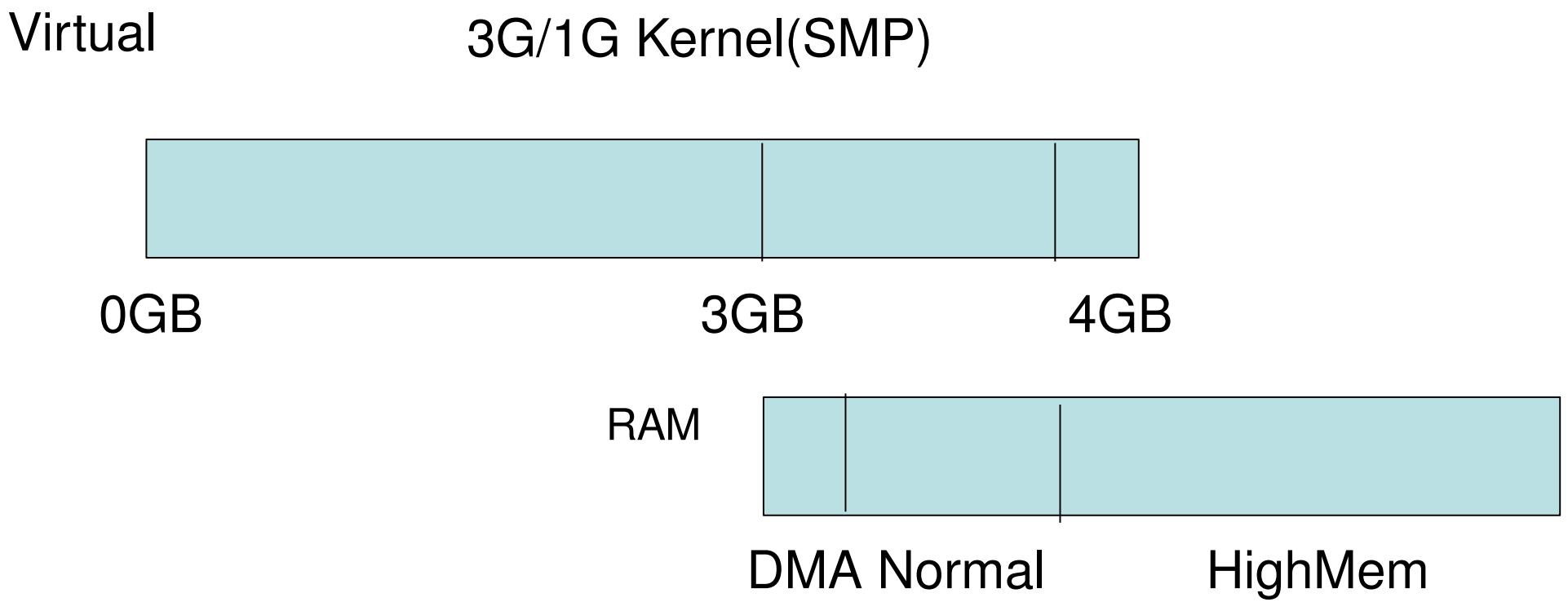
32-bit

- 3G/1G address space
- 4G/4G address space(RHEL4 only)

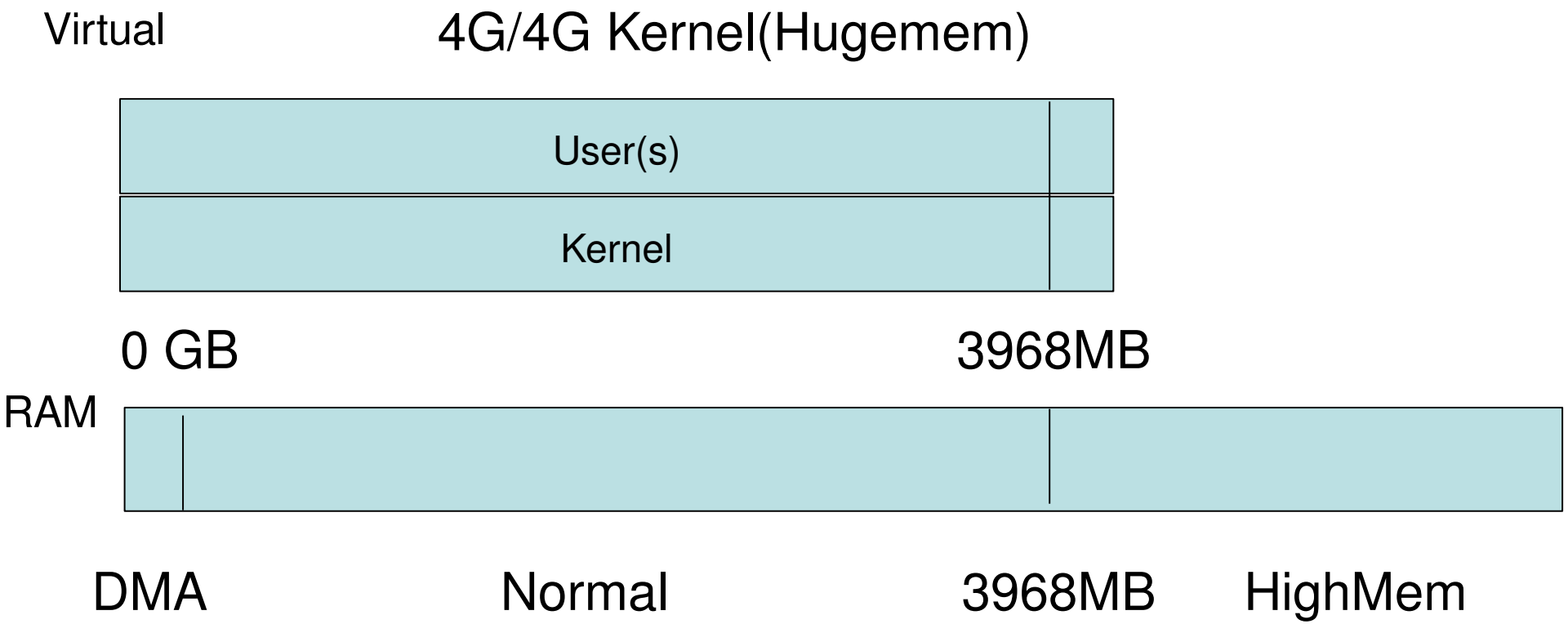
64-bit

- X86_64

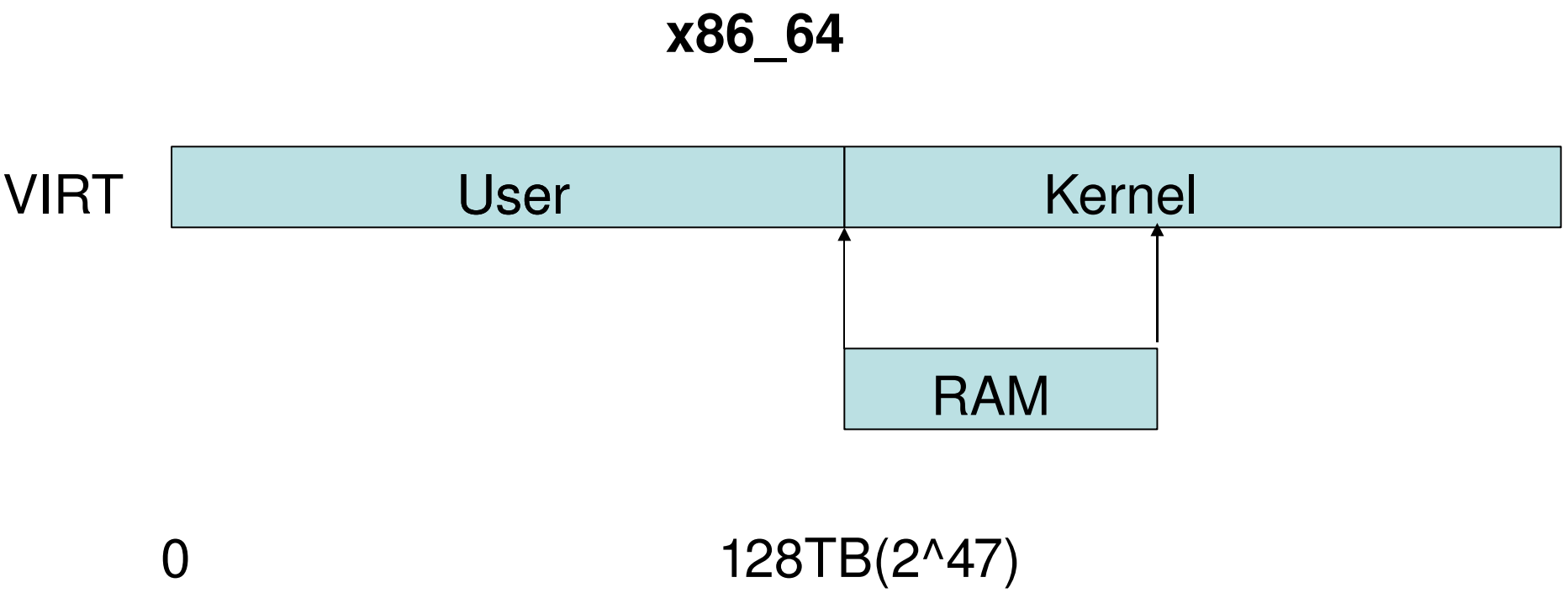
Linux 32-bit Address Spaces(SMP)



RHEL4 32-bit Address Space(Hugemem)



Linux 64-bit Address Space

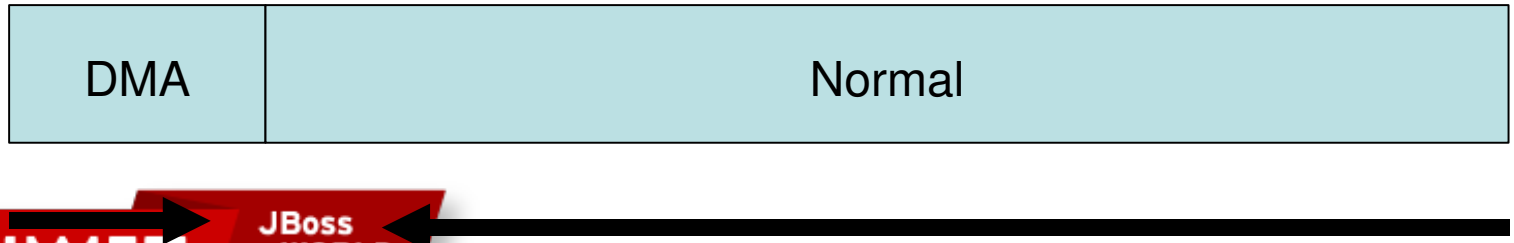


Memory Pressure

32- bit

Kernel Allocations **User Allocations**

64- bit



Kernel Memory Pressure

Static – Boot-time(DMA and Normal zones)

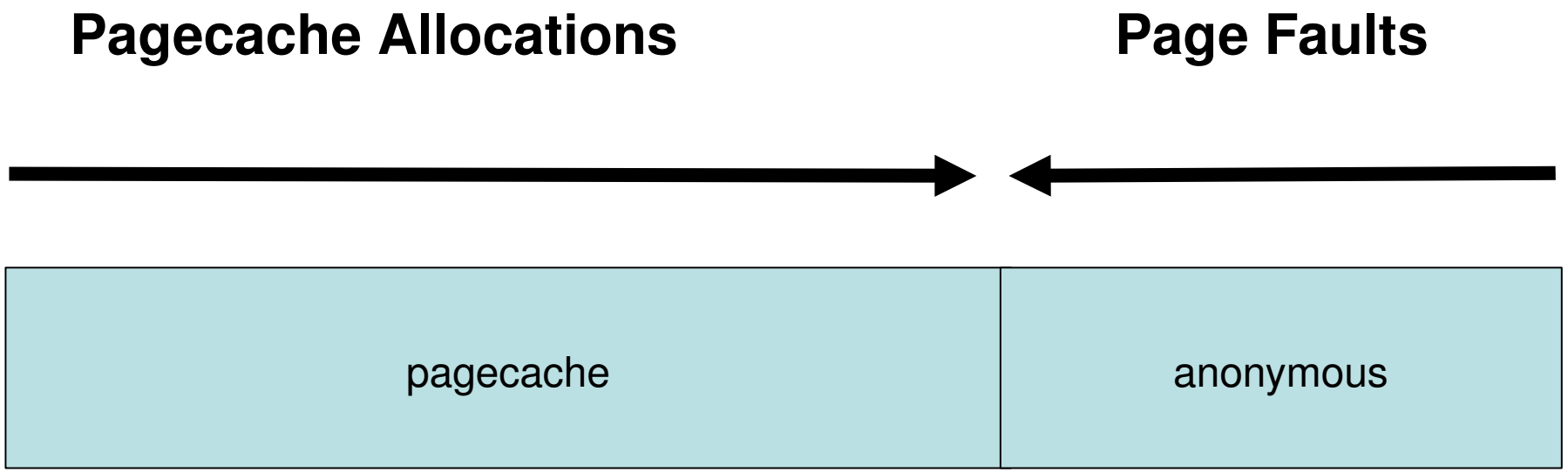
- Kernel text, data, BSS
- Bootmem allocator, tables and hashes(mem_map)

Dynamic

- Slabcache(Normal zone)
- Kernel data structs
- Inode cache, dentry cache and buffer header dynamics
- Pagetables(Highmem/Normal zone)

HughTLBfs(Highmem/Normal zone)

User Memory Pressure
Anonymous/pagecache split



PageCache/Anonymous memory split

Pagecache memory is global and grows when filesystem data is accessed until memory is exhausted.

Pagecache is freed:

- Underlying files are deleted.
- Unmount of the filesystem.
- Kswapd reclaims pagecache pages when memory is exhausted.
- /proc/sys/vm/drop_caches

Anonymous memory is private and grows on user demmand

- Allocation followed by pagefault.
- Swapin.

Anonymous memory is freed:

- Process unmaps anonymous region or exits.
- Kswapd reclaims anonymous pages(swapout) when memory is exhausted

PageCache/Anonymous memory split

Balance between pagecache and anonymous memory.

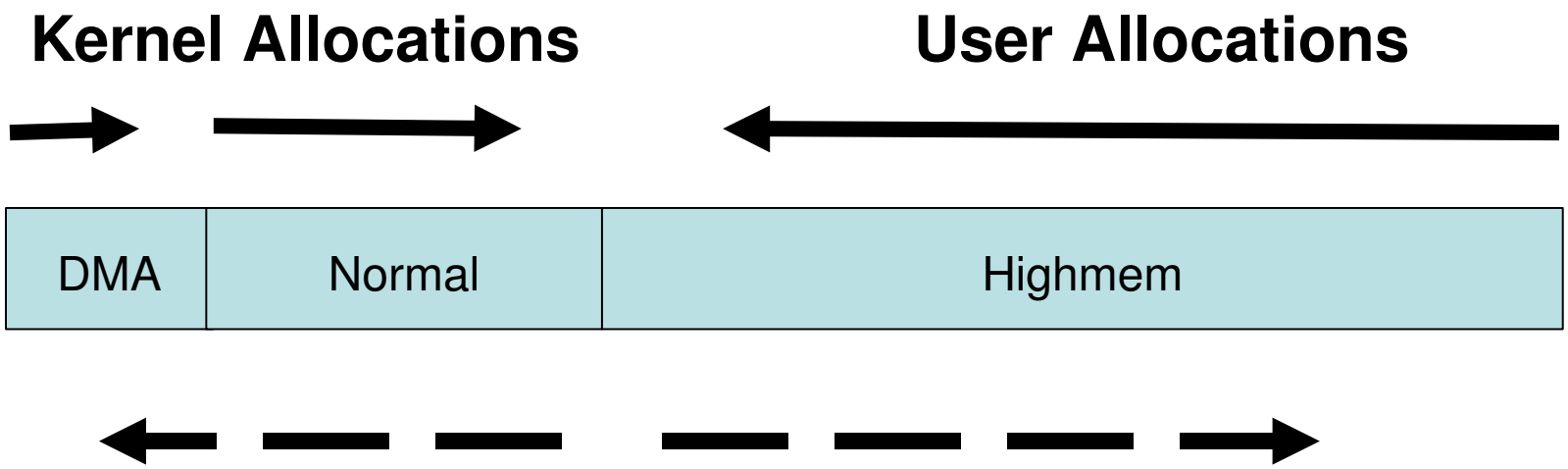
Dynamic.

Controlled via:

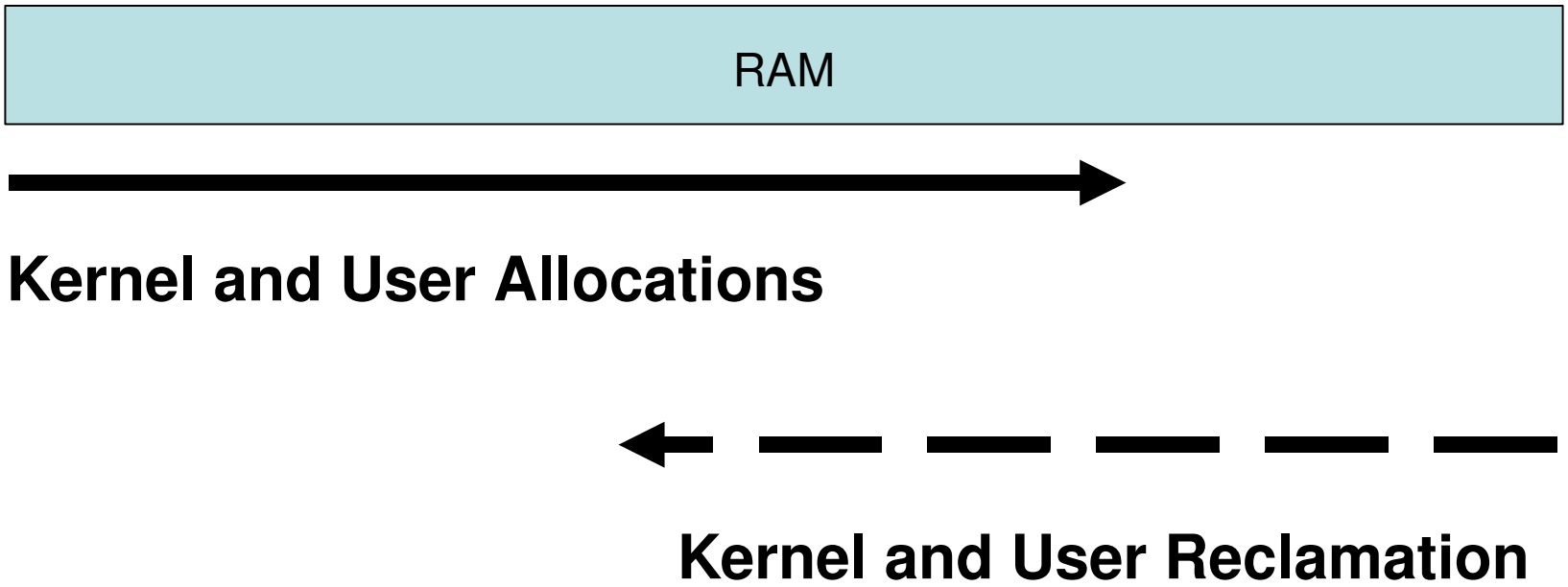
/proc/sys/vm/pagecache.
/proc/sys/vm/swappiness.

Swap files/partitions.

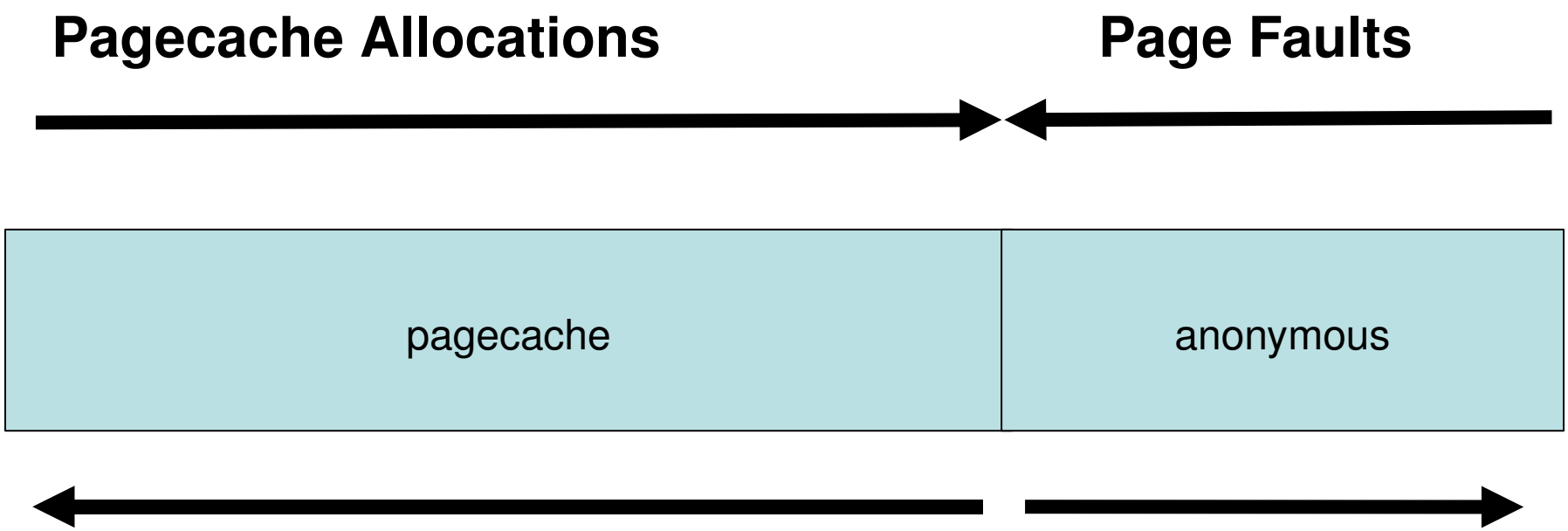
32-bit Memory Reclamation



64-bit Memory Reclamation



Anonymous/pagecache reclaiming



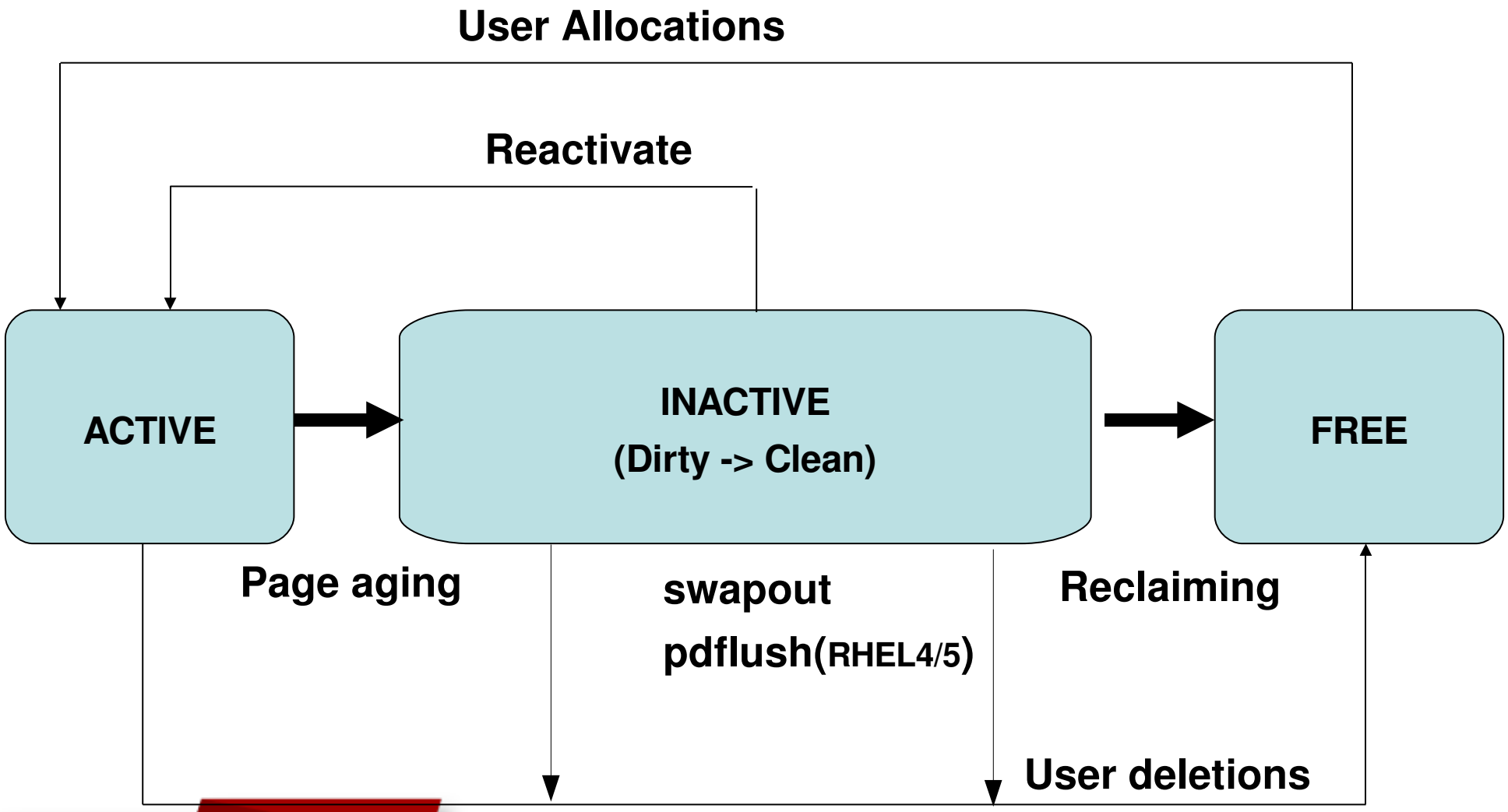
kswapd(bdflush/pdflush, kupdated)

- **page reclaim**
- **deletion of a file**
- **unmount filesystem**

kswapd

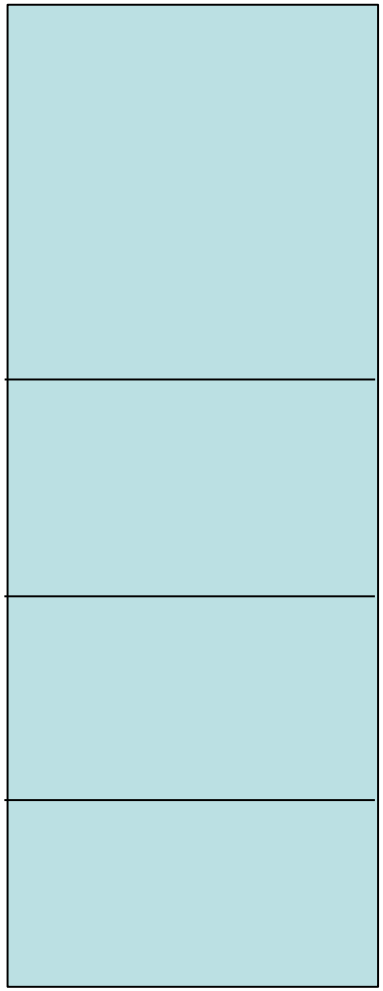
- **page reclaim (swapout)**
- **unmap**
- **exit**

Per Node/Zone Paging Dynamics



Memory reclaim Watermarks

Free List



All of RAM

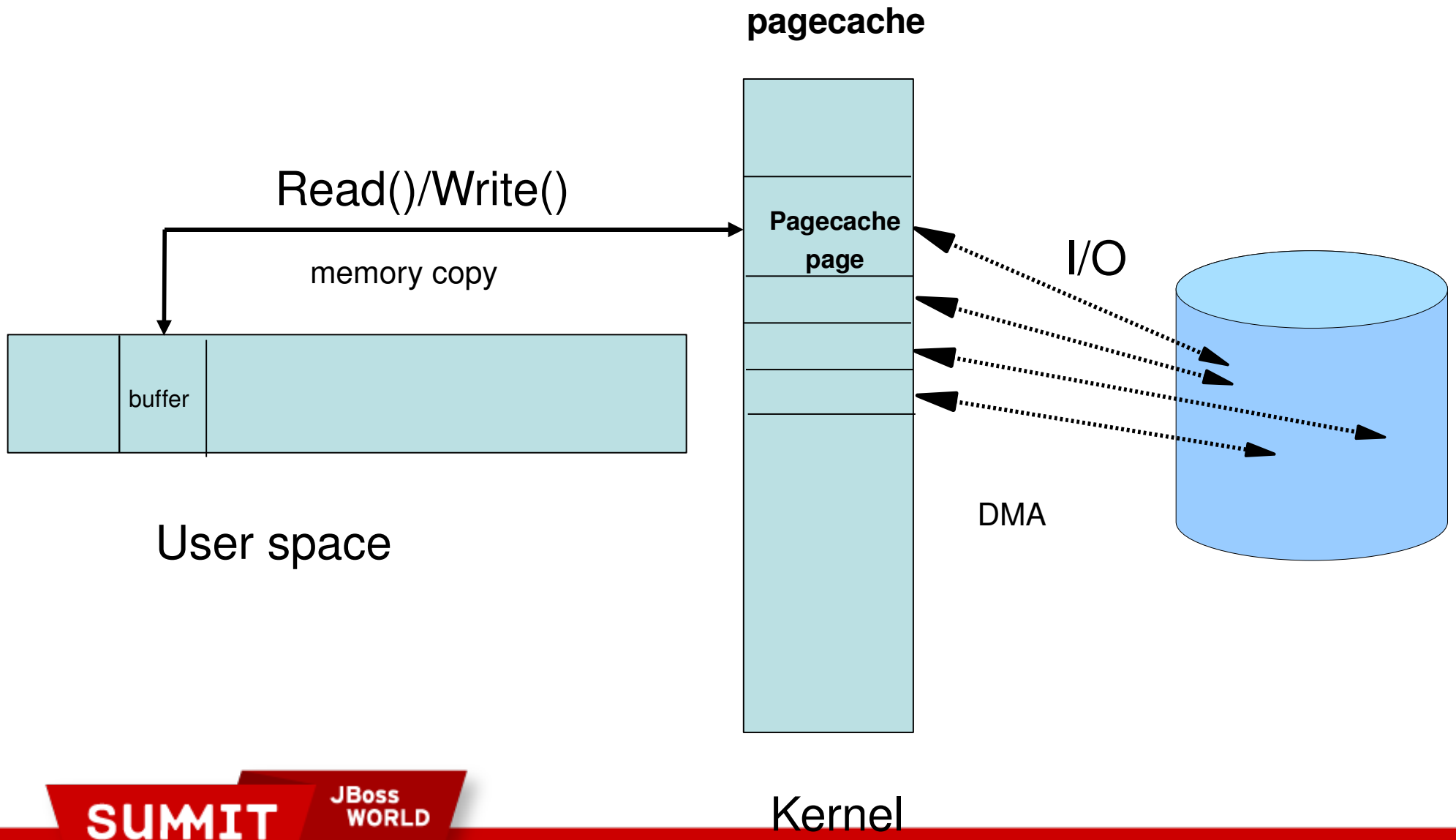
Do nothing

Pages High – kswapd sleeps above High
kswapd reclaims memory

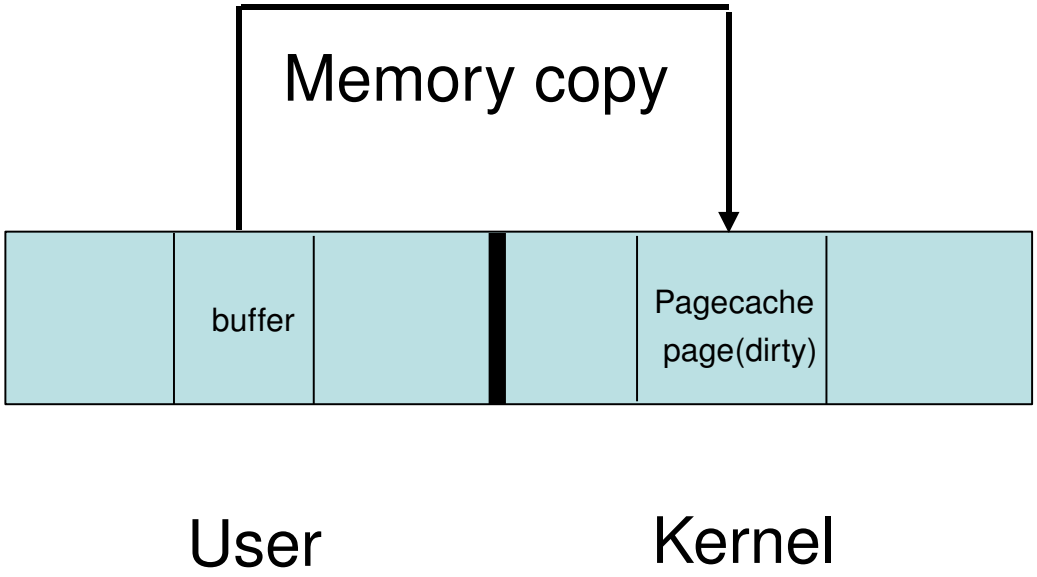
Pages Low – kswapd wakesup at Low
kswapd reclaims memory

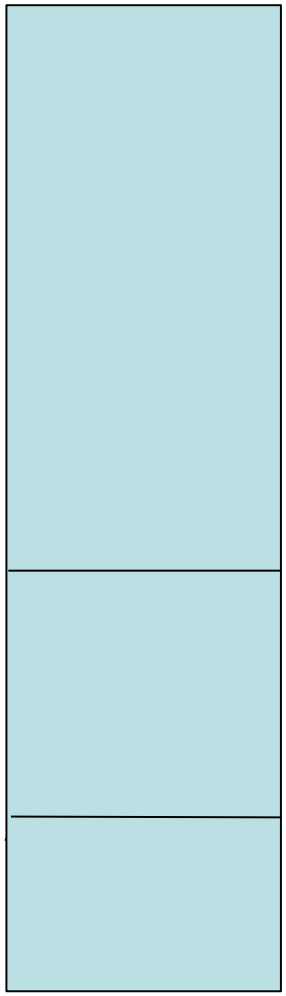
Pages Min – all memory allocators reclaim at Min
user processes/kswapd reclaim memory

File System & Disk IO



Buffered file system write





100% of pagecache RAM dirty

pdflushd and
write()'ng processes
write dirty buffers

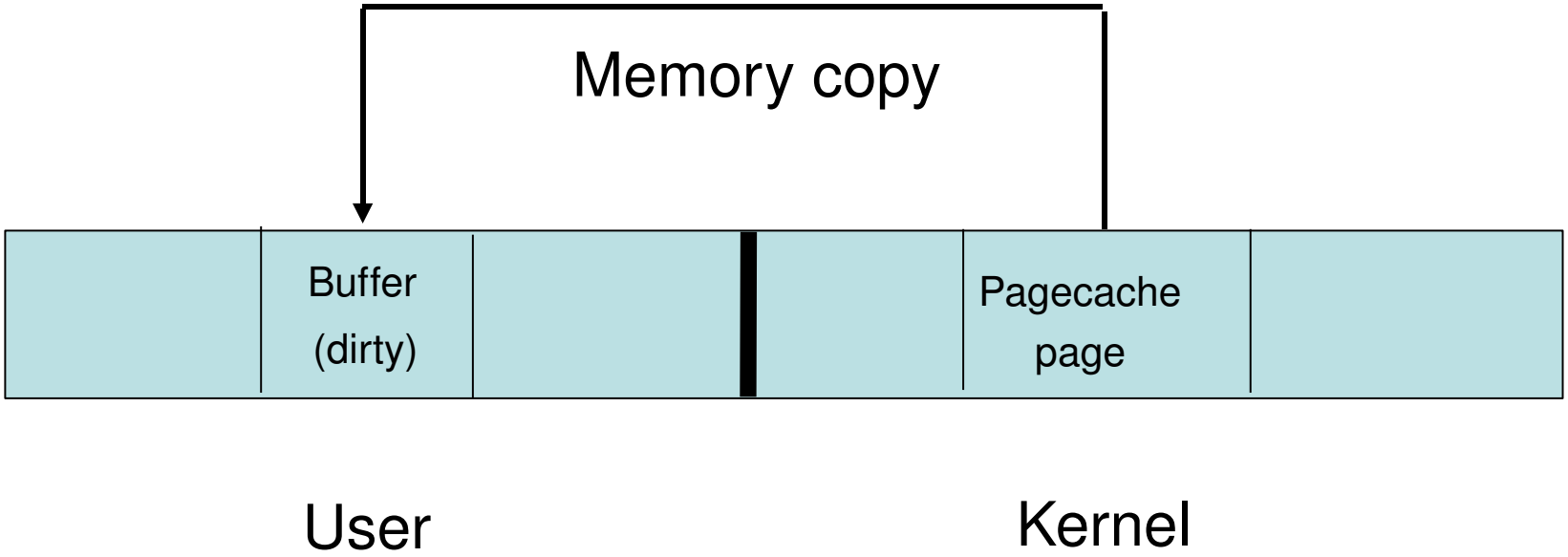
40% dirty) – processes start
synchronous writes

pdflushd writes dirty
buffers in
background

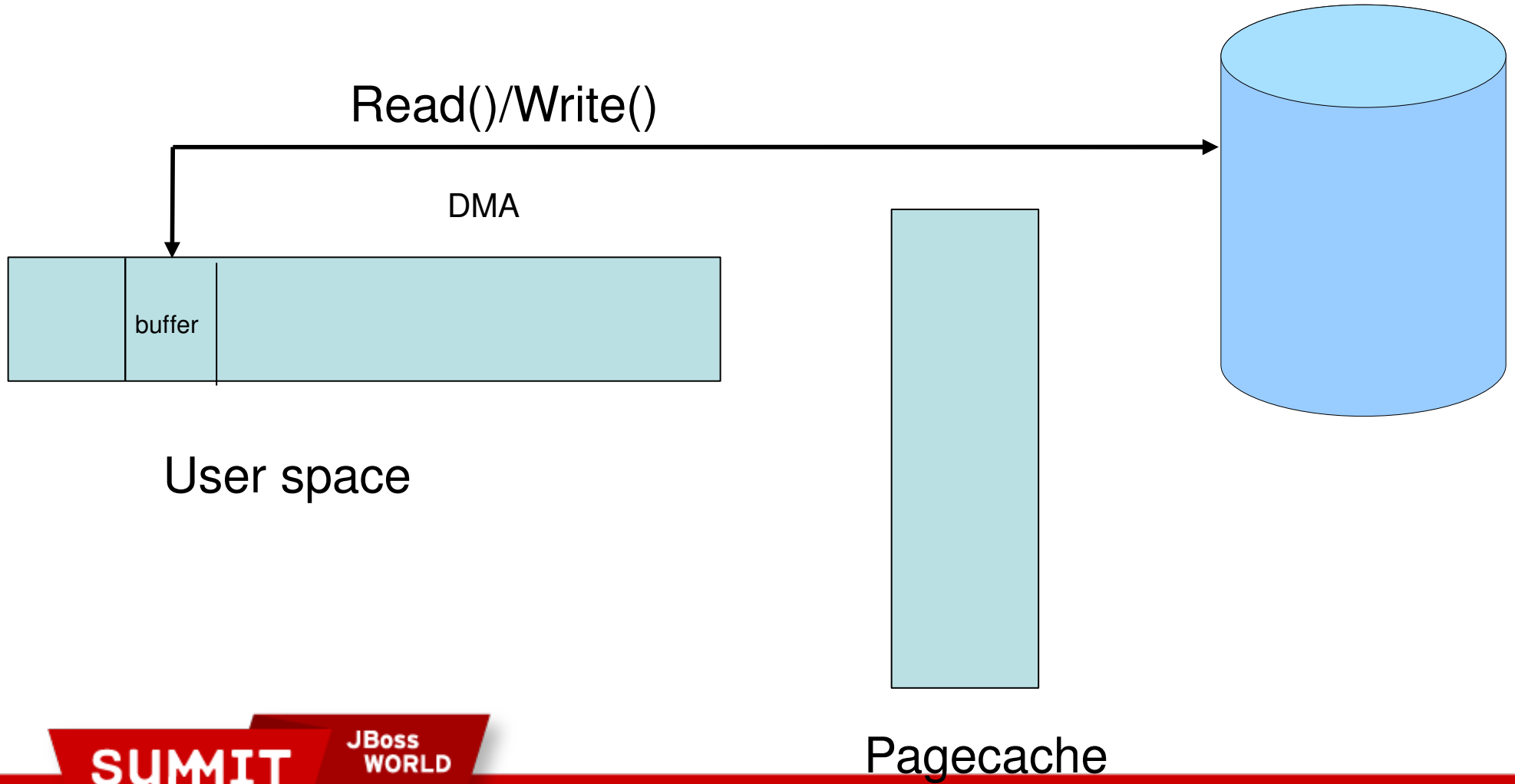
10% dirty – wakeup pdflushd

do_nothing

Buffered file system read



DirectIO file system read()/write()



Disk IO Schedulers

CFQ: Completely Fair Queuing default, balanced, fair for multiple luns, adaptors, smp servers

NOOP: No-operation in kernel, simple, low cpu overhead, leave opt to ramdisk, raid cntrl etc.

Deadline: Optimize for run-time-like behavior, low latency per IO, balance issues with large IO luns/controllers.

Anticipatory: Inserts delays to help stack aggregate IO, best on system w/ limited physical IO – SATA

Section 2 - Analyzing System Performance

Performance Monitoring Tools

What to run under certain loads

Analyzing System Performance

What to look for

Performance Monitoring Tools

- Standard Unix OS tools
  - Monitoring - cpu, memory, process, disk
  - oprofile
- Kernel Tools
  - /proc, info (cpu, mem, slab), dmesg, AltSysrq
- Networking
  -
- Profiling
  - nmi_watchdog=1, profile=2
  - Tracing strace, ltrace
  - dprobe, kprobe
- 3rd party profiling/ capacity monitoring
  - Perfmon, Caliper, vtune
  - SARcheck, KDE, BEA Patrol, HP Openview

Red Hat Top Tools

CPU Tools

1 – top

2 – vmstat

3 – ps aux

4 – mpstat -P all

5 – sar -u

6 – iostat

7 – oprofile

8 – gnome-system-monitor

9 – KDE-monitor

10 – /proc

Memory Tools

1 – top

2 – vmstat -s

3 – ps aur

4 – ipcs

5 – sar -r -B -W

6 – free

7 – oprofile

8 – gnome-system-monitor

9 – KDE-monitor

10 – /proc

Process Tools

1 – top

2 – ps -o pmem

3 – gprof

4 – strace,ltrace

5 – sar

Disk Tools

1 – iostat -x

2 – vmstat - D

3 – sar -DEV #

4 – nfsstat

5 – NEED MORE!

Monitoring Tools

mpstat – reveals per cpu stats, Hard/Soft Interrupt usage

vmstat – vm page info, context switch, total ints/s, cpu

netstat – per nic status, errors, statistics at driver level

lspci – list the devices on pci, indepth driver flags

oprofile – system level profiling, kernel/driver code

modinfo – list information about drivers, version, options

sar – collect, report, save system activity information

Many others available- iptraf, wireshark, etc

Sample use for some of these embedded in talk

top - press h – help,1-show cpus, m-memory, t-threads, > - column sort

```
top - 09:01:04 up 8 days, 15:22,  2 users,  load average: 1.71, 0.39, 0.12
Tasks: 114 total,   1 running, 113 sleeping,   0 stopped,   0 zombie
Cpu0  :  5.3% us,  2.3% sy,  0.0% ni,  0.0% id, 92.0% wa,  0.0% hi,  0.3% si
Cpu1  :  0.3% us,  0.3% sy,  0.0% ni, 89.7% id,  9.7% wa,  0.0% hi,  0.0% si
Mem:   2053860k total,  2036840k used,    17020k free,    99556k buffers
Swap:  2031608k total,      160k used,  2031448k free,   417720k cached

  PID USER      PR  NI  VIRT  RES  SHR S %CPU %MEM    TIME+  COMMAND
27830 oracle    16   0 1315m 1.2g 1.2g D  1.3 60.9   0:00.09 oracle
27802 oracle    16   0 1315m 1.2g 1.2g D  1.0 61.0   0:00.10 oracle
27811 oracle    16   0 1315m 1.2g 1.2g D  1.0 60.8   0:00.08 oracle
27827 oracle    16   0 1315m 1.2g 1.2g D  1.0 61.0   0:00.11 oracle
27805 oracle    17   0 1315m 1.2g 1.2g D  0.7 61.0   0:00.10 oracle
27828 oracle    15   0 27584 6648 4620 S  0.3  0.3   0:00.17 tpcc.exe
    1 root      16   0  4744  580  480 S  0.0  0.0   0:00.50 init
    2 root      RT   0     0    0    0 S  0.0  0.0   0:00.11 migration/0
    3 root      34  19     0    0    0 S  0.0  0.0   0:00.00 ksoftirqd/0
```


vmstat(paging vs swapping)

Vmstat 10

procs			memory			swap		io		system		cpu			
r	b	swpd	free	buff	cache	si	so	bi	bo	in	cs	us	sy	wa	id
2	0	0	5483524	200524	234576	0	0	54	63	152	513	0	3	0	96
0	2	0	1697840	200524	3931440	0	0	578	50482	1085	3994	1	22	14	63
3	0	0	7844	200524	5784109	0	0	59330	58946	3243	14430	7	32	18	42

Vmstat 10

procs			memory			swap		io		system		cpu			
r	b	swpd	free	buff	cache	si	so	bi	bo	in	cs	us	sy	wa	id
2	0	0	5483524	200524	234576	0	0	54	63	152	513	0	3	0	96
0	2	0	1662340	200524	234576	0	0	578	50482	1085	3994	1	22	14	63
3	0	235678	7384	200524	234576	18754	23745	193	58946	3243	14430	7	32	18	42

Vmstat - IOzone(8GB file with 6GB RAM)

```
#! deplete memory until pdflush turns on
procs                      memory      swap          io     system         cpu
 r  b   swpd   free   buff  cache   si   so    bi    bo   in    cs us sy wa id
 2  0      0 4483524 200524 234576    0    0    54    63  152   513  0  3  0 96
 0  2      0 1697840 200524 2931440   0    0   578 50482 1085  3994  1 22 14 63
 3  0      0 1537884 200524 3841092   0    0   193 58946 3243 14430  7 32 18 42
 0  2      0 528120 200524 6228172    0    0   478 88810 1771  3392  1 32 22 46
 0  1      0  46140 200524 6713736    0    0   179 110719 1447 1825  1 30 35 35
 2  2      0  50972 200524 6705744    0    0   232 119698 1316 1971  0 25 31 44
#! now transition from write to reads
procs                      memory      swap          io     system         cpu
 r  b   swpd   free   buff  cache   si   so    bi    bo   in    cs us sy wa id
 1  4      0  51040 200524 6705544    0    0     2 133519 1265   839  0 26 56 18
 1  1      0  35064 200524 6712724    0    0    40 118911 1367  2021  0 35 42 23
 0  1      0  68264 234372 6647020    0    0 76744    54 2048  4032  0  7 20 73
 0  1      0  34468 234372 6678016    0    0 77391    34 1620  2834  0  9 18 72
 0  1      0  47320 234372 6690356    0    0 81050    77 1783  2916  0  7 20 73
 1  0      0  38756 234372 6698344    0    0 76136    44 2027  3705  1  9 19 72
 0  1      0  31472 234372 6706532    0    0 76725    33 1601  2807  0  8 19 73
```


iostat -x of same IOzone EXT3 file system

Iostat metrics

rates perf sec	sizes and response time
r|w rqm/s – request merged/s	averq-sz – average request sz
r|w sec/s – 512 byte sectors/s	avequ-sz – average queue sz
r|w KB/s – Kilobyte/s	await – average wait time ms
r|w /s – operations/s	svcm – ave service time m

```
Linux 2.4.21-27.0.2.ELsmp (node1)

avg-cpu:  %user   %nice    %sys %iowait   %idle
           0.40    0.00    2.63    0.91   96.06

Device:    rrqm/s wrqm/s   r/s   w/s  rsec/s  wsec/s    rkB/s    wkB/s avgrq-sz avgqu-sz   await  svctm  %util
sdi       16164.60   0.00 523.40  0.00 133504.00    0.00 66752.00     0.00   255.07     1.00    1.91   1.88  98.40
sdi       17110.10   0.00 553.90  0.00 141312.00    0.00 70656.00     0.00   255.12     0.99    1.80   1.78  98.40
sdi       16153.50   0.00 522.50  0.00 133408.00    0.00 66704.00     0.00   255.33     0.98    1.88   1.86  97.00
sdi       17561.90   0.00 568.10  0.00 145040.00    0.00 72520.00     0.00   255.31     1.01    1.78   1.76 100.00
```


SAR

```
[root@localhost redhat]# sar -u 3 3
Linux 2.4.21-20.EL (localhost.localdomain)      05/16/2005

10:32:28 PM       CPU     %user     %nice   %system     %idle
10:32:31 PM       all      0.00      0.00      0.00    100.00
10:32:34 PM       all      1.33      0.00      0.33     98.33
10:32:37 PM       all      1.34      0.00      0.00     98.66
Average:          all      0.89      0.00      0.11     99.00

[root] sar -n DEV
Linux 2.4.21-20.EL (localhost.localdomain)      03/16/2005

01:10:01 PM     IFACE   rxpck/s   txpck/s   rxbyt/s   txbyt/s   rxcmp/s
txcmp/s  rxmcst/s
01:20:00 PM        lo      3.49      3.49    306.16    306.16      0.00
0.00      0.00
01:20:00 PM      eth0      3.89      3.53   2395.34    484.70      0.00
0.00      0.00
01:20:00 PM      eth1      0.00      0.00      0.00      0.00      0.00
0.00      0.00
```


Networking tools

Tuning tools

- ethtool – View and change Ethernet card settings
- sysctl – View and set */proc/sys* settings
- ifconfig – View and set ethX variables
- setpci – View and set pci bus params for device
- netperf – Can run a bunch of different network tests
- /proc – OS info, place for changing device tunables

ethtool

Works mostly at the HW level

- ethtool -S – provides HW level stats
  - Counters since boot time, create scripts to calculate diffs
- ethtool -c - Interrupt coalescing
- ethtool -g - provides ring buffer information
- ethtool -k - provides hw assist information
- ethtool -i - provides the driver information

CPU Utilization – Raw vs. Tuned IRQ, NAPI

Not Tuned

CPU	%user	%nice	%system	%iowait	%irq	%soft	%idle	intr/s
all	0.23	0.00	8.01	0.02	0.00	10.78	80.96	21034.49
0	0.00	0.00	0.00	0.01	0.00	52.16	47.83	20158.58
1	0.00	0.00	0.00	0.02	0.00	0.00	100.00	1254.14
2	0.00	0.00	0.00	0.08	0.00	0.00	99.93	1254.14
3	0.00	0.00	0.00	0.03	0.00	0.00	99.99	1254.13
4	1.79	0.00	64.11	0.00	0.00	34.11	0.01	1254.14
5	0.01	0.00	0.00	0.02	0.00	0.00	99.99	1254.14
6	0.00	0.00	0.00	0.00	0.00	0.00	100.01	1254.14
7	0.00	0.00	0.00	0.02	0.00	0.00	99.99	1254.14

With Tuning

CPU	%user	%nice	%system	%iowait	%irq	%soft	%idle	intr/s
all	0.26	0.00	10.44	0.00	0.00	12.50	76.79	11118.61
0	0.00	0.00	0.00	0.00	0.00	0.00	100.00	1.12
1	0.01	0.00	0.00	0.00	0.00	0.00	99.99	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.00
4	2.08	0.00	83.54	0.00	0.00	0.00	14.38	0.00
5	0.00	0.00	0.01	0.00	0.00	100.00	0.00	1195
6	0.00	0.00	0.00	0.00	0.00	0.02	99.98	0.68
7	0.00	0.00	0.00	0.00	0.03	0.00	99.98	1114.86

free/numastat – memory allocation

```
[root@localhost redhat]# free -l
             total       used       free     shared    buffers     cached
Mem:        511368     342336     169032          0      29712     167408
Low:        511368     342336     169032          0          0          0
High:            0          0          0          0          0          0
-/+ buffers/cache:     145216     366152
Swap:      1043240          0    1043240

numastat (on 2-cpu x86_64 based system)
                         node1          node0
numa_hit                 9803332       10905630
numa_miss                2049018        1609361
numa_foreign             1609361        2049018
interleave_hit             58689          54749
local_node               9770927       10880901
other_node               2081423        1634090
```


ps

```
[root@localhost root]# ps aux
[root@localhost root]# ps -aux | more
USER       PID %CPU %MEM    VSZ   RSS TTY      STAT START   TIME COMMAND
root         1  0.1  0.1   1528   516 ?        S    23:18   0:04 init
root         2  0.0  0.0      0     0 ?        SW   23:18   0:00 [keventd]
root         3  0.0  0.0      0     0 ?        SW   23:18   0:00 [kapmd]
root         4  0.0  0.0      0     0 ?        SWN  23:18   0:00 [ksoftirqd/0]
root         7  0.0  0.0      0     0 ?        SW   23:18   0:00 [bdflush]
root         5  0.0  0.0      0     0 ?        SW   23:18   0:00 [kswapd]
root         6  0.0  0.0      0     0 ?        SW   23:18   0:00 [kscand]
```


pstree

```
init─┬─/usr/bin/sealer
     ├─acpid
     ├─atd
     ├─auditd─┬─python
     │        └─{auditd}
     ├─automount─────6*[{automount}]
     ├─avahi-daemon─────avahi-daemon
     ├─bonobo-activati─────{bonobo-activati}
     ├─bt-applet
     ├─clock-applet
     ├─crond
     ├─cupsd─────cups-polld
     ├─3*[dbus-daemon─────{dbus-daemon}]
     ├─2*[dbus-launch]
     ├─dhclient
```


The /proc filesystem

/proc

meminfo

slabinfo

cpuinfo

pid<#>/maps

vmstat(RHEL4 & RHEL5)

zoneinfo(RHEL5)

sysrq-trigger

/proc/meminfo

RHEL4> cat /proc/meminfo
MemTotal: 32749568 kB
MemFree: 31313344 kB
Buffers: 29992 kB
Cached: 1250584 kB
SwapCached: 0 kB
Active: 235284 kB
Inactive: 1124168 kB
HighTotal: 0 kB
HighFree: 0 kB
LowTotal: 32749568 kB
LowFree: 31313344 kB
SwapTotal: 4095992 kB
SwapFree: 4095992 kB
Dirty: 0 kB
Writeback: 0 kB
Mapped: 1124080 kB
Slab: 38460 kB
CommitLimit: 20470776 kB
Committed_AS: 1158556 kB
PageTables: 5096 kB
VmallocTotal: 536870911 kB
VmallocUsed: 2984 kB
VmallocChunk: 536867627 kB

RHEL5> cat /proc/meminfo
MemTotal: 1025220 kB
MemFree: 11048 kB
Buffers: 141944 kB
Cached: 342664 kB
SwapCached: 4 kB
Active: 715304 kB
Inactive: 164780 kB
HighTotal: 0 kB
HighFree: 0 kB
LowTotal: 1025220 kB
LowFree: 11048 kB
SwapTotal: 2031608 kB
SwapFree: 2031472 kB
Dirty: 84 kB
Writeback: 0 kB
AnonPages: 395572 kB
Mapped: 82860 kB
Slab: 92296 kB
PageTables: 23884 kB
NFS_Unstable: 0 kB
Bounce: 0 kB
CommitLimit: 2544216 kB
Committed_AS: 804656 kB
VmallocTotal: 34359738367 kB
VmallocUsed: 263472 kB

/proc/slabinfo

```
slabinfo - version: 2.1
# name            <active_objs> <num_objs> <objsize> <objperslab> <pagesperslab> : tunables <limit>
<batchcount> <sharedfactor>: slabdata <active_slabs> <num_slabs> <sharedavail>
nfsd4_delegations      0      0    656    6    1 : tunables   54   27    8 : slabdata      0      0      0
nfsd4_stateids         0      0    128   30    1 : tunables  120   60    8 : slabdata      0      0      0
nfsd4_files            0      0     72   53    1 : tunables  120   60    8 : slabdata      0      0      0
nfsd4_stateowners      0      0    424    9    1 : tunables   54   27    8 : slabdata      0      0      0
nfs_direct_cache       0      0    128   30    1 : tunables  120   60    8 : slabdata      0      0      0
nfs_write_data        36     36    832    9    2 : tunables   54   27    8 : slabdata      4      4      0
nfs_read_data         32     35    768    5    1 : tunables   54   27    8 : slabdata      7      7      0
nfs_inode_cache     1383   1389   1040    3    1 : tunables   24   12    8 : slabdata    463    463      0
nfs_page               0      0    128   30    1 : tunables  120   60    8 : slabdata      0      0      0
fscache_cookie_jar     3     53     72   53    1 : tunables  120   60    8 : slabdata      1      1      0
ip_conntrack_expect    0      0    136   28    1 : tunables  120   60    8 : slabdata      0      0      0
ip_conntrack          75    130    304   13    1 : tunables   54   27    8 : slabdata     10     10      0
bridge_fdb_cache       0      0     64   59    1 : tunables  120   60    8 : slabdata      0      0      0
rpc_buffers            8      8   2048    2    1 : tunables   24   12    8 : slabdata      4      4      0
rpc_tasks             30     30    384   10    1 : tunables   54   27    8 : slabdata      3      3      0
```


/proc/cpuinfo

```
[lwoodman]$ cat /proc/cpuinfo
processor       : 0
vendor_id       : GenuineIntel
cpu family      : 6
model           : 15
model name      : Intel(R) Xeon(R) CPU            3060  @ 2.40GHz
stepping        : 6
cpu MHz         : 2394.070
cache size      : 4096 KB
physical id     : 0
siblings        : 2
core id         : 0
cpu cores       : 2
fpu             : yes
fpu_exception   : yes
cpuid level     : 10
wp              : yes
flags           : fpu vme de pse tsc msr pae mce cx8 apic sep mtrr pge mca cmov pat pse36 clflush
dts acpi mmx fxsr sse sse2 ss ht tm syscall nx lm constant_tsc pni monitor ds_cpl vmx est tm2 cx16
xtpr lahf_lm
bogomips        : 4791.41
clflush size    : 64
cache_alignment : 64
address sizes   : 36 bits physical, 48 bits virtual
power management:
```


32-bit /proc/<pid>/maps

```
[root@dhcp83-36 proc]# cat 5808/maps
0022e000-0023b000 r-xp 00000000 03:03 4137068    /lib/tls/libpthread-0.60.so
0023b000-0023c000 rw-p 0000c000 03:03 4137068    /lib/tls/libpthread-0.60.so
0023c000-0023e000 rw-p 00000000 00:00 0
0037f000-00391000 r-xp 00000000 03:03 523285     /lib/libnsl-2.3.2.so
00391000-00392000 rw-p 00011000 03:03 523285     /lib/libnsl-2.3.2.so
00392000-00394000 rw-p 00000000 00:00 0
00c45000-00c5a000 r-xp 00000000 03:03 523268     /lib/ld-2.3.2.so
00c5a000-00c5b000 rw-p 00015000 03:03 523268     /lib/ld-2.3.2.so
00e5c000-00f8e000 r-xp 00000000 03:03 4137064    /lib/tls/libc-2.3.2.so
00f8e000-00f91000 rw-p 00131000 03:03 4137064    /lib/tls/libc-2.3.2.so
00f91000-00f94000 rw-p 00000000 00:00 0
08048000-0804f000 r-xp 00000000 03:03 1046791    /sbin/ypbind
0804f000-08050000 rw-p 00007000 03:03 1046791    /sbin/ypbind
09794000-097b5000 rw-p 00000000 00:00 0
b5fdd000-b5fde000 ---p 00000000 00:00 0
```


64-bit /proc/<pid>/maps

```
# cat /proc/2345/maps
00400000-0100b000 r-xp 00000000 fd:00 1933328                            /usr/sybase/ASE-12_5/bin/dataserver.esd3
0110b000-01433000 rw-p 00c0b000 fd:00 1933328                            /usr/sybase/ASE-12_5/bin/dataserver.esd3
01433000-014eb000 rwxp 01433000 00:00 0
40000000-40001000 ---p 40000000 00:00 0
40001000-40a01000 rwxp 40001000 00:00 0
2a95f73000-2a96073000 ---p 0012b000 fd:00 819273                         /lib64/tls/libc-2.3.4.so
2a96073000-2a96075000 r--p 0012b000 fd:00 819273                         /lib64/tls/libc-2.3.4.so
2a96075000-2a96078000 rw-p 0012d000 fd:00 819273                         /lib64/tls/libc-2.3.4.so
2a96078000-2a9607e000 rw-p 2a96078000 00:00 0
2a9607e000-2a98c3e000 rw-s 00000000 00:06 360450                         /SYSV0100401e (deleted)
2a98c3e000-2a98c47000 rw-p 2a98c3e000 00:00 0
2a98c47000-2a98c51000 r-xp 00000000 fd:00 819227                         /lib64/libnss_files-2.3.4.so
2a98c51000-2a98d51000 ---p 0000a000 fd:00 819227                         /lib64/libnss_files-2.3.4.so
2a98d51000-2a98d53000 rw-p 0000a000 fd:00 819227                         /lib64/libnss_files-2.3.4.so
2a98d53000-2a98d57000 r-xp 00000000 fd:00 819225                         /lib64/libnss_dns-2.3.4.so
2a98d57000-2a98e56000 ---p 00004000 fd:00 819225                         /lib64/libnss_dns-2.3.4.so
2a98e56000-2a98e58000 rw-p 00003000 fd:00 819225                         /lib64/libnss_dns-2.3.4.so
2a98e58000-2a98e69000 r-xp 00000000 fd:00 819237                         /lib64/libresolv-2.3.4.so
2a98e69000-2a98f69000 ---p 00011000 fd:00 819237                         /lib64/libresolv-2.3.4.so
2a98f69000-2a98f6b000 rw-p 00011000 fd:00 819237                         /lib64/libresolv-2.3.4.so
2a98f6b000-2a98f6d000 rw-p 2a98f6b000 00:00 0
35c7e00000-35c7e08000 r-xp 00000000 fd:00 819469                         /lib64/libpam.so.0.77
35c7e08000-35c7f08000 ---p 00008000 fd:00 819469                         /lib64/libpam.so.0.77
35c7f08000-35c7f09000 rw-p 00008000 fd:00 819469                         /lib64/libpam.so.0.77
35c8000000-35c8011000 r-xp 00000000 fd:00 819468                         /lib64/libaudit.so.0.0.0
35c8011000-35c8110000 ---p 00011000 fd:00 819468                         /lib64/libaudit.so.0.0.0
35c8110000-35c8118000 rw-p 00010000 fd:00 819468                         /lib64/libaudit.so.0.0.0
35c9000000-35c900b000 r-xp 00000000 fd:00 819457                         /lib64/libgcc_s-3.4.4-20050721.so.1
35c900b000-35c910a000 ---p 0000b000 fd:00 819457                         /lib64/libgcc_s-3.4.4-20050721.so.1
35c910a000-35c910b000 rw-p 0000a000 fd:00 819457                         /lib64/libgcc_s-3.4.4-20050721.so.1
7fbfff1000-7fc0000000 rwxp 7fbfff1000 00:00 0
ffffffffff600000-ffffffffffe00000 ---p 00000000 00:00 0
```


/proc/vmstat

```
cat /proc/vmstat
nr_anon_pages 98893
nr_mapped 20715
nr_file_pages 120855
nr_slab 23060
nr_page_table_pages
5971
nr_dirty 21
nr_writeback 0
nr_unstable 0
nr_bounce 0
numa_hit 996729666
numa_miss 0
numa_foreign 0
numa_interleave 87657
numa_local 996729666
numa_other 0
pgpgin 2577307
pgpgout 106131928
pswpin 0
pswpout 34
pgalloc_dma 198908
pgalloc_dma32
997707549
pgalloc_normal 0
```

```
CONTINUED...
pgrefill_dma 18338
pgrefill_dma32 1353451
pgrefill_normal 0
pgrefill_high 0
pgsteal_dma 0
pgsteal_dma32 0
pgsteal_normal 0
pgsteal_high 0
pgscan_kswapd_dma 7235
pgscan_kswapd_dma32 417984
pgscan_kswapd_normal 0
pgscan_kswapd_high 0
pgscan_direct_dma 12
pgscan_direct_dma32 1984
pgscan_direct_normal 0
pgscan_direct_high 0
pginodesteal 166
slabs_scanned 1072512
kswapd_steal 410973
kswapd_inodesteal 61305
pageoutrun 7752
allocstall 29
pgrotated 73
```


Alt Sysrq M

```
Free pages:    15809760kB (0kB HighMem)
Active:51550 inactive:54515 dirty:44 writeback:0 unstable:0 free:3952440 slab:8727 mapped-
file:5064 mapped-anon:20127 pagetables:1627
Node 0 DMA free:10864kB min:8kB low:8kB high:12kB active:0kB inactive:0kB present:10460kB
pages_scanned:0 all_unreclaimable? no
Node 0 DMA32 free:2643124kB min:2760kB low:3448kB high:4140kB active:0kB inactive:0kB
present:2808992kB pages_scanned:0 all_unreclaimable? no
Node 0 Normal free:13155772kB min:13480kB low:16848kB high:20220kB active:206200kB
inactive:218060kB present:13703680kB pages_scanned:0 all_unreclaimable? no
Node 0 HighMem free:0kB min:128kB low:128kB high:128kB active:0kB inactive:0kB present:0kB
pages_scanned:0 all_unreclaimable? no
Node 0 DMA: 4*4kB 2*8kB 3*16kB 1*32kB 2*64kB 1*128kB 1*256kB 0*512kB 2*1024kB 0*2048kB
2*4096kB = 10864kB
Node 0 DMA32: 1*4kB 0*8kB 1*16kB 1*32kB 0*64kB 1*128kB 0*256kB 2*512kB 2*1024kB 3*2048kB
643*4096kB = 2643124kB
Node 0 Normal: 453*4kB 161*8kB 44*16kB 15*32kB 4*64kB 4*128kB 0*256kB 1*512kB 0*1024kB
1*2048kB 3210*4096kB = 13155772kB
Node 0 HighMem: empty
85955 pagecache pages
Swap cache: add 0, delete 0, find 0/0, race 0+0
Free swap  = 2031608kB
Total swap = 2031608kB
Free swap:       2031608kB
4521984 pages of RAM
446612 reserved pages
21971 pages shared
0 pages swap cached
```


Alt Sysrq M - NUMA

```
Free pages:    15630596kB (0kB HighMem)
Active:77517 inactive:67928 dirty:1000 writeback:0 unstable:0 free:3907649 slab:10391 mapped-file:8975
mapped-anon:38003 pagetables:4731
Node 0 DMA free:10864kB min:8kB low:8kB high:12kB active:0kB inactive:0kB present:10460kB pages_scanned:0
all_unreclaimable? no
lowmem_reserve[]: 0 2743 8045 8045
Node 0 DMA32 free:2643480kB min:2760kB low:3448kB high:4140kB active:0kB inactive:0kB present:2808992kB
pages_scanned:0 all_unreclaimable? no
Node 0 Normal free:4917364kB min:5340kB low:6672kB high:8008kB active:204836kB inactive:197340kB
present:5429760kB pages_scanned:0 all_unreclaimable? no
Node 0 HighMem free:0kB min:128kB low:128kB high:128kB active:0kB inactive:0kB present:0kB pages_scanned:0
all_unreclaimable? no
Node 1 DMA free:0kB min:0kB low:0kB high:0kB active:0kB inactive:0kB present:0kB pages_scanned:0
all_unreclaimable? no
Node 1 DMA32 free:0kB min:0kB low:0kB high:0kB active:0kB inactive:0kB present:0kB pages_scanned:0
all_unreclaimable? no
Node 1 Normal free:8058888kB min:8140kB low:10172kB high:12208kB active:105232kB inactive:74372kB
present:8273920kB pages_scanned:0 all_unreclaimable? no
Node 1 HighMem free:0kB min:128kB low:128kB high:128kB active:0kB inactive:0kB present:0kB pages_scanned:0
all_unreclaimable? no
Node 0 DMA: 6*4kB 5*8kB 3*16kB 2*32kB 3*64kB 2*128kB 0*256kB 0*512kB 2*1024kB 0*2048kB 2*4096kB = 10864kB
Node 0 DMA32: 2*4kB 2*8kB 0*16kB 2*32kB 1*64kB 1*128kB 1*256kB 2*512kB 2*1024kB 3*2048kB 643*4096kB =
2643480kB
Node 0 Normal: 91*4kB 47*8kB 27*16kB 5*32kB 5*64kB 0*128kB 0*256kB 1*512kB 2*1024kB 1*2048kB 1199*4096kB =
4917364kB
Node 1 Normal: 78*4kB 48*8kB 477*16kB 326*32kB 261*64kB 105*128kB 55*256kB 33*512kB 20*1024kB 0*2048kB
1943*4096kB = 8058888kB
107476 pagecache pages
4521984 pages of RAM
```


Alt Sysrq T

```
gdmgreeter    S ffff810009036800     0  7511   7483                7489 (NOTLB)
 ffff81044ae05b38 0000000000000082 0000000000000080 0000000000000000
 0000000000000000 000000000000000a ffff810432ed97a0 ffff81010f387080
 0000002a3a0d4398 0000000000003b57 ffff810432ed9988 0000000600000000
Call Trace:
 [<ffffffff8006380f>] schedule_timeout+0x1e/0xad
 [<ffffffff80049b33>] add_wait_queue+0x24/0x34
 [<ffffffff8002db7e>] pipe_poll+0x2d/0x90
 [<ffffffff8002f764>] do_sys_poll+0x277/0x360
 [<ffffffff8001e99c>] __pollwait+0x0/0xe2
 [<ffffffff8008be44>] default_wake_function+0x0/0xe
 [<ffffffff8008be44>] default_wake_function+0x0/0xe
 [<ffffffff8008be44>] default_wake_function+0x0/0xe
 [<ffffffff80012f1a>] sock_def_readable+0x34/0x5f
 [<ffffffff8004a81a>] unix_stream_sendmsg+0x281/0x346
 [<ffffffff80037c3a>] do_sock_write+0xc6/0x102
 [<ffffffff801277da>] avc_has_perm+0x43/0x55
 [<ffffffff80276a6e>] unix_ioctl+0xc7/0xd0
 [<ffffffff8021f48f>] sock_ioctl+0x1c1/0x1e5
 [<ffffffff800420a7>] do_ioctl+0x21/0x6b
 [<ffffffff800302a0>] vfs_ioctl+0x457/0x4b9
 [<ffffffff800b6193>] audit_syscall_entry+0x180/0x1b3
 [<ffffffff8004c4f6>] sys_poll+0x2d/0x34
 [<ffffffff8005d28d>] tracesys+0xd5/0xe0
```


Alt Sysrq W and P

```
SysRq : Show CPUs
CPU2:
 ffff81010f30bf48 0000000000000000 ffff81010f305e20 ffffffff801ae69e
 0000000000000000 0000000000000200 ffffffff803ea2a0 ffffffff801ae6cd
 ffffffff801ae69e ffffffff80022d85 ffffffff80197393 00000000000000ff
Call Trace:
 <IRQ>  [<ffffffff801ae69e>] showacpu+0x0/0x3b
 [<ffffffff801ae6cd>] showacpu+0x2f/0x3b
 [<ffffffff801ae69e>] showacpu+0x0/0x3b
 [<ffffffff80022d85>] smp_call_function_interrupt+0x57/0x75
 [<ffffffff80197393>] acpi_processor_idle+0x0/0x463
 [<ffffffff8005dc22>] call_function_interrupt+0x66/0x6c
 <EOI>  [<ffffffff80197324>] acpi_safe_halt+0x25/0x36
 [<ffffffff8019751a>] acpi_processor_idle+0x187/0x463
 [<ffffffff80197395>] acpi_processor_idle+0x2/0x463
 [<ffffffff80197393>] acpi_processor_idle+0x0/0x463
 [<ffffffff80197393>] acpi_processor_idle+0x0/0x463
 [<ffffffff80049399>] cpu_idle+0x95/0xb8
 [<ffffffff80076e12>] start_secondary+0x45a/0x469
```


Profiling Tools: OProfile

Open source project – http://oprofile.sourceforge.net

Upstream; Red Hat contributes

Originally modeled after DEC Continuous Profiling Infrastructure (DCPI)

System-wide profiler (both kernel and user code)

Sample-based profiler with SMP machine support

Performance monitoring hardware support

Relatively low overhead, typically <10%

Designed to run for long times

Included in base Red Hat Enterprise Linux product

Events to measure with Oprofile:

Initially time-based samples most useful:

PPro/PII/PIII/AMD: CPU_CLK_UNHALTED

P4: GLOBAL_POWER_EVENTS

IA64: CPU_CYCLES

TIMER_INT (fall-back profiling mechanism) default

Processor specific performance monitoring hardware can provide additional kinds of sampling

Many events to choose from

Branch mispredictions

Cache misses - TLB misses

Pipeline stalls/serializing instructions

oprofile – builtin to RHEL4 & 5 (smp)

opcontrol – on/off data

--start start collection

--stop stop collection

--dump output to disk

--event=:name:count

Example:

 # opcontrol –start

 # /bin/time test1 &

 # sleep 60

 # opcontrol –stop

 # opcontrol dump

opreport – analyze profile

-r reverse order sort

-t [percentage] theshold to view

-f /path/filename

-d details

opannotate

-s /path/source

-a /path/assembly

oprofile – opcontrol and opreport cpu_cycles

```
# CPU: Core 2, speed 2666.72 MHz (estimated)
Counted CPU_CLK_UNHALTED events (Clock cycles when not halted) with a unit mask of 0x00 (Unhalted core c
ycles) count 100000
CPU_CLK_UNHALT...|
  samples|      %|
------------------
397435971 84.6702 vmlinux
 19703064  4.1976 zeus.web
 16914317  3.6034 e1000
 12208514  2.6009 ld-2.5.so
 11711746  2.4951 libc-2.5.so
  5164664  1.1003 sim.cgi
  2333427  0.4971 oprofiled
  1295161  0.2759 oprofile
  1099731  0.2343 zeus.cgi
   968623  0.2064 ext3
   270163  0.0576 jbd
```


Profiling Tools: SystemTap

Technology: Kprobes:

In current 2.6 kernels

Upstream 2.6.12, backported to RHEL4 kernel

Kernel instrumentation without recompile/reboot

Uses software int and trap handler for instrumentation

Debug information:

Provides map between executable and source code

Generated as part of RPM builds

Available at: ftp://ftp.redhat.com

Safety: Instrumentation scripting language:

No dynamic memory allocation or assembly/C code

Types and type conversions limited

Restrict access through pointers

Script compiler checks:

Infinite loops and recursion – Invalid variable access

Profiling Tools: SystemTap

Red Hat, Intel, IBM & Hitachi collaboration

Linux answer to Solaris Dtrace

Dynamic instrumentation

Tool to take a deep look into a running system:

Assists in identifying causes of performance problems

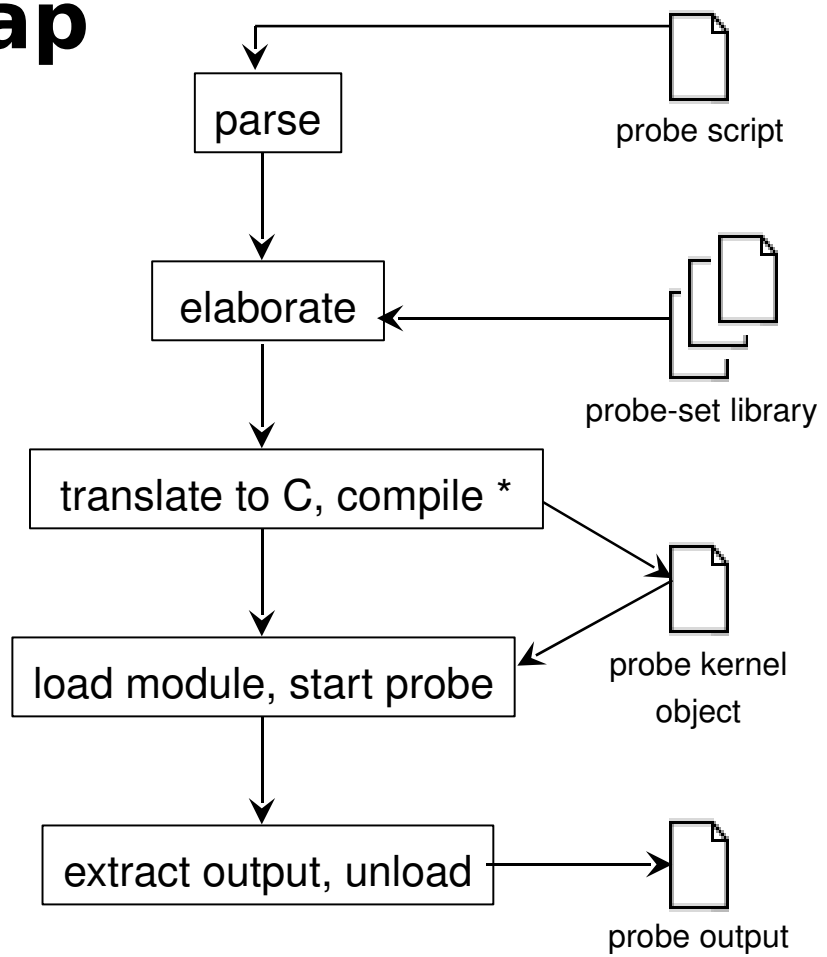
Simplifies building instrumentation

Current snapshots available from:
http://sources.redhat.com/systemtap

Source for presentations/papers

Kernel space tracing today, user space tracing under development

Technology preview status until 5.1



* Solaris Dtrace is interpretive

SystemTap: Kernel debugging

Several tracepoints were added to RHEL5 kernel

```
trace_mm_filemap_fault(area->vm_mm, address, page);
trace_mm_anon_userfree(mm, addr, page);
trace_mm_filemap_userunmap(mm, addr, page);
trace_mm_filemap_cow(mm, address, new_page);
trace_mm_anon_cow(mm, address, new_page);
trace_mm_anon_pgin(mm, address, page);
trace_mm_anon_fault(mm, address, page);
trace_mm_page_free(page);
trace_mm_page_allocation(page, zone->free_pages);
trace_mm_pdflush_bgwriteout(_min_pages);
trace_mm_pdflush_kupdate(nr_to_write);
trace_mm_anon_unmap(page, ret == SWAP_SUCCESS);
trace_mm_filemap_unmap(page, ret == SWAP_SUCCESS);
trace_mm_pagereclaim_pgout(page, PageAnon(page));
trace_mm_pagereclaim_free(page, PageAnon(page));
trace_mm_pagereclaim_shrinkinactive_i2a(page);
trace_mm_pagereclaim_shrinkinactive_i2i(page);
trace_mm_pagereclaim_shrinkinactive(nr_reclaimed);
trace_mm_pagereclaim_shrinkactive_a2a(page);
trace_mm_pagereclaim_shrinkactive_a2i(page);
trace_mm_pagereclaim_shrinkactive(pgscanned);
```


SystemTap: Kernel debugging

Several custom scripts enable/use tracepoints

(/usr/local/share/doc/systemtap/examples)

```
#! /usr/local/bin/stap
global traced_pid
function log_event:long ()
{
        return (!traced_pid ||traced_pid == (task_pid(task_current())))
}
probe kernel.trace("mm_pagereclaim_shrinkinactive") {
        if (!log_event()) next
        reclaims[pid()]++
        command[pid()]=execname()
}
//MM kernel tracepoints prolog and epilog routines
probe begin {
        printf("Starting mm tracepoints\n");
        traced_pid = target();
        if (traced_pid) {
                printf("mode Specific Pid, traced pid: %d\n", traced_pid);
        } else {
                printf("mode - All Pids\n");
        }
        printf("\n");
}
probe end {
        printf("Terminating mm tracepoints\n");
        printf("Command            Pid       Direct    Activate   Deactivate Reclaims   Freed\n");
        printf("-------            ---       ------    --------   ---------- --------   -----\n");
        foreach (pid in reclaims-)
```

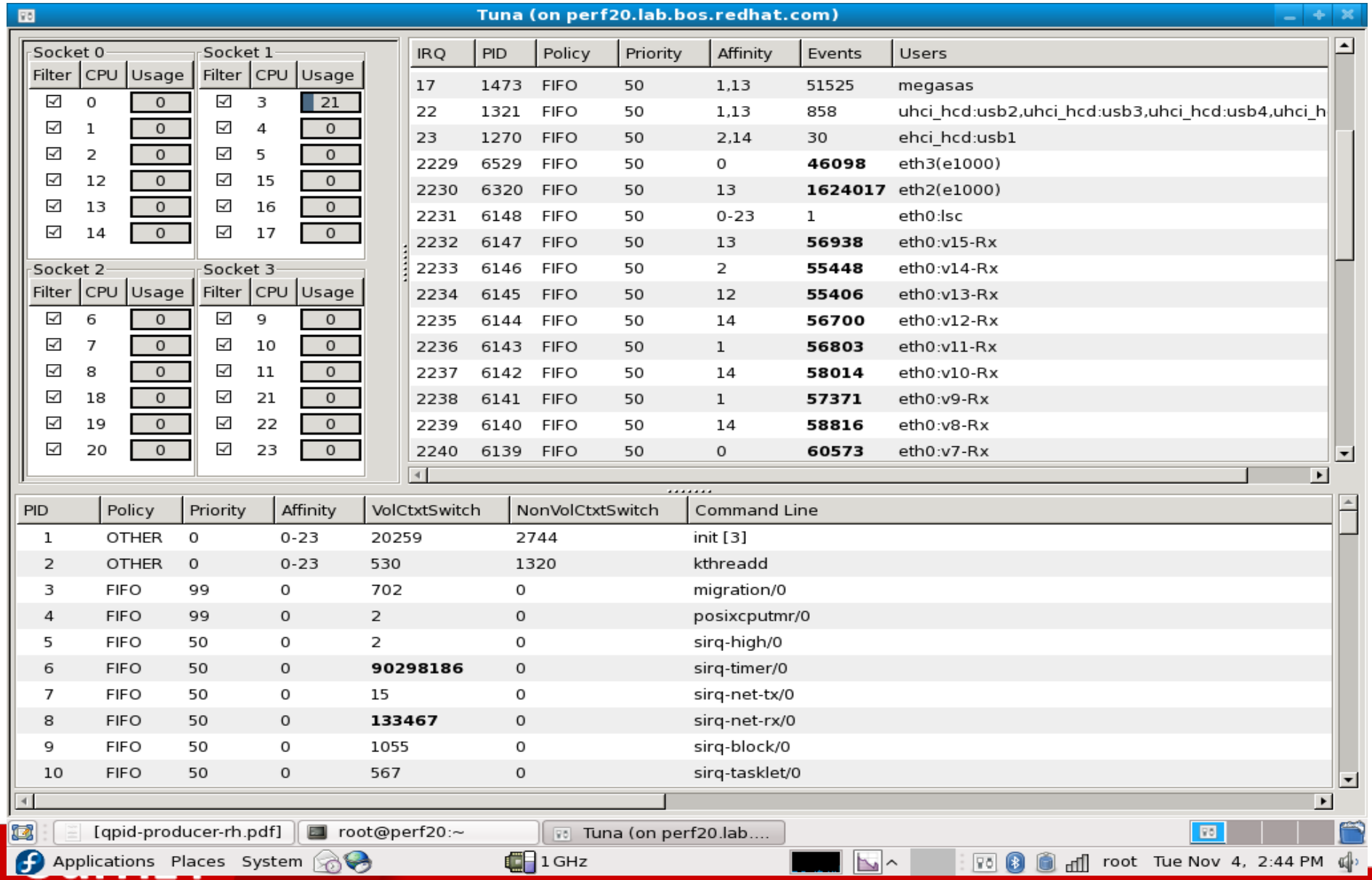

SystemTap: Kernel debugging

Command	Pid	Direct	Activate	Deactivate	Reclaims	Freed
kswapd0	544	0	1503767	919437	15157	430730
kswapd1	545	0	1806788	824347	12117	341408
memory	25435	997	569757	308360	4621	115837
mixer_applet2	7687	6	4180	1013	33	981
Xorg	7491	5	1906	2839	20	382
gnome-terminal	7161	2	1038	695	12	320
gnome-terminal	7701	5	2614	2245	7	172
cupsd	7100	1	927	0	4	128

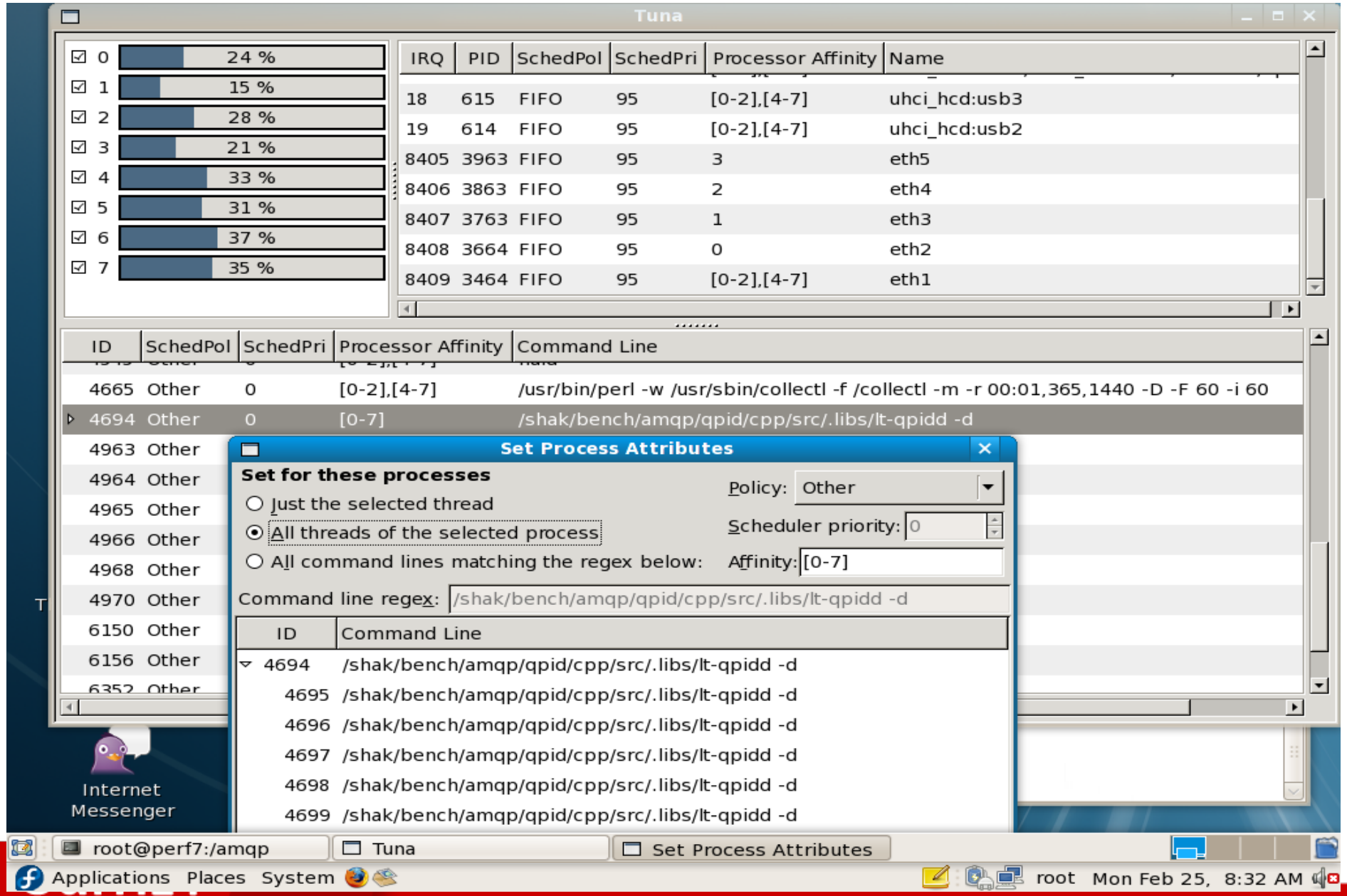
SystemTap: Kernel debugging

Command	Pid	Alloc	Free	A_fault	A_ufree	A_pgin	A_cow	A_unmap
memory	25685	2842784	4064408	2834840	3989816	14	0	48185
kswapd1	545	3007	53257	0	0	0	0	49884
kswapd0	544	620	25241	0	0	0	0	17568
mixer_applet2	7687	302	2827	0	0	1	0	1241
sshd	25051	227	0	0	0	6	0	0
kjournald	863	207	283	0	0	0	0	2149
Xorg	7491	169	898	0	0	0	0	310
gnome-power-man	7653	152	0	0	0	18	0	0
avahi-daemon	7252	150	1280	0	0	48	0	160
irqbalance	6725	126	364	13	13	18	0	190
bash	25053	122	0	0	0	13	0	0
hald	7264	89	0	0	0	83	0	0
gconfd-2	7163	82	526	0	0	68	0	116

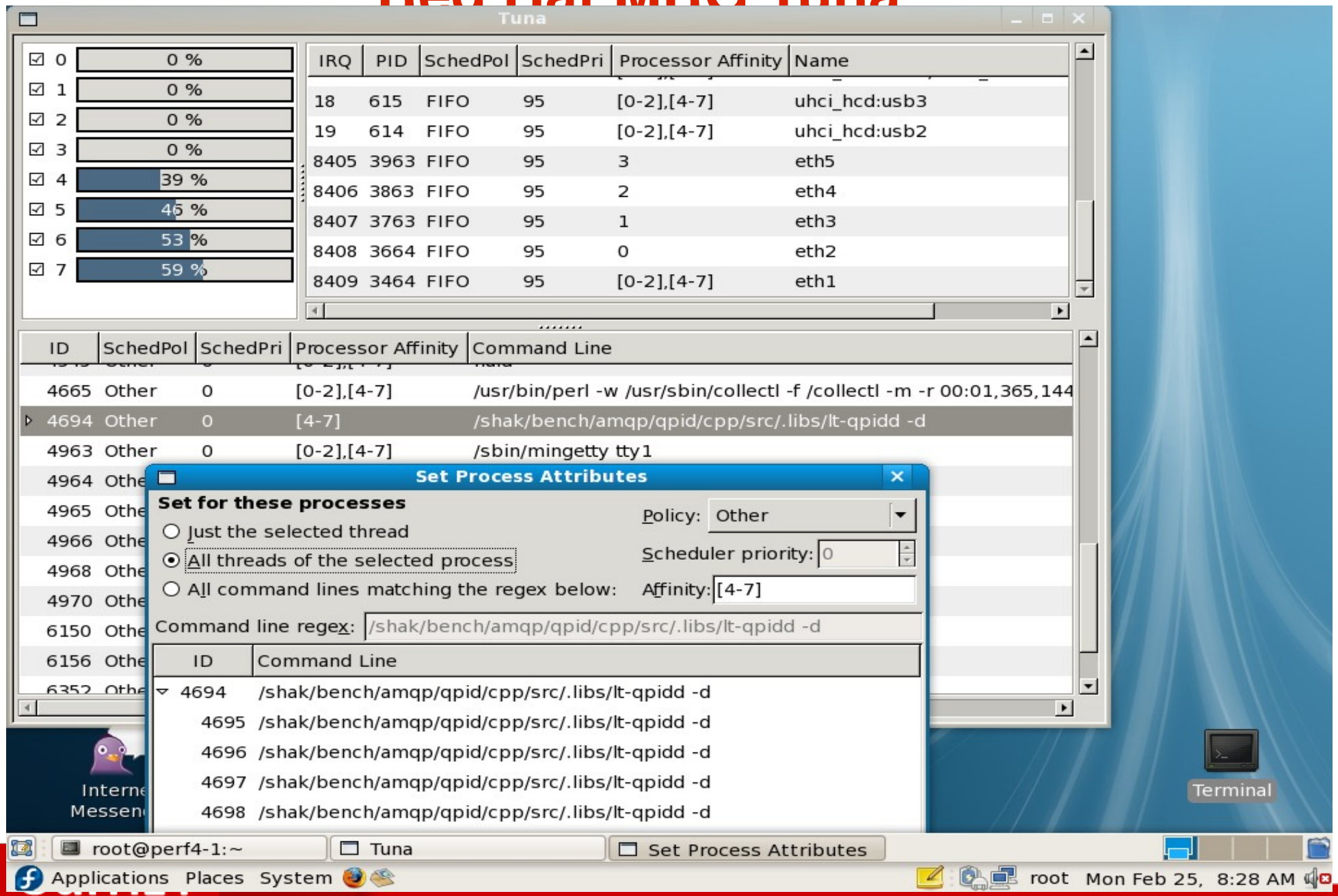
Red Hat MRG Tuna



Red Hat MRG Tuna con't



Red Hat MRG Tuna



Red Hat MRG Tuna

TUNA command line

Usage: tuna [OPTIONS]

```
    -h, --help                 Give this help list
    -g, --gui                  Start the GUI
  -c, --cpus=CPU-LIST                  CPU-LIST affected by commands
  -C, --affect_children                Operation will affect children threads
  -f, --filter               Display filter the selected entities
  -i, --isolate                        Move all threads away from CPU-LIST
  -I, --include                        Allow all threads to run on CPU-LIST
  -K, --no_kthreads          Operations will not affect kernel threads
  -m, --move                           move selected entities to CPU-LIST
  -p, --priority=[POLICY]:RTPRIO       set thread scheduler POLICY and RTPRIO
  -P, --show_threads         show thread list
  -s, --save=FILENAME                  save kthreads sched tunables to FILENAME
  -S, --sockets=CPU-SOCKET-LIST   CPU-SOCKET-LIST affected by commands
  -t, --threads=THREAD-LIST   THREAD-LIST affected by commands
  -U, --no_uthreads          Operations will not affect user threads
  -W, --what_is                        Provides help about selected entities
```

Examples

tuna -c 0-3 -i (isolate cpu 0-3), tune -S 1 – i (isolate socket 1 = cpu 0-3 intelq)

tuna -t PID -C -p fifo:50 -S 1 -m -P (move PID# to socket 1, sched:fifo +50 prior

Section 3: Tuning RHEL

How to tune Linux

Capacity tuning

Fix problems by adding resources

Performance Tuning

Throughput versus Latency

Methodology

1) Document config
2) Baseline results
3) While results non-optimal
    a) Monitor/Instrument system/workload
    b) Apply tuning 1 change at a time
    c) Analyze results, exit or loop
4) Document final config

Tuning - setting kernel parameters

/proc

[root@foobar fs]# cat /proc/sys/kernel/sysrq (see “0”)

[root@foobar fs]# echo 1 > /proc/sys/kernel/sysrq

[root@foobar fs]# cat /proc/sys/kernel/sysrq (see “1”)

Sysctl command

[root@foobar fs]# sysctl kernel.sysrq

kernel.sysrq = 0

[root@foobar fs]# sysctl -w kernel.sysrq=1

kernel.sysrq = 1

[root@foobar fs]# sysctl kernel.sysrq

kernel.sysrq = 1

Edit the /etc/sysctl.conf file

Kernel sysctl configuration file for Red Hat Linux

Controls the System Request debugging functionality of the kernel

kernel.sysrq = 1

Capacity Tuning

- Memory
  - /proc/sys/vm/overcommit_memory
  - /proc/sys/vm/overcommit_ratio
  - /proc/sys/vm/max_map_count
  - /proc/sys/vm/nr_hugepages
- Kernel
  - /proc/sys/kernel/msgmax
  - /proc/sys/kernel/msgmnb
  - /proc/sys/kernel/msgmni
  - /proc/sys/kernel/shmall
  - /proc/sys/kernel/shmmax
  - /proc/sys/kernel/shmmni
  - /proc/sys/kernel/threads-max
- Filesystems
  - /proc/sys/fs/aio_max_nr
  - /proc/sys/fs/file_max
- OOM kills

OOM kills – lowmem consumption

```
Free pages:     9003696kB (8990400kB HighMem)
Active:323264 inactive:346882 dirty:327575 writeback:3686 unstable:0 free:2250924 slab:177094
mapped:15855 pagetables:987
DMA free:12640kB min:16kB low:32kB high:48kB active:0kB inactive:0kB present:16384kB
pages_scanned:149 all_unreclaimable? yes
protections[]: 0 0 0
Normal free:656kB min:928kB low:1856kB high:2784kB active:6976kB inactive:9976kB present:901120kB
pages_scanned:28281 all_unreclaimable? yes
protections[]: 0 0 0
HighMem free:8990400kB min:512kB low:1024kB high:1536kB active:1286080kB inactive:1377552kB
present:12451840kB pages_scanned:0 all_unreclaimable? no
protections[]: 0 0 0
DMA: 4*4kB 4*8kB 3*16kB 4*32kB 4*64kB 1*128kB 1*256kB 1*512kB 1*1024kB 1*2048kB 2*4096kB =
12640kB
Normal: 0*4kB 2*8kB 0*16kB 0*32kB 0*64kB 1*128kB 0*256kB 1*512kB 0*1024kB 0*2048kB 0*4096kB =
656kB
HighMem: 15994*4kB 17663*8kB 11584*16kB 8561*32kB 8193*64kB 1543*128kB 69*256kB 2101*512kB
1328*1024kB 765*2048kB 875*4096kB = 8990400kB
Swap cache: add 0, delete 0, find 0/0, race 0+0
Free swap:       8385912kB
3342336 pages of RAM
2916288 pages of HIGHMEM
224303 reserved pages
666061 pages shared
0 pages swap cached
Out of Memory: Killed process 22248 (httpd).
oom-killer: gfp_mask=0xd0
```


OOM kills – IO system stall

```
Free pages: 15096kB (1664kB HighMem) Active:34146 inactive:1995536 dirty:255
writeback:314829 unstable:0 free:3774 slab:39266 mapped:31803 pagetables:820
DMA free:12552kB min:16kB low:32kB high:48kB active:0kB inactive:0kB present:16384kB
pages_scanned:2023 all_unreclaimable? yes
protections[]: 0 0 0
Normal free:880kB min:928kB low:1856kB high:2784kB active:744kB inactive:660296kB
present:901120kB pages_scanned:726099 all_unreclaimable? yes
protections[]: 0 0 0
HighMem free:1664kB min:512kB low:1024kB high:1536kB active:135840kB inactive:7321848kB
present:7995388kB pages_scanned:0 all_unreclaimable? no
protections[]: 0 0 0
DMA: 2*4kB 4*8kB 2*16kB 4*32kB 3*64kB 1*128kB 1*256kB 1*512kB 1*1024kB 1*2048kB 2*4096kB =
12552kB
Normal: 0*4kB 18*8kB 14*16kB 0*32kB 0*64kB 0*128kB 0*256kB 1*512kB 0*1024kB 0*2048kB 0*4096kB
= 880kB
HighMem: 6*4kB 9*8kB 66*16kB 0*32kB 0*64kB 0*128kB 0*256kB 1*512kB 0*1024kB 0*2048kB 0*4096kB
= 1664kB
Swap cache: add 856, delete 599, find 341/403, race 0+0
0 bounce buffer pages
Free swap:       4193264kB
2228223 pages of RAM
1867481 pages of HIGHMEM
150341 reserved pages
343042 pages shared
257 pages swap cached
kernel: Out of Memory: Killed process 3450 (hpsmhd).
```


Eliminating OOMkills

- RHEL4
  - /proc/sys/vm/oom-kill – oom kill enable/disable flag(default 1).
- RHEL5
  - /proc/<pid>/oom_adj – per-process OOM adjustment(-17 to +15)
  - Set to -17 to disable that process from being OOM killed
  - Decrease to decrease OOM kill likelyhood.
  - Increase to increase OOM kill likelyhood.
  - /proc/<pid>/oom_score – current OOM kill priority.

General Performance Tuning Considerations

Over Committing RAM

Swap device location

Storage device and limits limits

Kernel selection

Trading off between Throughput and Latency

Performance Tuning

Kernel Selection

VM tuning

Processor related tuning

NUMA related tuning

Disk & IO tuning

Hugepages

KVM host and guests

RHEL4 kernel selection

- x86
  - Standard kernel(no PAE, 3G/1G)
    - UP systems with <= 4GB RAM
  - SMP kernel(PAE, 3G/1G)
    - SMP systems with < ~16GB RAM
  - Highmem/Lowmem ratio <= 16:1
    - Hugemem kernel(PAE, 4G/4G)
    - SMP systems > ~16GB RAM
- X86_64
  - Standard kernel for UP systems
  - SMP kernel for systems with up to 8 CPUs
  - LargeSMP kernel for systems up to 512 CPUs

RHEL5 kernel selection

- x86
  - Standard kernel(no PAE, 3G/1G)
  - UP and SMP systems with <= 4GB RAM
  - PAE kernel(PAE, 3G/1G)
  - UP and SMP systems with >4GB RAM
- X86_64
  - Standard kernel for all systems

VM: swappiness

Controls how aggressively the system reclaims “mapped” memory:

Anonymous memory - swapping

Mapped file pages – writing if dirty and freeing

System V shared memory - swapping

Decreasing: more aggressive reclaiming of unmapped pagecache memory

Increasing: more aggressive swapping of mapped memory

/proc/sys/vm/swappiness

Sybase server with /proc/sys/vm/swappiness set to 60(default)

```
procs -----------memory---------- ---swap--  -----io---- --system-- ----cpu----
r  b   swpd   free   buff  cache   si   so    bi    bo   in    cs  us sy id wa
5  1 643644 26788   3544 32341788 880 120    4044 7496  1302 20846 25 34 25 16
```

Sybase server with /proc/sys/vm/swappiness set to 10

```
procs -----------memory---------- ---swap--  -----io---- --system-- ----cpu----
r  b   swpd   free   buff  cache   si   so    bi    bo   in    cs  us sy id wa
8  3      0  24228   6724 32280696  0    0    23888 63776 1286 20020 24 38 13 26
```


/proc/sys/vm/min_free_kbytes

Directly controls the page reclaim watermarks in KB

 # echo 1024 > /proc/sys/vm/min_free_kbytes

Node 0 DMA free:4420kB min:8kB low:8kB high:12kB

Node 0 DMA32 free:14456kB min:1012kB low:1264kB high:1516kB

----

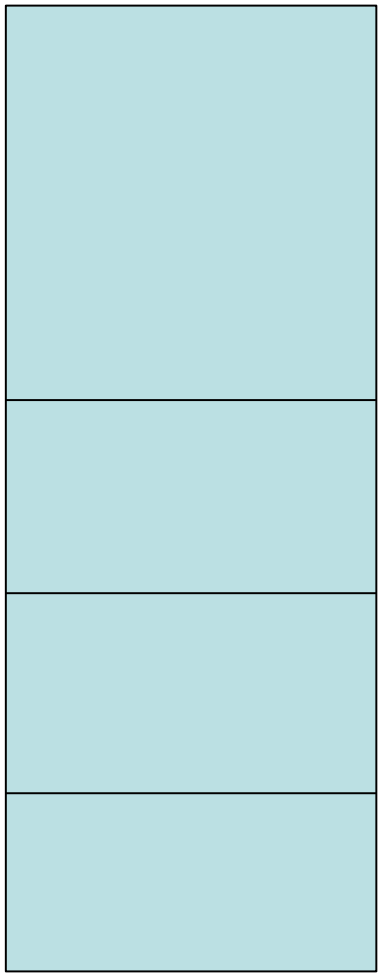
echo 2048 > /proc/sys/vm/min_free_kbytes

Node 0 DMA free:4420kB min:20kB low:24kB high:28kB

Node 0 DMA32 free:14456kB min:2024kB low:2528kB high:3036kB

Memory reclaim Watermarks - min_free_kbytes

Free List



All of RAM

Do nothing

Pages High – kswapd sleeps above High

kswapd reclaims memory

Pages Low – kswapd wakesup at Low

kswapd reclaims memory

Pages Min – all memory allocators reclaim at Min

user processes/kswapd reclaim memory

/proc/sys/vm/dirty_ratio

Absolute limit to percentage of dirty pagecache memory

Default is 40%

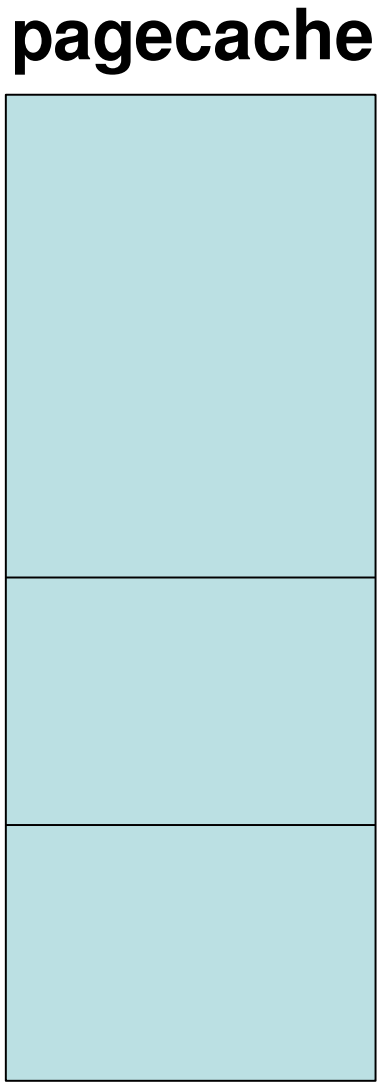
Lower means less dirty pagecache and smaller IO streams

Higher means more dirty pagecache and larger IO streams

/proc/sys/vm/dirty_background_ratio

- Controls when dirty pagecache memory starts getting written.
- Default is 10%
- Lower
  - pdflush starts earlier
  - less dirty pagecache and smaller IO streams
- Higher
  - pdflush starts later
  - more dirty pagecache and larger IO streams

dirty_ratio and dirty_background_ratio



100% of pagecache RAM dirty

pdflushd and write()'ng processes write dirty buffers

dirty_ratio(40% of RAM dirty) – processes start synchronous writes

pdflushd writes dirty buffers in background

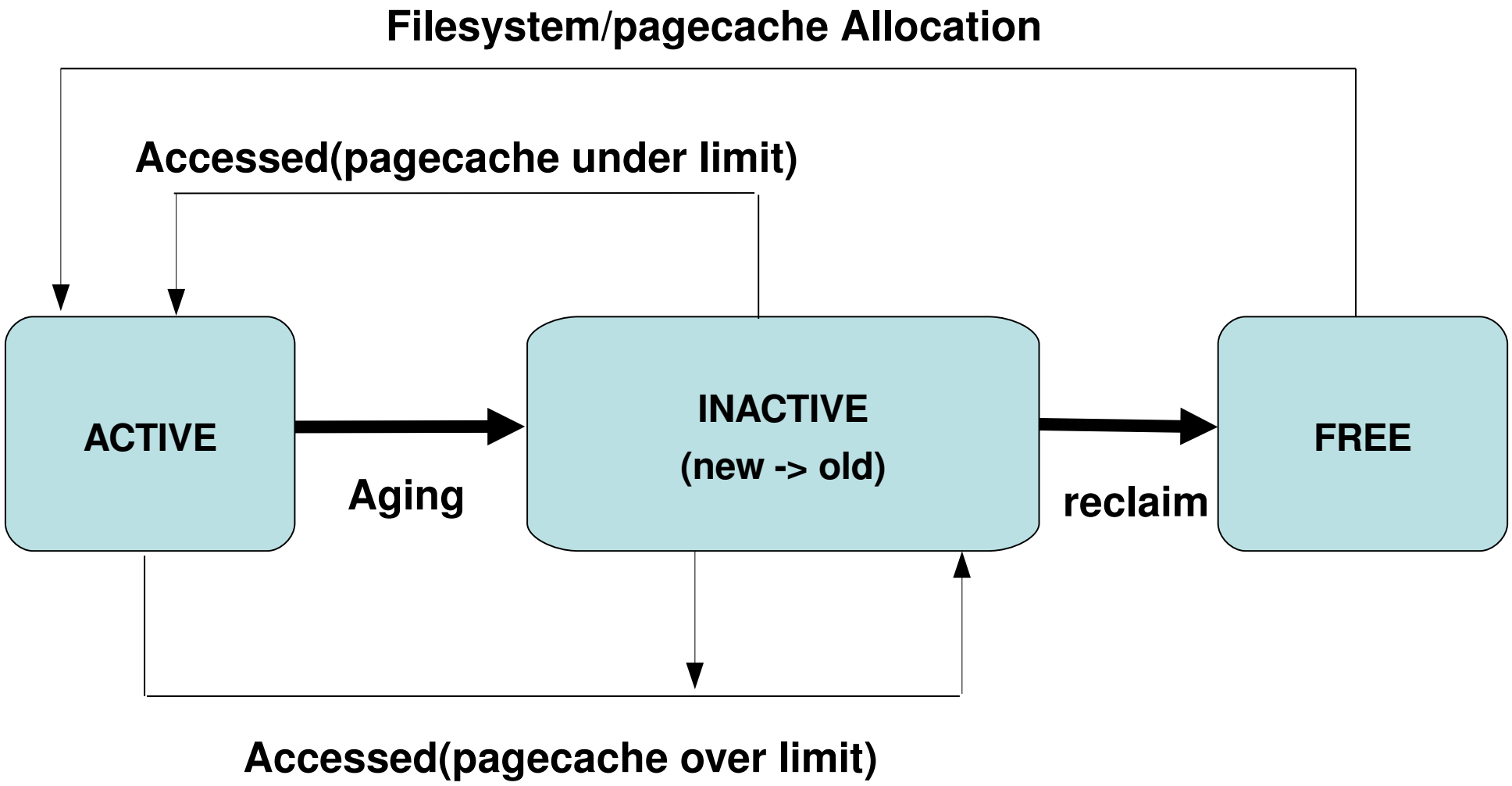
dirty_background_ratio(10% of RAM dirty) – wakeup pdflushd

do_nothing

/proc/sys/vm/pagecache

- Controls when pagecache memory is deactivated.
- Default is 100%
- Lower
  - Prevents swapping out anonymous memory
- Higher
  - Favors pagecache pages
  - Disabled at 100%

Pagecache Tuning



(Hint)flushing the pagecache

echo 1 > /proc/sys/vm/drop_caches

```
procs -----------memory---------- ---swap-- -----io---- --system-- ----cpu----
 r  b   swpd   free   buff  cache   si   so    bi    bo   in    cs us sy id wa
 0  0    224  57184 107808 3350196    0    0     0    56 1136   212  0  0 83 17
 0  0    224  57184 107808 3350196    0    0     0     0 1039   198  0  0 100  0
 0  0    224  57184 107808 3350196    0    0     0     0 1021   188  0  0 100  0
 0  0    224  57184 107808 3350196    0    0     0     0 1035   204  0  0 100  0
 0  0    224  57248 107808 3350196    0    0     0     0 1008   164  0  0 100  0
 3  0    224 2128160    176 1438636    0    0     0     0 1030   197  0 15 85  0
 0  0    224 3610656    204  34408    0    0    28    36 1027   177  0 32 67  2
 0  0    224 3610656    204  34408    0    0     0     0 1026   180  0  0 100  0
 0  0    224 3610720    212  34400    0    0     8     0 1010   183  0  0 99  1
```


(Hint)flushing the slabcache

echo 2 > /proc/sys/vm/drop_caches

[tmp]# cat /proc/meminfo
MemTotal: 3907444 kB
MemFree: 3104576 kB

Slab: 415420 kB

Hugepagesize: 2048 kB

tmp]# cat /proc/meminfo
MemTotal: 3907444 kB
MemFree: 3301788 kB

Slab: 218208 kB

Hugepagesize: 2048 kB

CPUspeed and performance:

Enabled = governor set to “ondemand”

Looks at cpu usage to regulate power

Within 3-5% of performance for cpu loads

IO loads can keep cpu stepped down -15-30%

Supported in RHEL5 virtualization

To turn off – else may leave cpu’s in reduced step

If its not using performance, then:

```
# echo performance > /sys/devices/system/cpu/cpu0/cpufreq/scaling_governor
```

Then check to see if it stuck:

```
# cat /sys/devices/system/cpu/cpu0/cpufreq/scaling_governor
```

Check /proc/cpuinfo to make sure your seeing the expected CPU freq.

Proceed to “normal” service disable

Service cpuspeed stop

Chkconfig cpuspeed off

CPU Scheduler

Recognizes differences between logical and physical processors

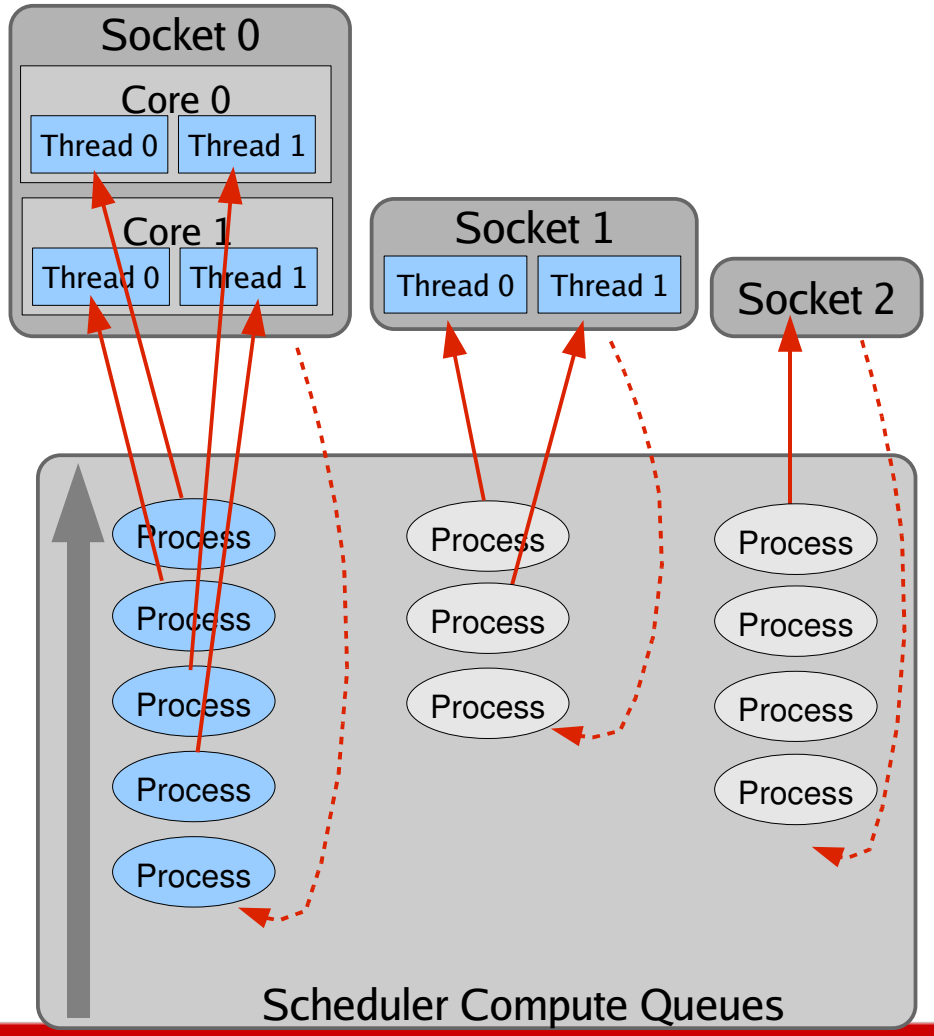
I.E. Multi-core, hyperthreaded & chips/sockets

Optimizes process scheduling to take advantage of shared on-chip cache, and NUMA memory nodes

Implements multilevel run queues
for sockets and cores (as opposed to one run queue per processor or per system)

Strong CPU affinity avoids task bouncing

Requires system BIOS to report CPU topology correctly



NUMA related Tuning

Numastat

Numactl

Hugetlbfs

/sys/devices/system/node

NUMAstat and NUMActl

EXAMPLES

numactl --interleave=all bigdatabase arguments Run big database with its memory interleaved on all CPUs.

numactl --cpubind=0--membind=0,1 process Run process on node 0 with memory allocated on node 0 and 1.

numactl --preferred=1 numactl --show Set preferred node 1 and show the resulting state.

numactl --interleave=all --shmkeyfile /tmp/shmkey Interleave all of the sysv shared memory regiion specified by /tmp/shmkey over all nodes.

numactl --offset=1G --length=1G --membind=1 --file /dev/shm/A --touch Bind the second gigabyte in the tmpfs file /dev/shm/A to node 1.

numactl --localalloc /dev/shm/file Reset the policy for the shared memory file file to the default localalloc policy.

NUMAstat and NUMActl

NUMAstat to display system NUMA characteristics on a numasystem

```
[root@perf5 ~]# numastat
                           node3           node2           node1           node0
numa_hit                   72684           82215          157244          325444
numa_miss                      0               0               0               0
numa_foreign                   0               0               0               0
interleave_hit              2668            2431            2763            2699
local_node                 67306           77456          152115          324733
other_node                  5378            4759            5129             711
```

NUMActl to control process and memory”

TIP

numactl [--interleave nodes] [--preferred node] [--membind nodes] [--cpubind nodes] [--localalloc] command {arguments ...}

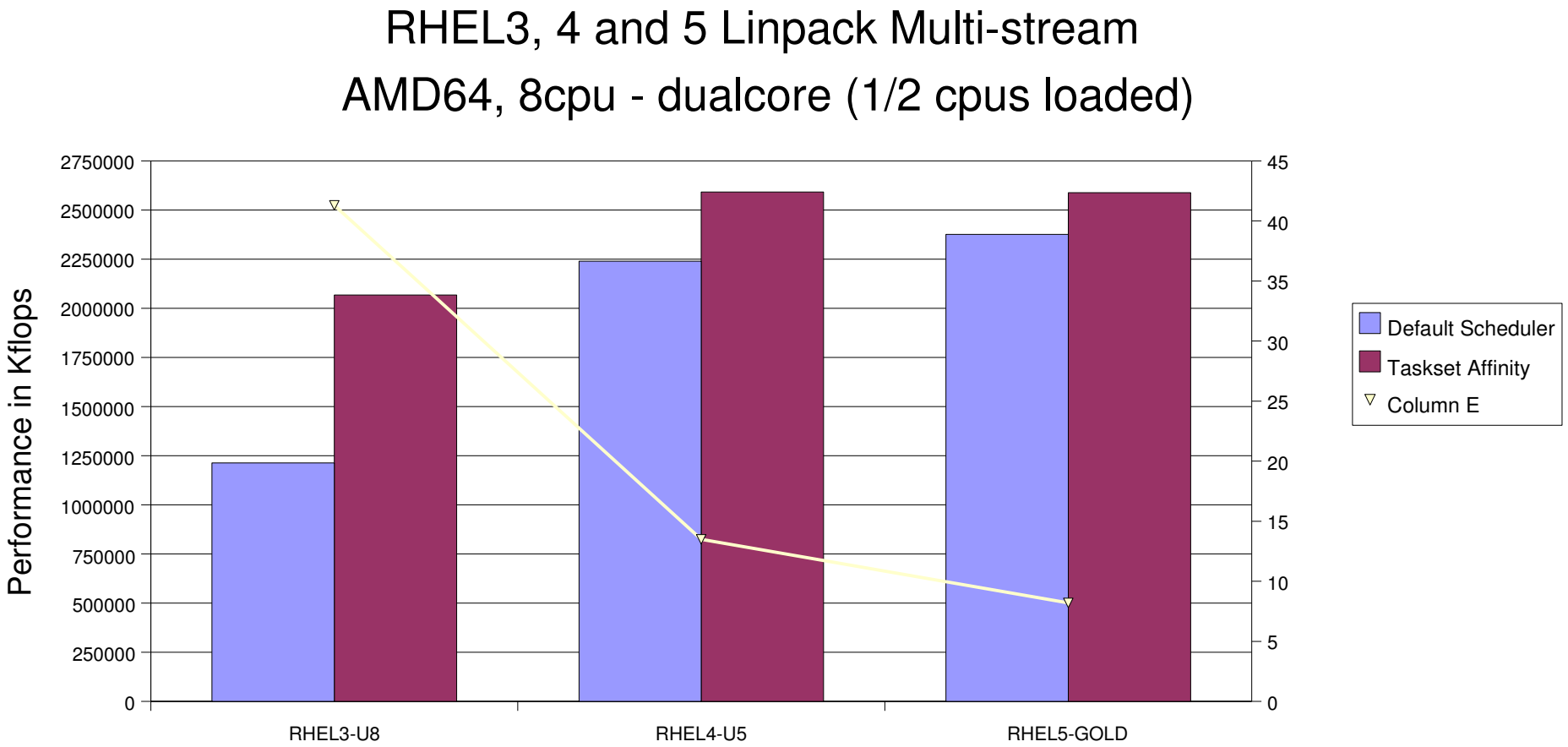
App < memory single NUMA zone

Numactl use –cpubind cpus within same socket

App > memory of a single NUMA zone

Numactl –interleave XY and –cpubind XY

Linux NUMA Evolution (NEWer)



Limitations :

Numa “spill” to different numa boundaries

Process migrations – no way back

Lack of page replication – text, read mostly

HugeTLBFS

The Translation Lookaside Buffer (TLB) is a small CPU cache of recently used virtual to physical address mappings

TLB misses are extremely expensive on today's very fast, pipelined CPUs

Large memory applications can incur high TLB miss rates

HugeTLBs permit memory to be managed in very large segments

Example: x86_64

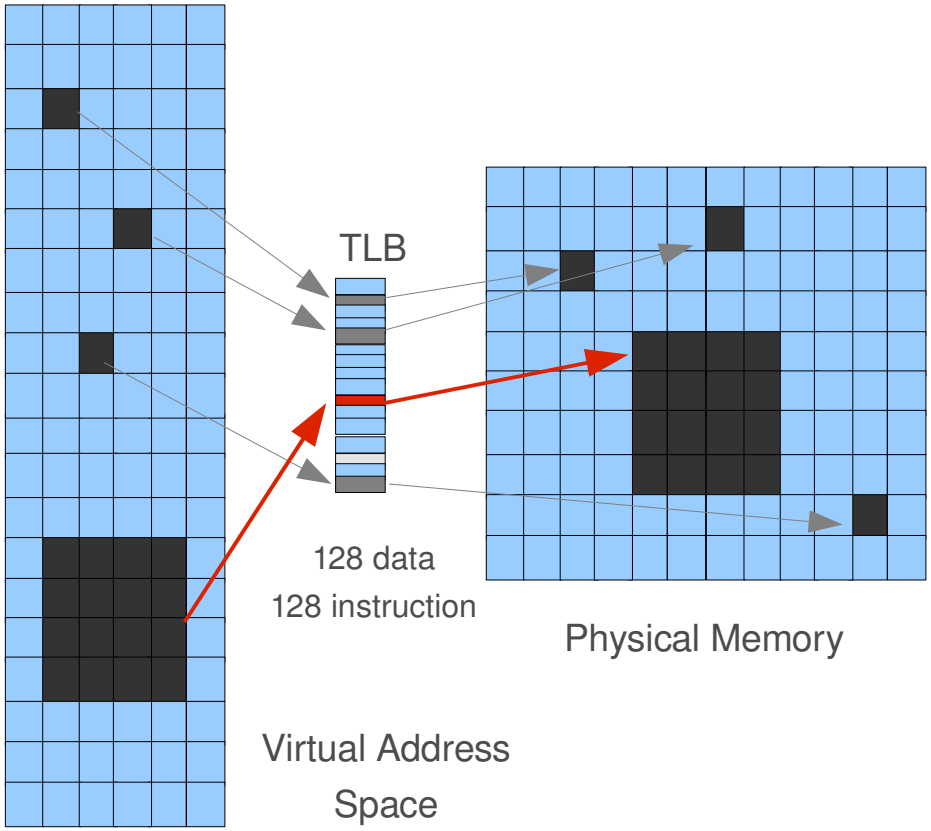
- Standard page: 4KB
- Huge page: 2MB
- 512:1 difference

File system mapping interface

Ideal for databases

Example: 128 entry TLB can fully map 256MB

* RHEL6 – 1GB hugepage support



Hugepages - before

```
$vmstat
procs -----------memory---------- ---swap-- -----io---- --system-- -----cpu------
 r  b   swpd   free   buff  cache   si   so    bi    bo   in   cs us sy id wa st
 0  0      0 15623656  31044 401120    0    0   187    14  163   75  1  0 97  2  0
```

```
$cat /proc/meminfo
MemTotal:       16301368 kB
MemFree:        15623604 kB
...
HugePages_Total:       0
HugePages_Free:        0
HugePages_Rsvd:        0
Hugepagesize:       2048 kB
```


Hugepages reserving

```
$echo 2000 > /proc/sys/vm/nr_hugepages
$vmstat
procs -----------memory---------- ---swap-- -----io---- --system-- -----cpu------
 r  b   swpd   free   buff  cache   si   so    bi    bo   in   cs us sy id wa st
 0  0      0 11526632  31168 401780    0    0   129    10  156   63  1  0 98  1
0
```

```
$cat /proc/meminfo
MemTotal:       16301368 kB
MemFree:        11526520 kB
...
HugePages_Total:  2000
HugePages_Free:   2000
HugePages_Rsvd:      0
Hugepagesize:     2048 kB
```


Hugepages - using

```
$mount -t hugetlbfs hugetlbfs /huge
$cp 1GB-file /huge/junk
```

```
$vmstat
procs -----------memory---------- ---swap-- -----io---- --system-- -----cpu------
 r  b   swpd   free   buff  cache   si   so    bi    bo   in   cs us sy id wa st
 0  0      0 10526632  31168 1401780    0    0   129    10  156   63  1  0 98  1
0
```

```
$cat /proc/meminfo
LowTotal:     16301368 kB
LowFree:      11524756 kB
...
HugePages_Total:  2000
HugePages_Free:   1488
HugePages_Rsvd:      0
Hugepagesize:     2048 kB
```


Hugepages - releasing

```
$rm /huge/junk
$cat /proc/meminfo
MemTotal:      16301368 kB
MemFree:       11524776 kB
...
HugePages_Total:  2000
HugePages_Free:   2000
HugePages_Rsvd:      0
Hugepagesize:     2048 kB


$echo 0 > /proc/sys/vm/nr_hugepages
$vmstat
procs -----------memory---------- ---swap-- -----io---- --system-- -----cpu------
 r  b   swpd   free   buff  cache   si   so    bi    bo   in   cs us sy id wa st
 0  0      0 15620488  31512 401944    0    0    71     6  149   59  1  0 98  1  0


$cat /proc/meminfo
MemTotal:      16301368 kB
MemFree:       15620500 kB
...
HugePages_Total:     0
HugePages_Free:      0
HugePages_Rsvd:      0
Hugepagesize:     2048 kB
```


NUMA Hugepages - reserving

[root@dhcp-100-19-50 ~]# cat /sys/devices/system/node/*/meminfo | grep Huge

Node 0 HugePages_Total: 0

Node 0 HugePages_Free: 0

Node 1 HugePages_Total: 0

Node 1 HugePages_Free: 0

[root@dhcp-100-19-50 ~]# echo 6000 > /proc/sys/vm/nr_hugepages

[root@dhcp-100-19-50 ~]# cat /sys/devices/system/node/*/meminfo | grep Huge

Node 0 HugePages_Total: 2980

Node 0 HugePages_Free: 2980

Node 1 HugePages_Total: 3020

Node 1 HugePages_Free: 3020

NUMA Hugepages - using

[root@dhcp-100-19-50 ~]# mount -t hugetlbfs hugetlbfs /huge

[root@dhcp-100-19-50 ~]# /usr/tmp/mmapwrite /huge/junk 32 &

[1] 18804

[root@dhcp-100-19-50 ~]# Writing 1048576 pages of random junk to file /huge/junk

wrote 4294967296 bytes to file /huge/junk

[root@dhcp-100-19-50 ~]# cat /sys/devices/system/node/*/meminfo | grep Huge

Node 0 HugePages_Total: 2980

Node 0 HugePages_Free: 2980

Node 1 HugePages_Total: 3020

Node 1 HugePages_Free: 972

NUMA Hugepages - using(overcommit)

[root@dhcp-100-19-50 ~]# /usr/tmp/mmapwrite /huge/junk 33 &

[1] 18815

[root@dhcp-100-19-50 ~]# Writing 2097152 pages of random junk to file /huge/junk

wrote 8589934592 bytes to file /huge/junk

[root@dhcp-100-19-50 ~]# cat /sys/devices/system/node/*/meminfo | grep Huge

Node 0 HugePages_Total: 2980

Node 0 HugePages_Free: 1904

Node 1 HugePages_Total: 3020

Node 1 HugePages_Free: 0

NUMA Hugepages - reducing

[root@dhcp-100-19-50 ~]# cat /sys/devices/system/node/*/meminfo | grep Huge

Node 0 HugePages_Total: 2980

Node 0 HugePages_Free: 2980

Node 1 HugePages_Total: 3020

Node 1 HugePages_Free: 3020

[root@dhcp-100-19-50 ~]# echo 3000 > /proc/sys/vm/nr_hugepages

[root@dhcp-100-19-50 ~]# cat /sys/devices/system/node/*/meminfo | grep Huge

Node 0 HugePages_Total: 0

Node 0 HugePages_Free: 0

Node 1 HugePages_Total: 3000

Node 1 HugePages_Free: 3000

NUMA Hugepages - freeing/reserving

[root@dhcp-100-19-50 ~]# echo 6000 > /proc/sys/vm/nr_hugepages

[root@dhcp-100-19-50 ~]# cat /sys/devices/system/node/*/meminfo | grep Huge

Node 0 HugePages_Total: 2982

Node 0 HugePages_Free: 2982

Node 1 HugePages_Total: 3018

Node 1 HugePages_Free: 3018

[root@dhcp-100-19-50 ~]# echo 0 > /proc/sys/vm/nr_hugepages

[root@dhcp-100-19-50 ~]# echo 3000 > /proc/sys/vm/nr_hugepages

[root@dhcp-100-19-50 ~]# cat /sys/devices/system/node/*/meminfo | grep Huge

Node 0 HugePages_Total: 1500

Node 0 HugePages_Free: 1500

Node 1 HugePages_Total: 1500

Node 1 HugePages_Free: 1500

Section 4: RHEL6 tuning preview

More scalable VM system

- cgroups
- Transparent Hugepages
- 1GB hugepage support
- finer grained tuning

More scalable VM system

Separate page-lists for anonymous & pagecache pages

Ticketed spin-locks

Transparent hugepages

1GB hugepage support

One flush daemon per bdi/filesystem

Finer graned tuning for very large memory systems

memory and cpu cgroups

cgroups

1GB/2CPU subset of a 16GB/8CPU system

```
#mount -t cgroup xxx /cgroups
#mkdir -p /cgroups/test
#cd /cgroups/test
#echo 1 > cpuset.mems
#echo 2-3 > cpuset.cpus
#echo 1000000000 > memory.limit_in_bytes
#echo $$ > tasks
```


cgroups

```
[root@dhcp-100-19-50 ~]# memory 2 1 &
[root@dhcp-100-19-50 ~]# vmstat 1
procs -----------memory---------- ---swap-- -----io---- --system-- -----cpu------
 r  b   swpd   free   buff  cache   si   so    bi    bo   in   cs us sy id wa st
 0  0      0 15465636  33636 459612    5   67    16    68   46   27  1  0 99  0  0
 0  0      0 15465504  33636 459612    0    0     0     0  246  160  0  0 100  0  0
 1  0      0 14598736  33636 459612    0    0     0     0 1648  299  1  5 94  0  0
 1  0 114092 14484980  33636 459528    0 114176     0 114176 2974 1031  0  6 82 12  0
 0  1 264672 14479896  33636 459508    0 150496     0 150496 2630  568  0  2 90  7  0
 0  1 375612 14479524  33636 459612    0 110940     0 110940 2301  322  0  4 76 19  0
 0  1 500064 14477788  33636 459692    0 124452     0 124452 1869  273  0  2 91  7  0
 1  0 609908 14477540  33636 459628    0 109888     0 109888 1960  198  0  8 76 15  0
 0  1 709996 14478476  33636 459400    0 100044     0 100044 2243  260  0  3 91  6  0
 0  1 818924 14478352  33636 459600    0 108928     0 108928 2210  342  0  4 77 18  0
 0  1 932920 14478476  33636 459548    0 113996     0 113996 1951  303  0  2 91  7  0
 1  0 1055352 14476864  33636 459516    0 122560     0 122560 1885  197  0  6 76 17  0
```


cgroups

```
[root@dhcp-100-19-50 ~]# forkoff 10 100 100000 &
[root@dhcp-100-19-50 ~]# 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  :  0.0%us,  0.2%sy,  0.0%ni, 99.8%id,  0.0%wa,  0.0%hi,  0.0%si,  0.0%st
Cpu1  :  0.0%us,  0.2%sy,  0.0%ni, 99.8%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  : 89.6%us, 10.0%sy,  0.0%ni,  0.0%id,  0.0%wa,  0.2%hi,  0.2%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
Mem:  16469476k total,  1993064k used, 14476412k free,    33740k buffers
Swap:  2031608k total,   185404k used,  1846204k free,   459644k cached
```


Transparent Hugepages

transparent_hugepages=always

[root@dhcp-100-19-50 code]# time ./memory 15 0
real 0m7.024s
user 0m0.073s
sys 0m6.847s

[root@dhcp-100-19-50 ~]# cat /proc/meminfo
AnonHugePages: 15572992 kB

Transparent Hugepages

transparent_hugepages=never

[root@dhcp-100-19-50 code]# time ./memory 15 0
real 0m12.434s
user 0m0.936s
sys 0m11.416s

[root@dhcp-100-19-50 ~]# cat /proc/meminfo
AnonHugePages: 0 kB

1GB Hugepages

default_hugepagesz=1073741824 hugepagesz=1073741824 hugepages=8

cat /proc/meminfo | more

```
HugePages_Total:       8
HugePages_Free:        8
HugePages_Rsvd:        0
HugePages_Surp:        0
Hugepagesize:    1048576 kB
DirectMap4k:        7104 kB
DirectMap2M:     2088960 kB
DirectMap1G:    14680064 kB
```


1GB Hugepages

#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 | more

```
HugePages_Total:       8
HugePages_Free:        0
HugePages_Rsvd:        0
HugePages_Surp:        0
Hugepagesize:    1048576 kB
DirectMap4k:        7104 kB
DirectMap2M:     2088960 kB
DirectMap1G:    14680064 kB
```


Finer grained tuning

/proc/sys/vm/dirty_background_bytes

/proc/sys/vm/dirty_bytes

/proc/sys/kernel/sched_*

Section 5: RHEL tuning examples

JVM

iozone

Oracle

Sybase

KVM

Benchmarking

JVM Tuning

Eliminate swapping

- Lower swappiness to 10%(or lower if necessary).

Promote pagecache reclaiming

Lower dirty_background_ratio to 10%

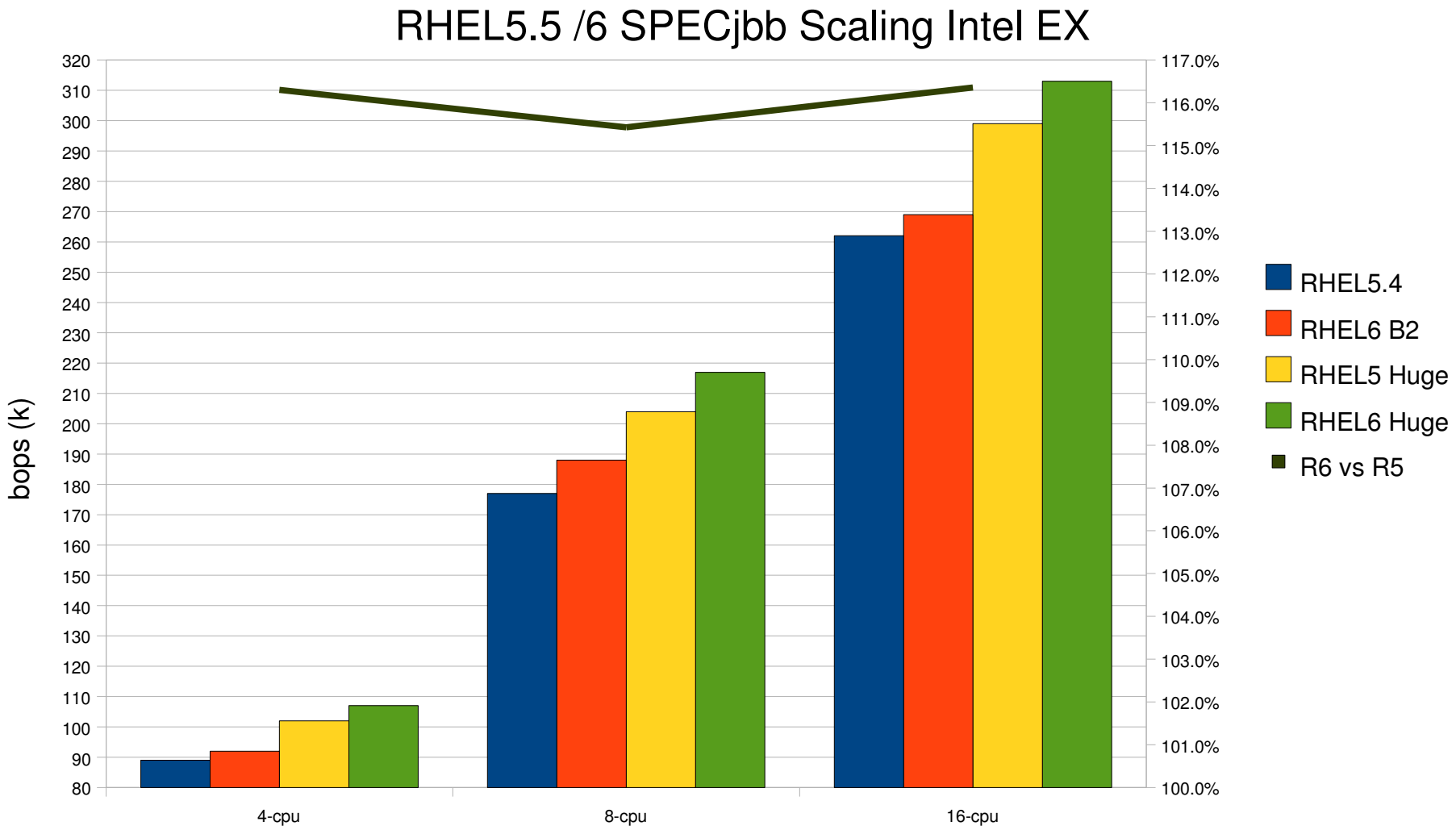
Lower dirty_ratio if necessary

Promote inode cache reclaiming

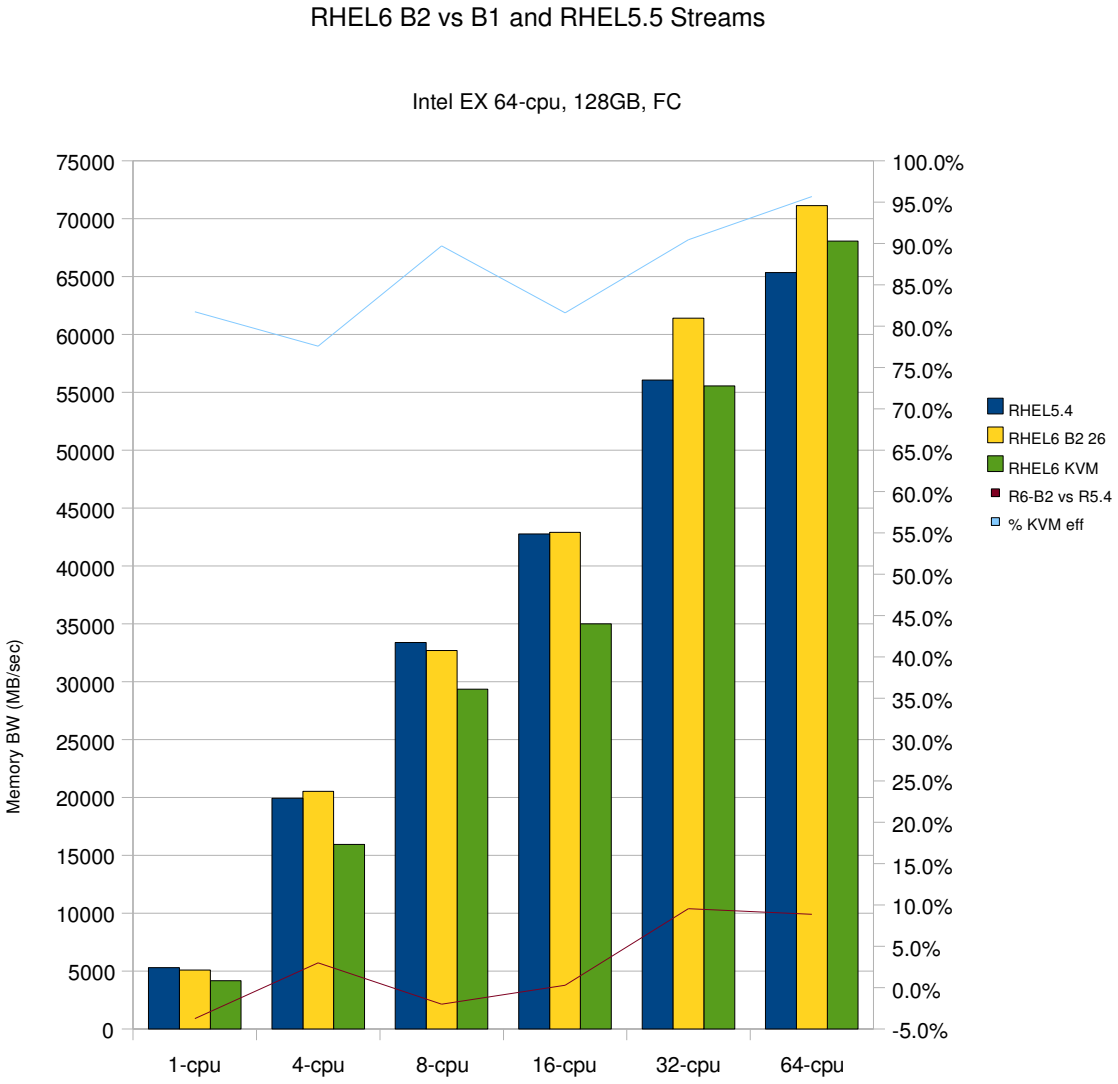
- Lower vfs_cache_pressure

Use Hugepages

Performance – RHEL6 B2 Linux Intel EX Specjbb Java – Huge/Transparent Huge Pages



RHEL5/6 CPU Perf Scaling 48/64 cpu



- **Linpack hits 3rd level cache, scales at arch limit**
- **Streams runs at memory bandwidth, hits socket limit**
- **Test default scheduler, vs taskset cpu affinity, and numaclt cpu/memory binding with 5%.**

Understanding IOzone Results

GeoMean per category are statistically meaningful.

Understand HW setup

Disk, RAID, HBA, PCI

Layout file systems

LVM or MD devices

Partions w/ fdisk

Baseline raw IO DD/DT

EXT3 perf w/ IOzone

In-cache – file sizes which fit goal -> 90% memory BW.

Out-of-cache – file sizes more tan 2x memory size

O_DIRECT – 95% of raw

Global File System – GFS goal --> 90-95% of local EXT3

Use raw command

fdisk /dev/sdX

raw /dev/raw/rawX /dev/sdX1

dd if=/dev/raw/rawX bs=64k

Mount file system

mkfs –t ext3 /dev/sdX1

Mount –t ext3 /dev/sdX1 /perf1

IOzone commands

Iozone –a –f /perf1/t1 (incache)

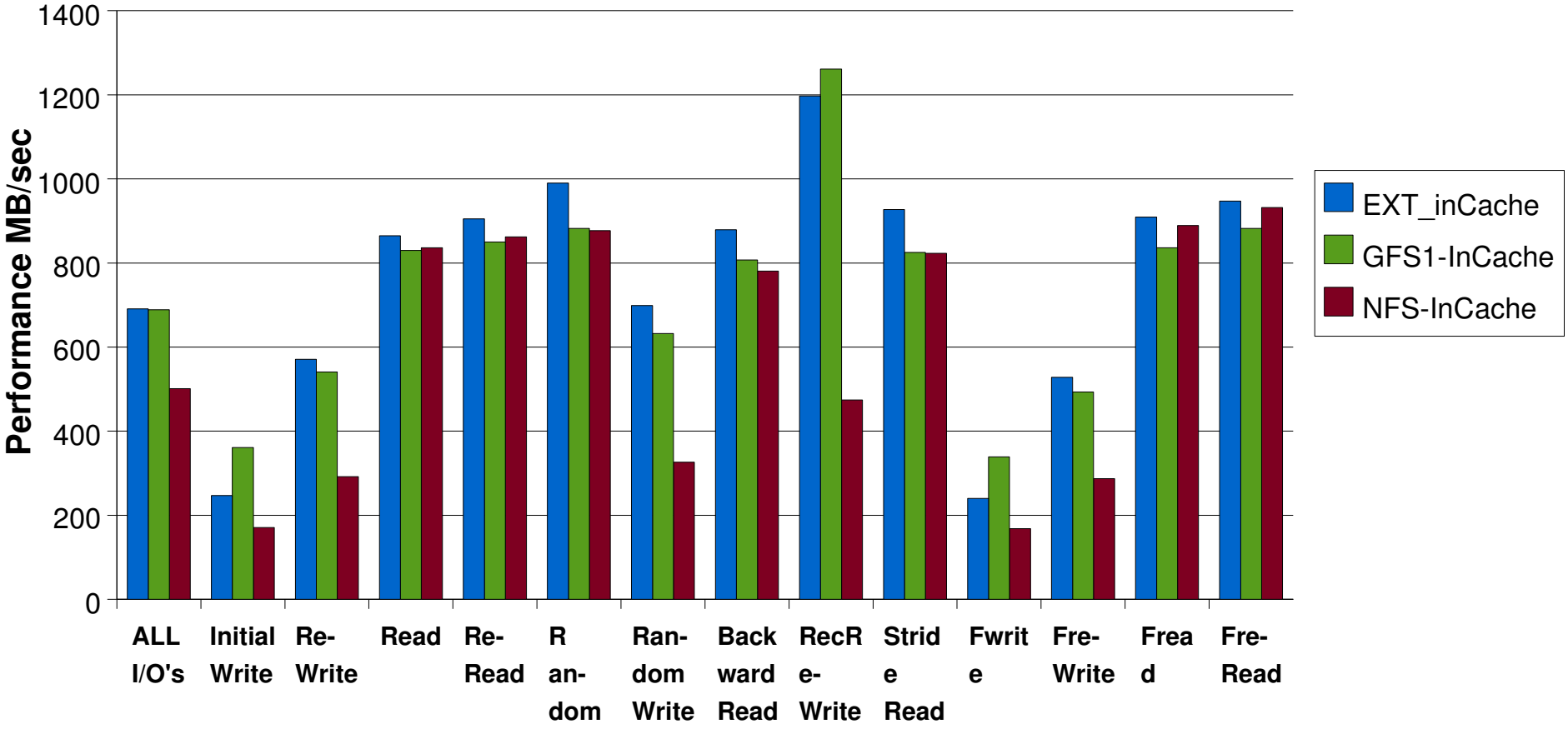
Iozone –a -I –f /perf1/t1 (w/ dio)

Iozone –s 2xmem –f /perf1/t1 (big)

EXT3, GFS, NFS Iozone in cache

RHEL5 In-Cache IOzone EXT3, GFS1, GFS2

(Geom 1M-4GB, 1k-1m)



Using IOzone w/ o_direct – mimic database

Problem :

Filesystems use memory for file cache

Databases use memory for database cache

Users want filesystem for management outside database access (copy, backup etc)

You DON'T want BOTH to cache.

Solution :

Filesystems that support Direct IO

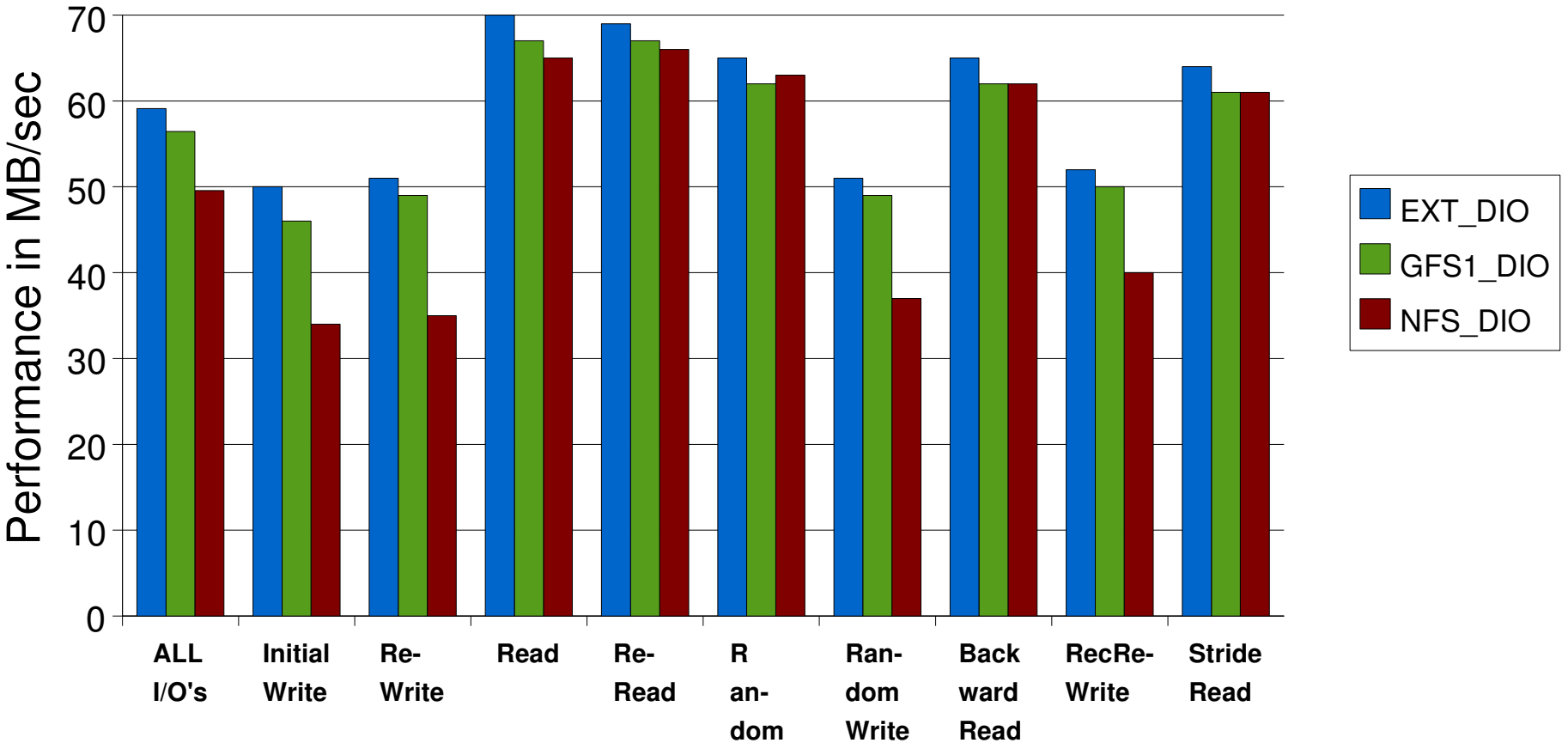
Open files with o_direct option

Databases which support Direct IO (ORACLE)

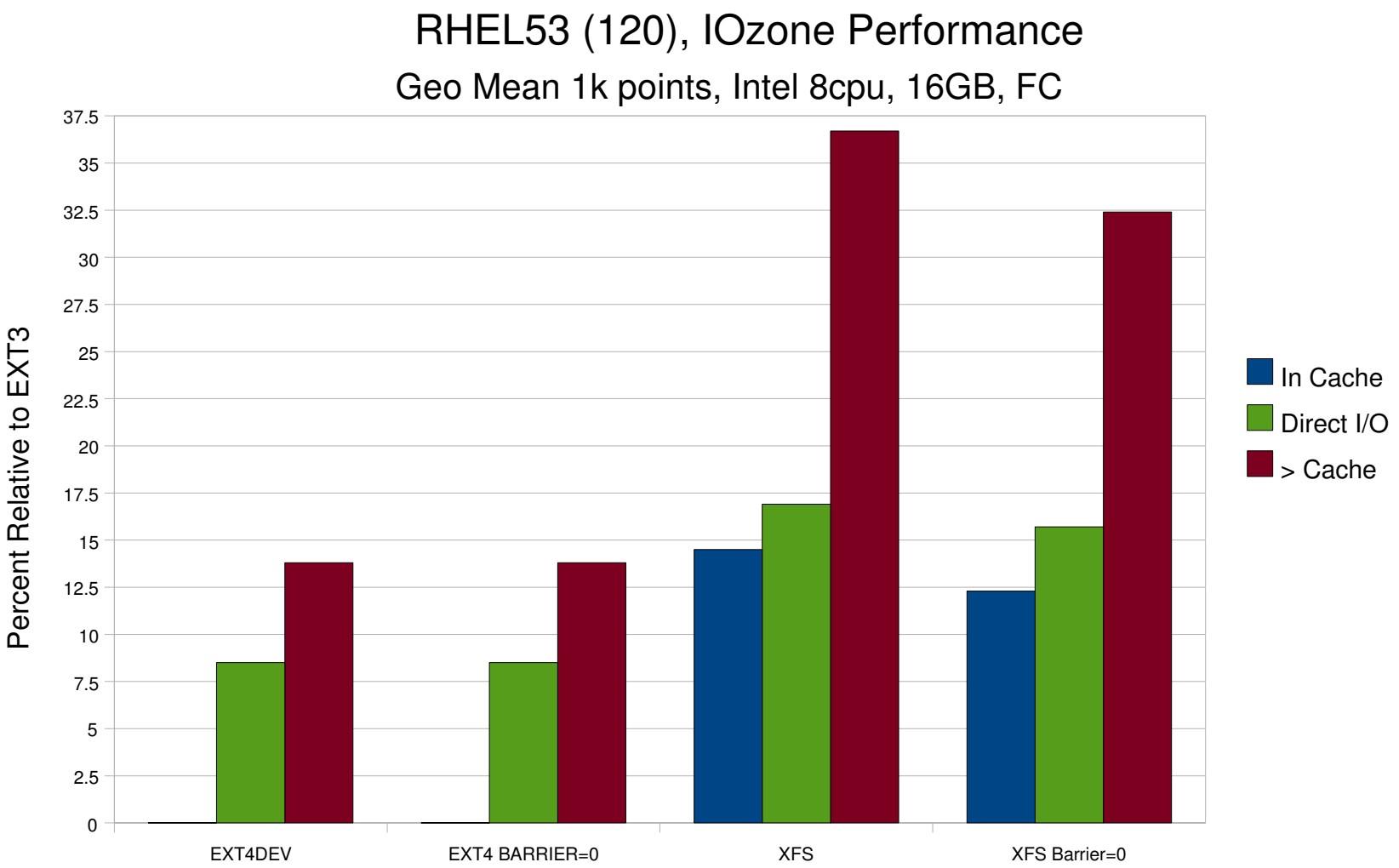
NO DOUBLE CACHING!

EXT3, GFS, NFS Iozone w/ DirectIO

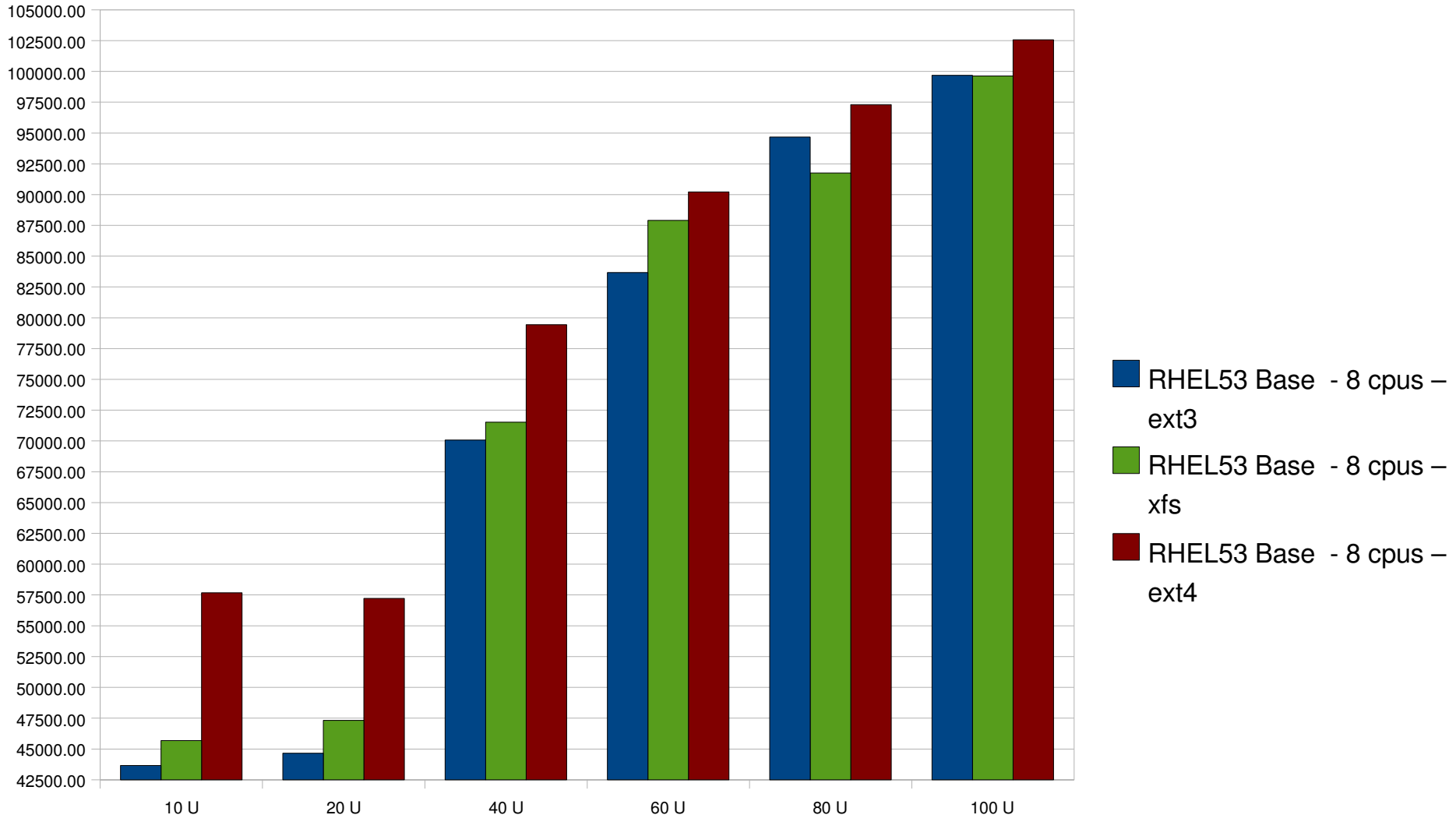
RHEL5 Direct_IO IOzone EXT3, GFS, NFS
(Geom 1M-4GB, 1k-1m)



RHEL5.3 IOzone EXT3, EXT4, XFS eval



RHEL5 Oracle 10.2 Performance Filesystems
Intel 8-cpu, 16GB, 2 FC MPIO, AIO/DIO



Large App and Database Performance

Scaling 1-24 core single servers

Huge Pages

2MB huge pages

Set value in /etc/sysctl.conf (vm.nr_hugepages)

NUMA

Localized memory access for certain workloads improves performance

Asynchronous I/O to File Systems

Allows application to continue processing while I/O is in progress

Eliminates Synchronous I/O stall

Critical for I/O intensive server applications

Red Hat Enterprise Linux – since 2002

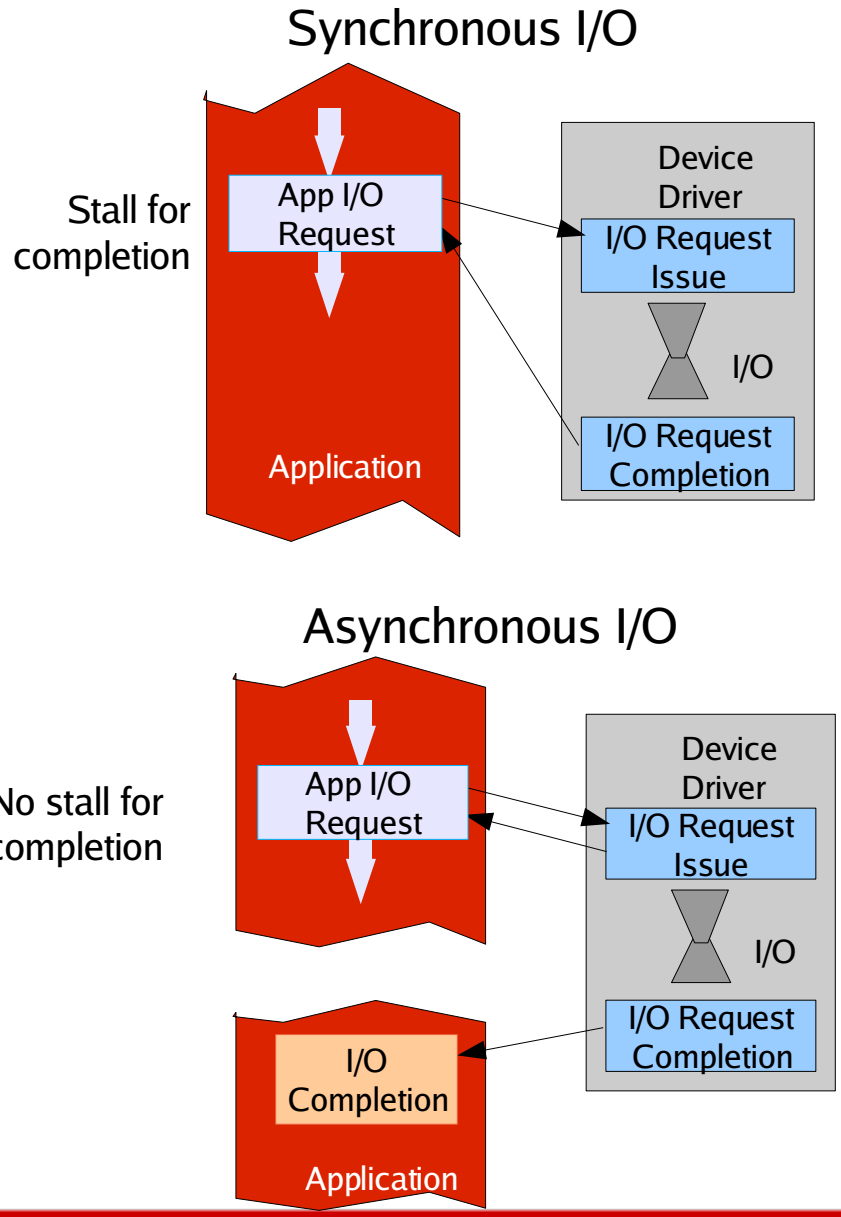
Support for RAW devices only

With Red Hat Enterprise Linux 4, significant improvement:

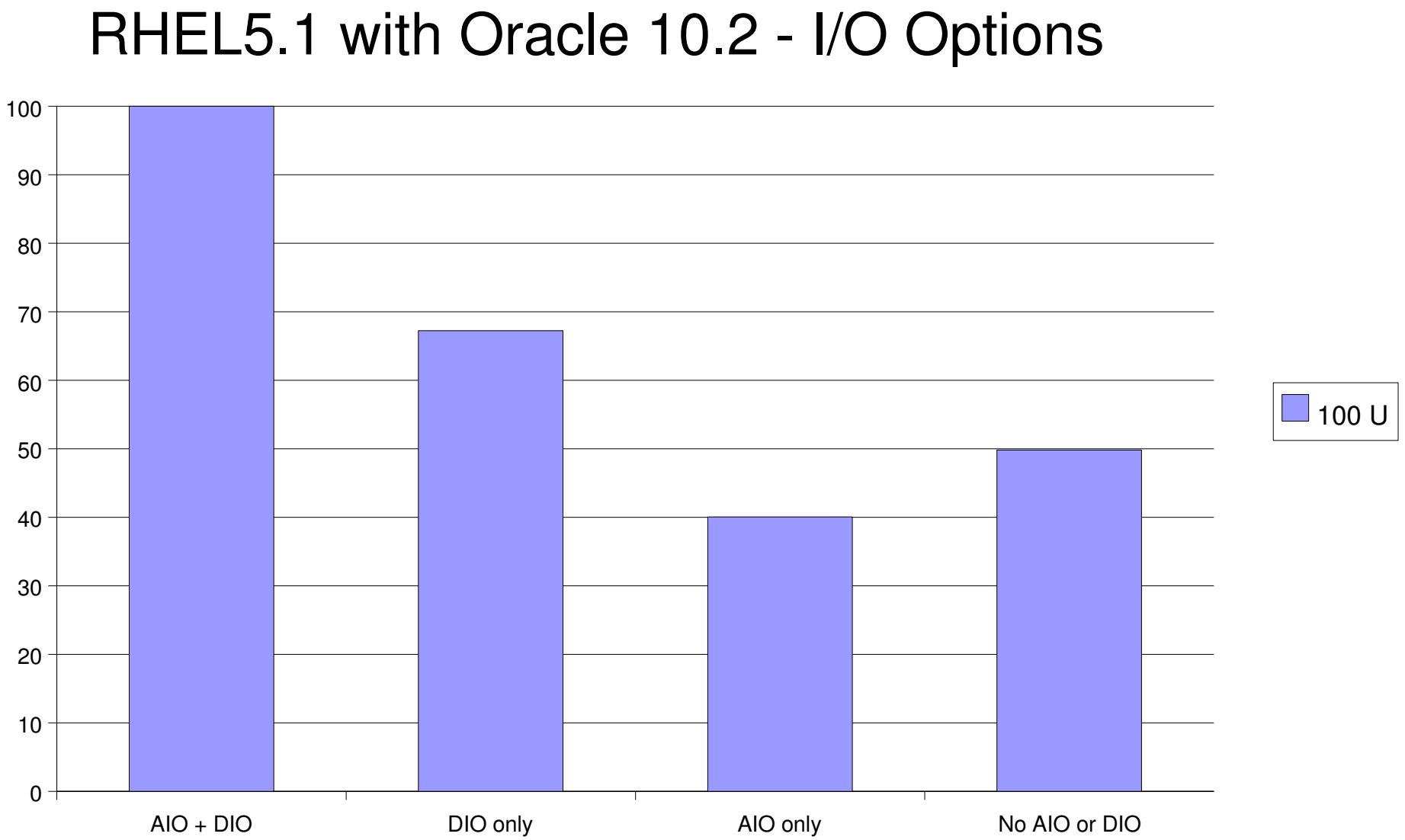
Support for Ext3, NFS, GFS file system access

Supports Direct I/O (e.g. Database applications)

Makes benchmark results more appropriate for real-world comparisons



RHEL5.1 Oracle 10.2 - I/O options



Disk IO tuning - RHEL4/5

RHEL4/5 – 4 tunable I/O Schedulers

CFQ – elevator=cfq. Completely Fair Queuing default, balanced, fair for multiple luns, adaptors, smp servers

NOOP – elevator=noop. No-operation in kernel, simple, low cpu overhead, leave opt to ramdisk, raid cntrl etc.

Deadline – elevator=deadline. Optimize for run-time-like behavior, low latency per IO, balance issues with large IO luns/controllers (NOTE: current best for FC5)

Anticipatory – elevator=as. Inserts delays to help stack aggregate IO, best on system w/ limited physical IO – SATA

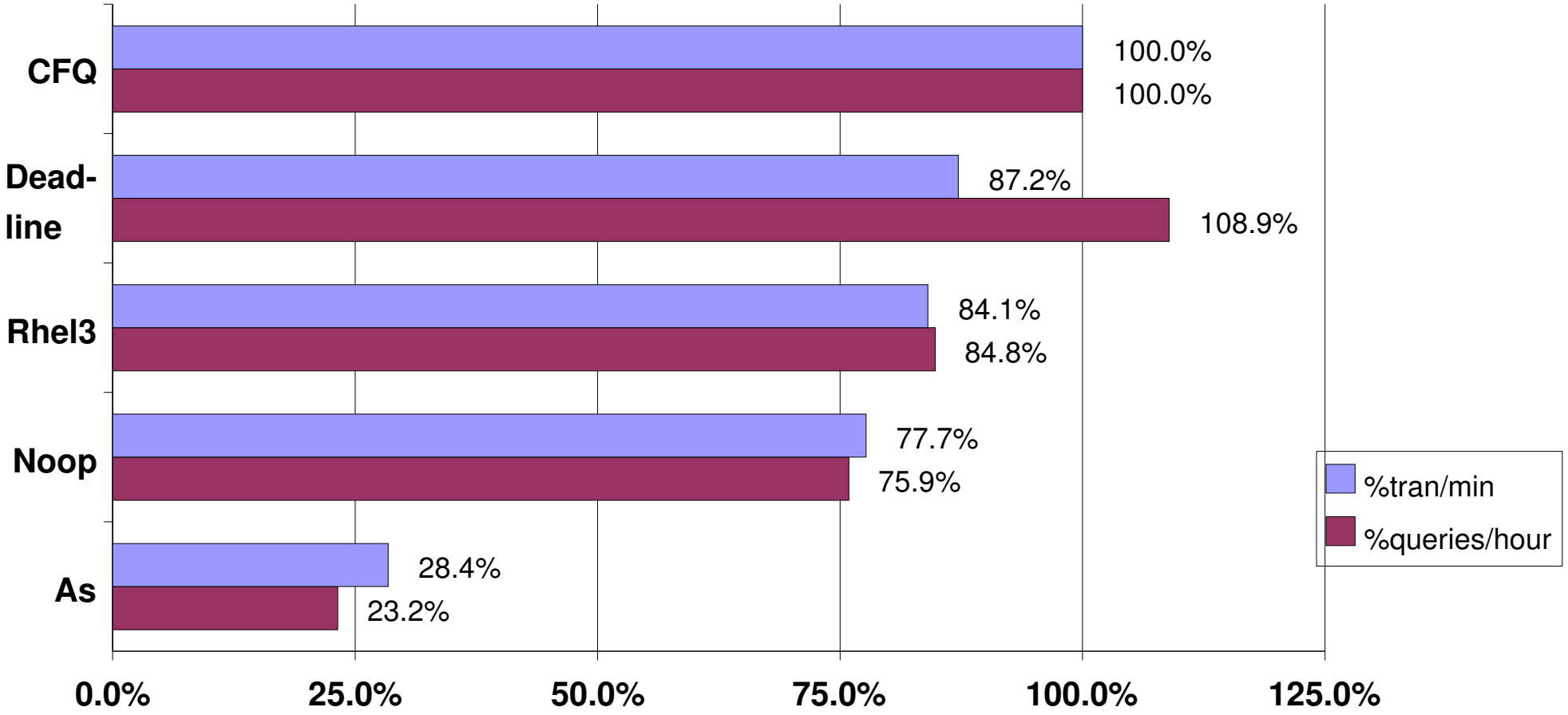
RHEL4 - Set at boot time on command line

RHEL5 – Change on the fly

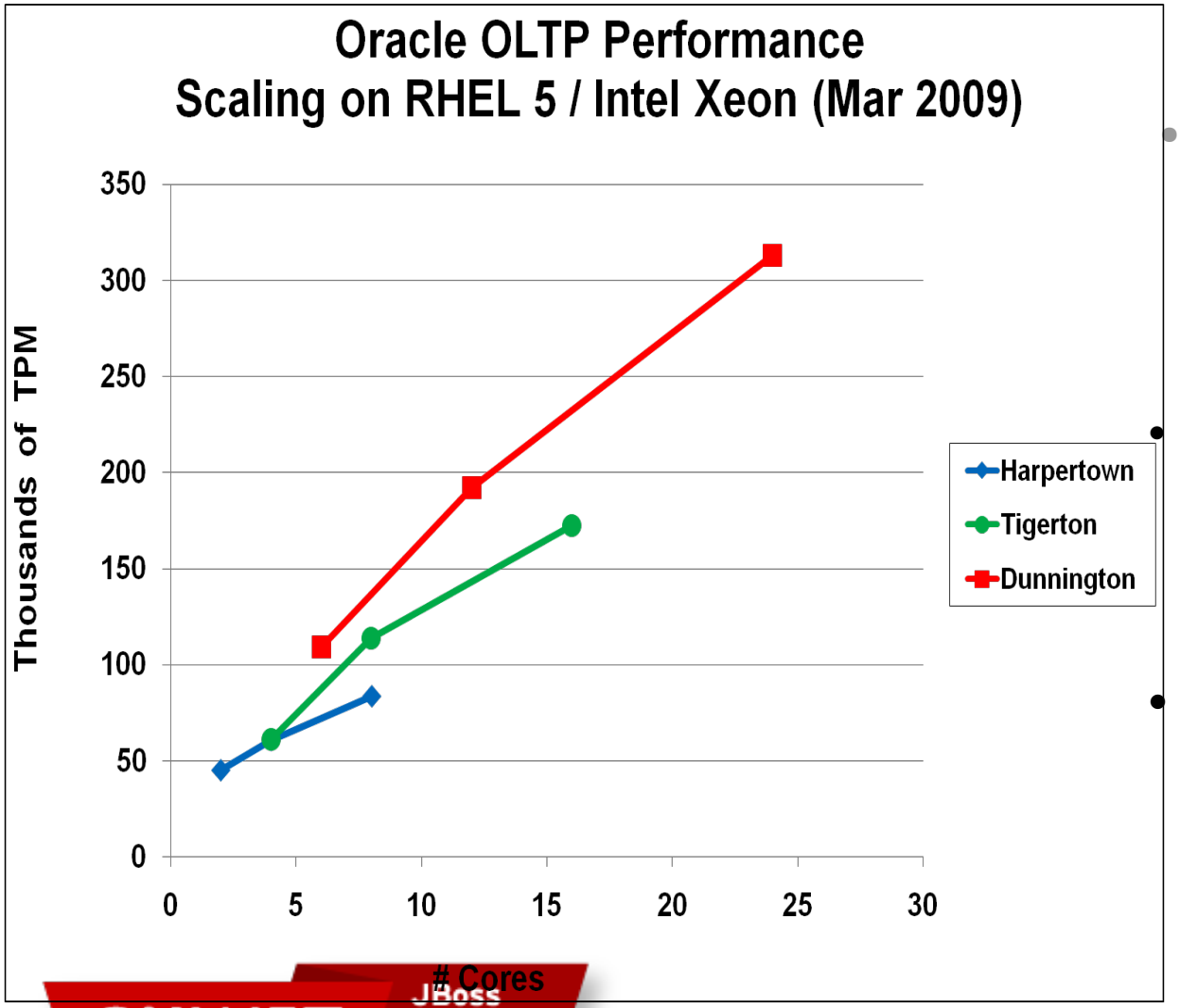
echo deadline > /sys/block/<*sdx*>/queue/scheduler

RHEL5 IO schedules vs RHEL3 for Database

Oracle 10G oltp/dss (relative performance)

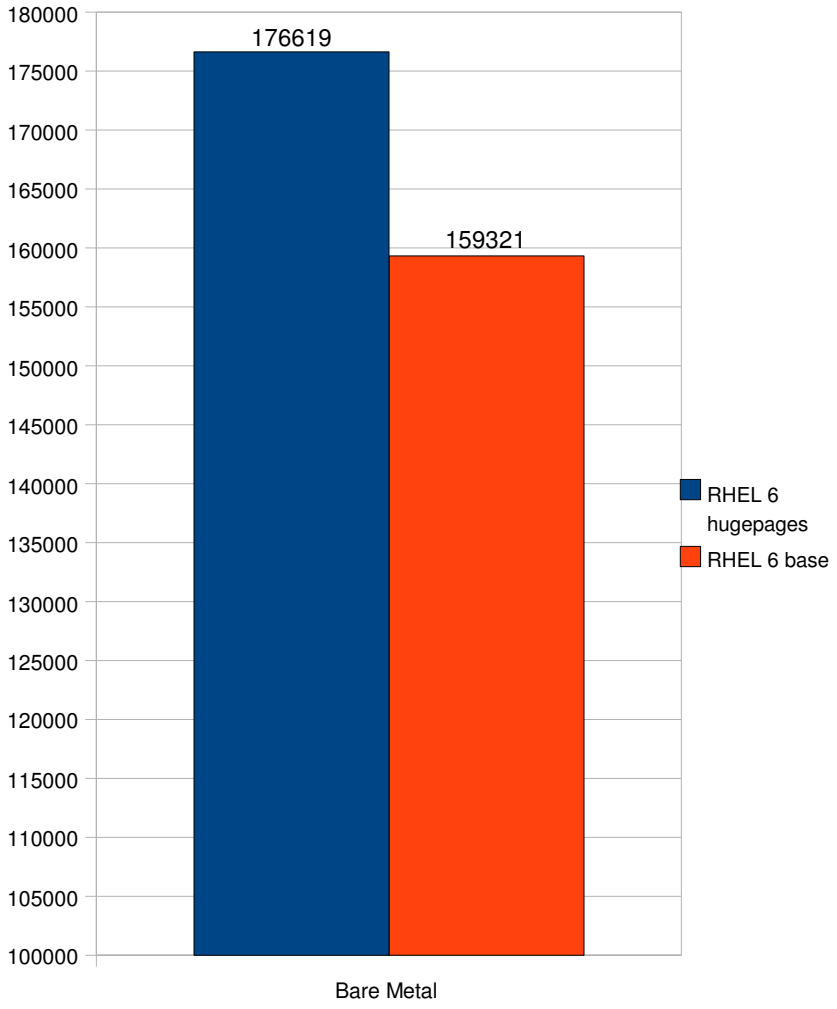


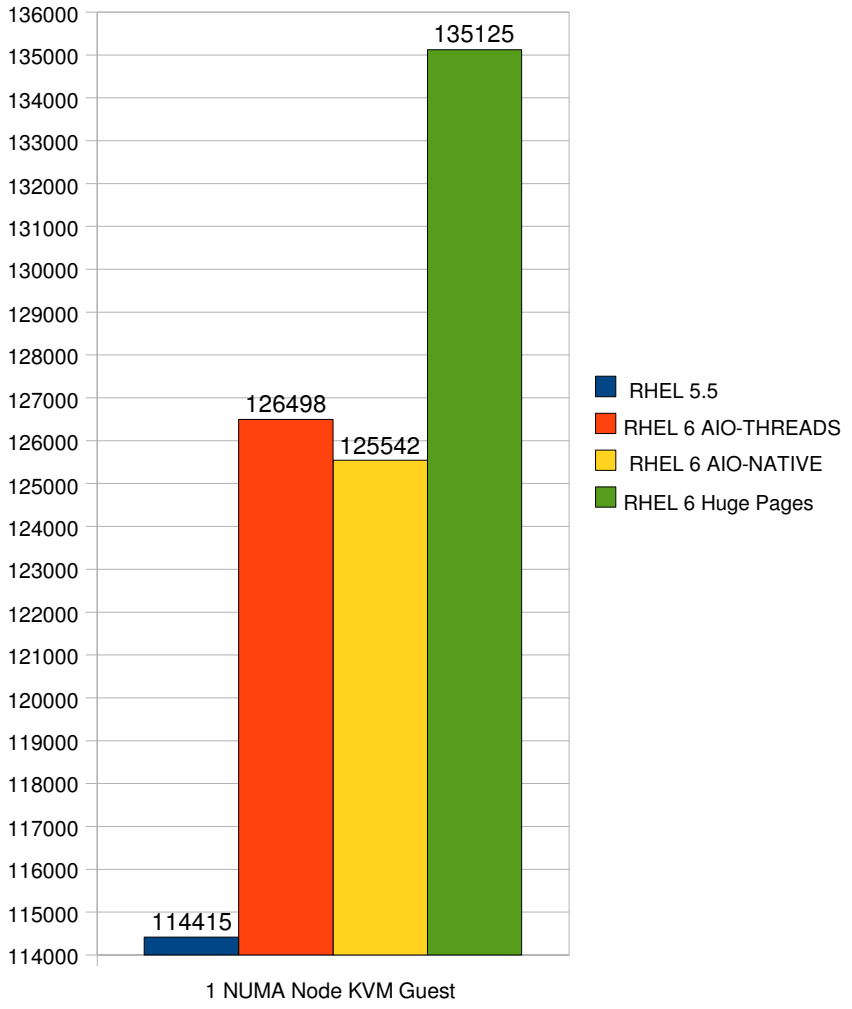
Oracle 10g Performance Scaling on RHEL5



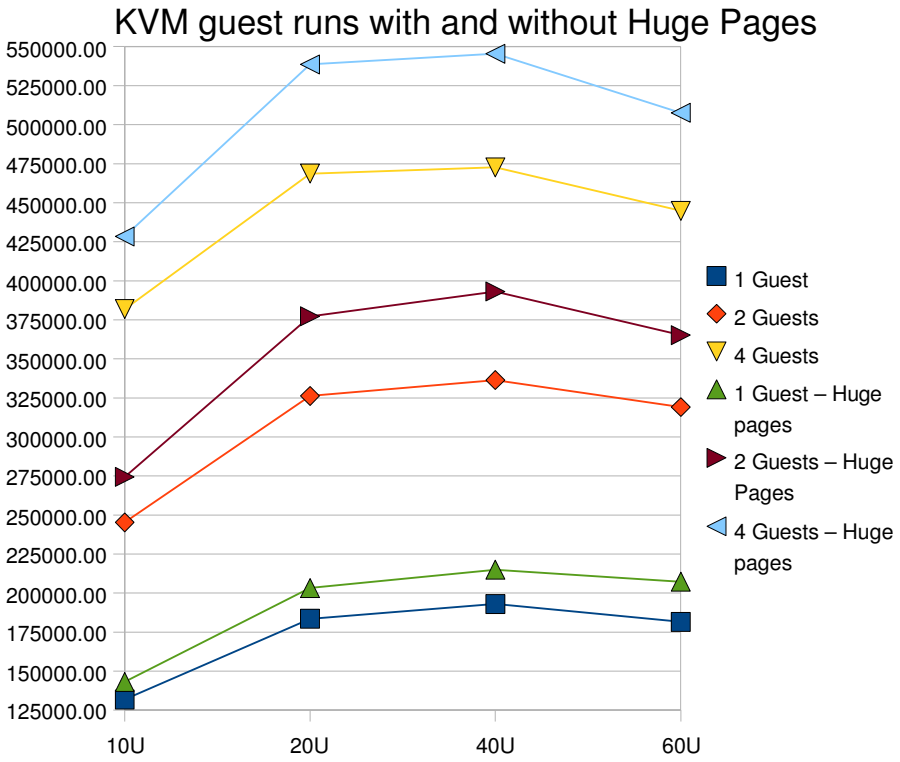
- **Oracle OLTP performance on RHEL scales well to 24 cores.**
- **See Reference Architecture talk on Benchmark Papers/Results**
- **Testing on larger servers with the most recent x86_64 technology is anticipated in the coming year.**

RHEL Sybase 15.0 AMD-MC 48cpu + KVM



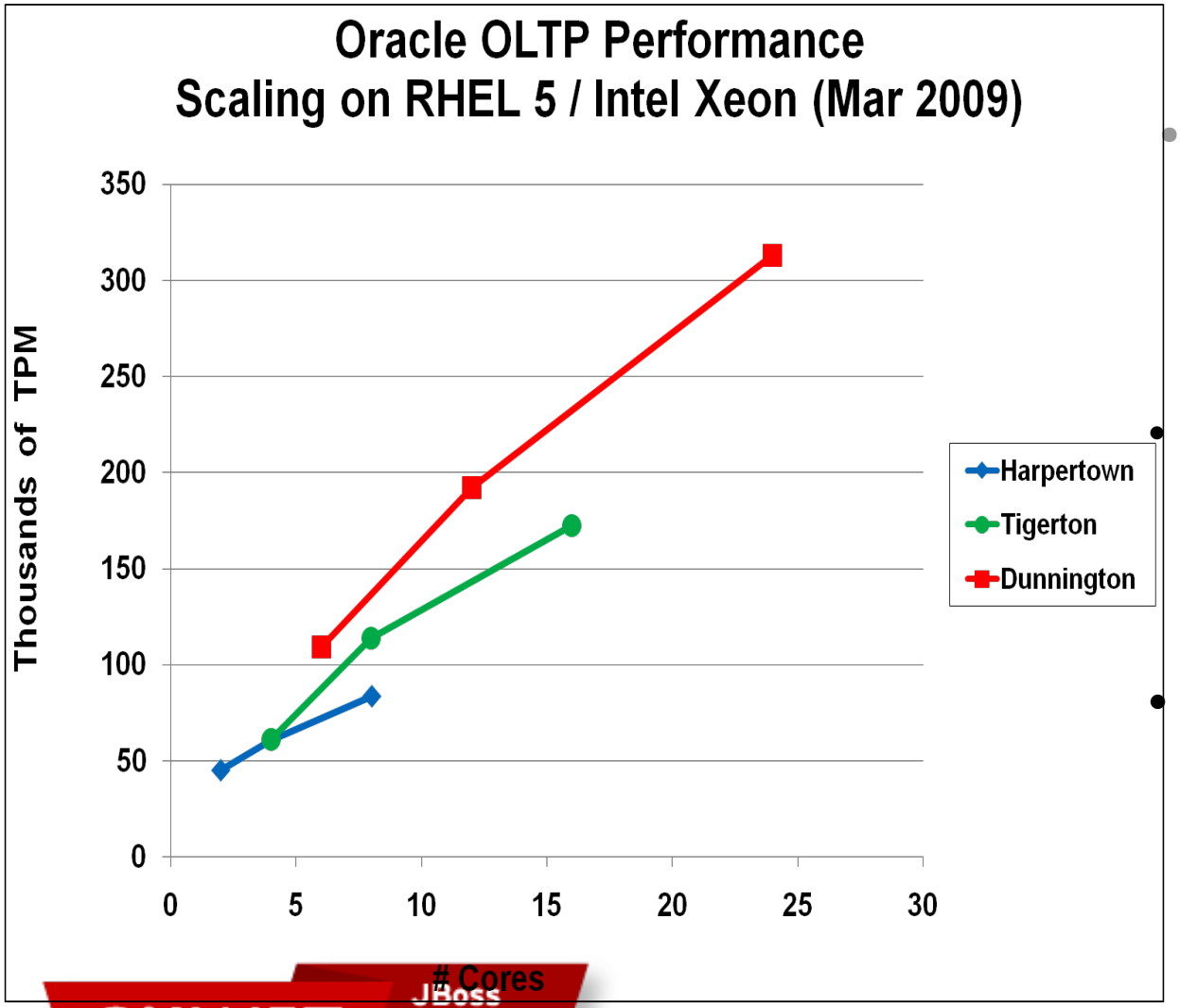


AMD – Magny Cours – RHEL5.5 – KVM



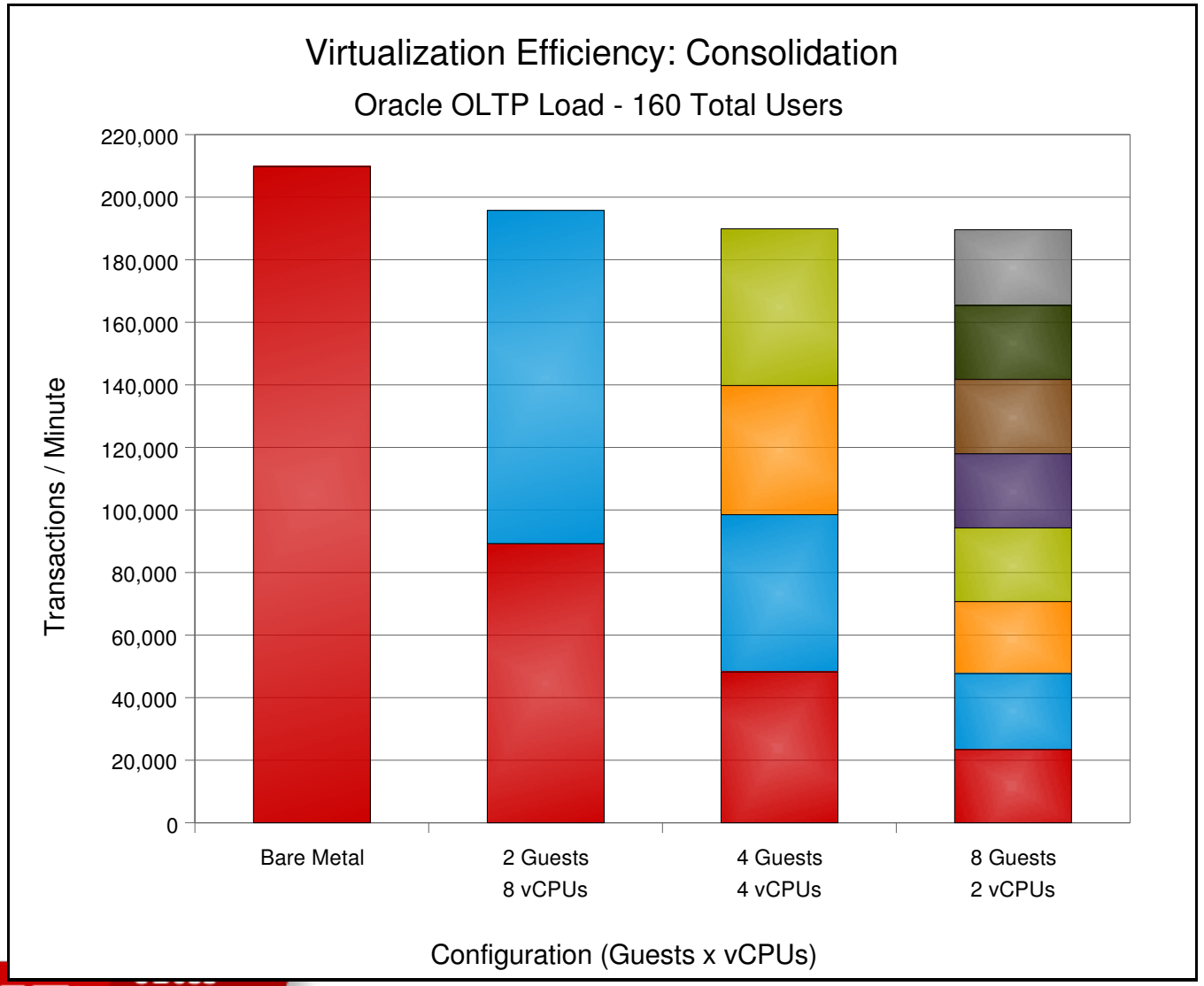
Using huge pages with libvirt, gives a significant performance boost

Oracle 10g Performance Scaling on RHEL5



- **Oracle OLTP performance on RHEL scales well to 24 cores.**
- **See Reference Architecture talk on Benchmark Papers/Results**
- **Testing on larger servers with the most recent x86_64 technology is anticipated in the coming year.**

Oracle 10g: RHEL5.4 KVM Virtualization Efficiency



Summary Benchmark Tuning

Use Hugepages.

Dont overcommit memory

If memory must be over committed

    Eliminate all swapping.

Maximize pagecache reclaiming

Place swap partition(s) on separate device(s).

Use Direct IO

Dont turn NUMA off.

Linux Performance Tuning References

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Axboe, J., "Deadline IO Scheduler Tunables, SuSE, EDF R&D, 2003.

Braswell, B, Ciliendo, E, "Tuning Red Hat Enterprise Linux on IBMeServer xSeries Servers, http://www.ibm.com/redbooks

Corbet, J., "The Continuing Development of IO Scheduling", http://lwn.net/Articles/21274.

Ezolt, P, Optimizing Linux Performance, www.hp.com/hpbooks, Mar 2005.

Heger, D, Pratt, S, "Workload Dependent Performance Evaluation of the Linux 2.6 IO Schedulers", Linux Symposium, Ottawa, Canada, July 2004.

Red Hat Enterprise Linux "Performance Tuning Guide"

http://people.redhat.com/dshaks/rhel3_perf_tuning.pdf

Network, NFS Performance covered in separate talks

http://nfs.sourceforge.net/nfs-howto/performance.html

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