IBM Linux Technology Center

Linux on System z performance hints and tips

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Session 2591

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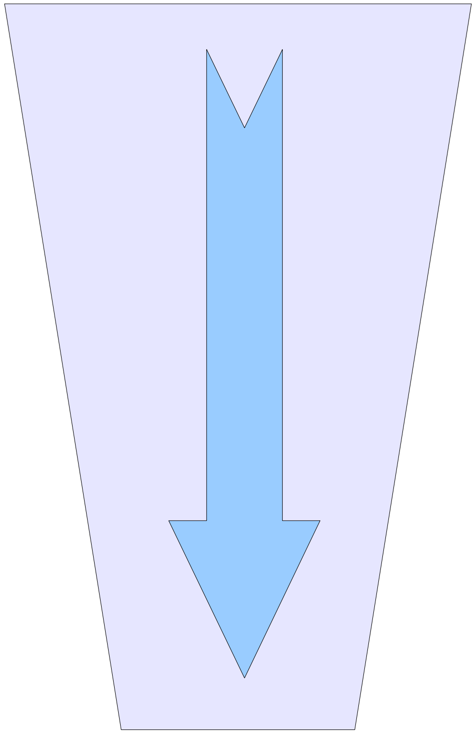
Agenda

- Tuning
  - Application
    - C/C++
  - Middleware
    - Java
  - Linux
    - Networking
    - DASD
  - Virtualization
  - Hardware / Setup
- Monitoring
  - Oprofile
  - SCSI

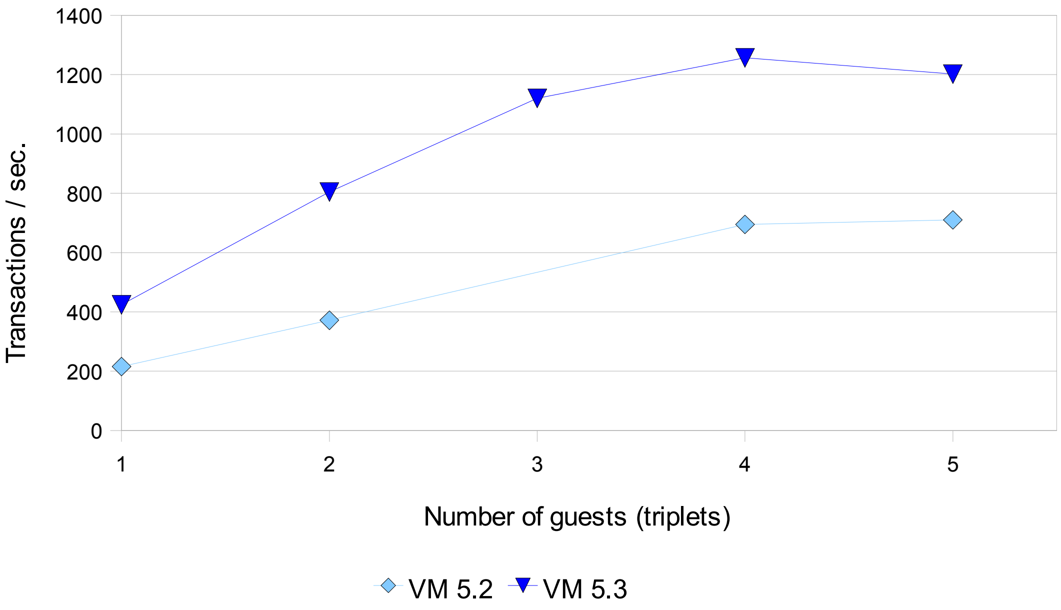
Optimize your stack in the right direction

- Diminishing effect of tuning efforts
  - Application design
  - Application implementation
  - Middleware
  - Operating system
  - Virtualization layer
  - Hardware



Impact of newer software releases

Virtualization Performance - Throughput Comparison



- Hardware:
  System z9(TM) 2094-S18
  8-way 1.65 GHz
- Software upgraded
  - z/VM 5.2 → 5.3
  - Java 1.4 → 1.5
  - WebSphere Application server 6.0.2 → 6.1.0.11
  - DB2 8.2 → 9.1

Keep your system current!

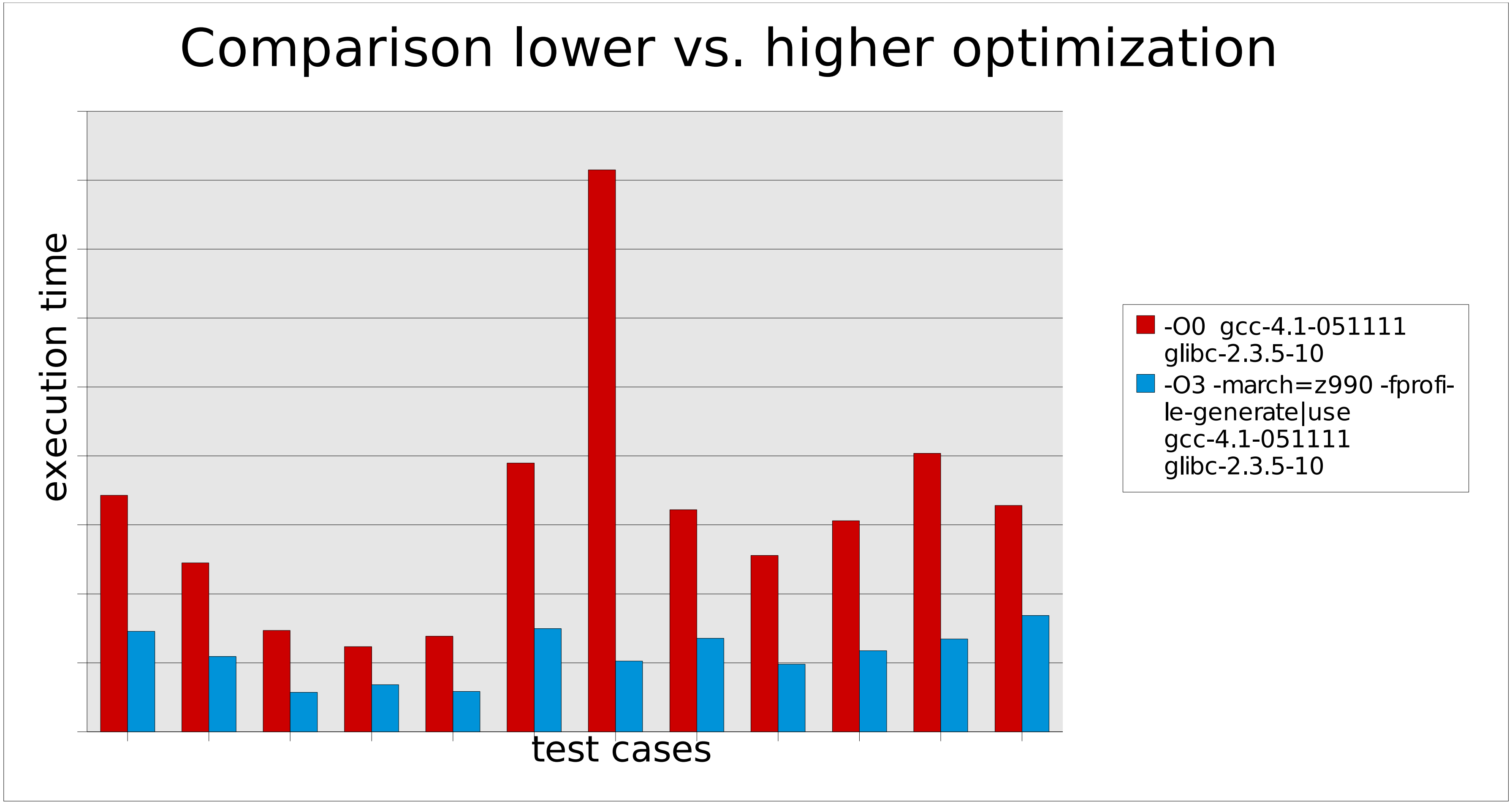
The newer software levels provides a significant improvement in throughput!

Optimizing C/C++ code

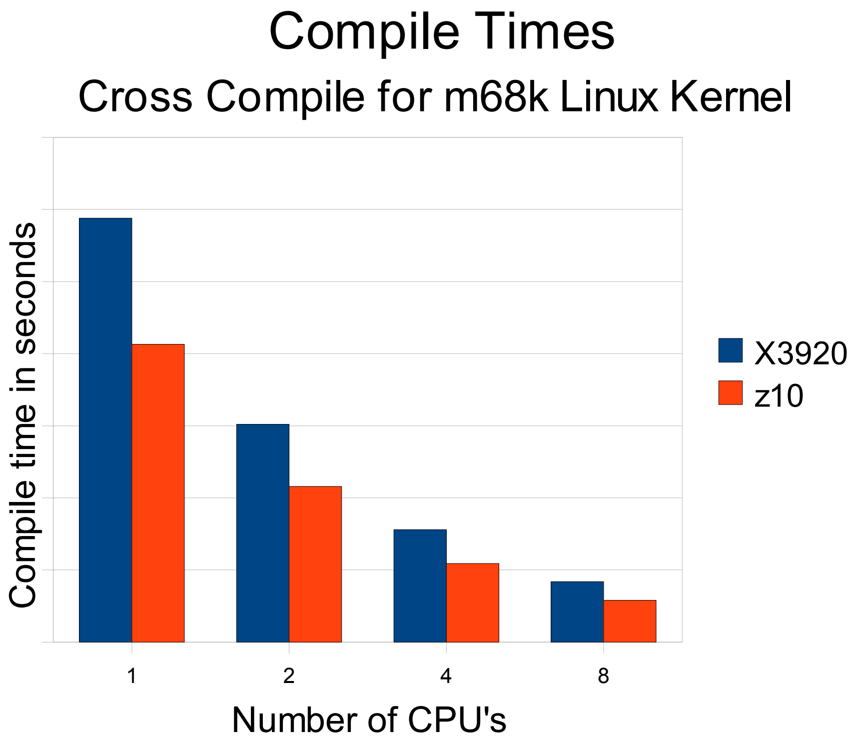
- **Use -O3 optimization as default**
  - no debugging options
    Further optimization:
  - architecture dependent options
    - **-march**=values <G5,z900,z990> <z9-109 with gcc-4.1> <z10 with patched gcc 4.3>
    - **-mtune**=values <G5,z900,z990> <z9-109 with gcc-4.1> <z10 with patched gcc 4.3>
  - inline assembler functions
- Next step: application design
  - dynamic or static linking
  - Avoid –fPIC for executables
  - right use of inlined C / C++ functions
- Fine Tuning: additional general options on a file by file basis
  - -funroll-loops -ffast-math

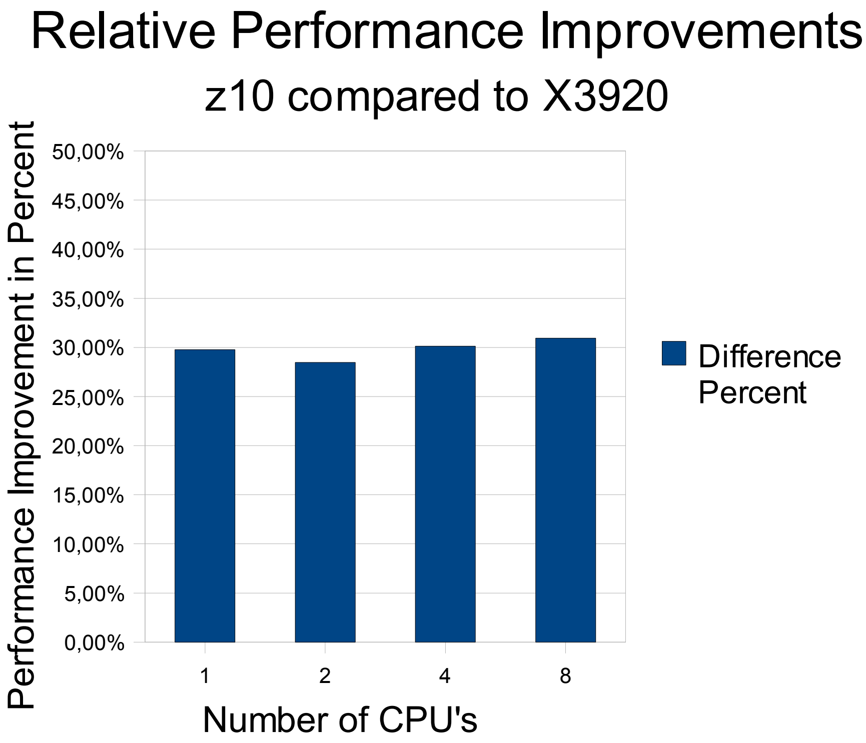
Results of changing compiler options

- Using -O3 instead of no optimization cuts runtime up to 50%



GCC Cross Compile Performance on System z





Java basics

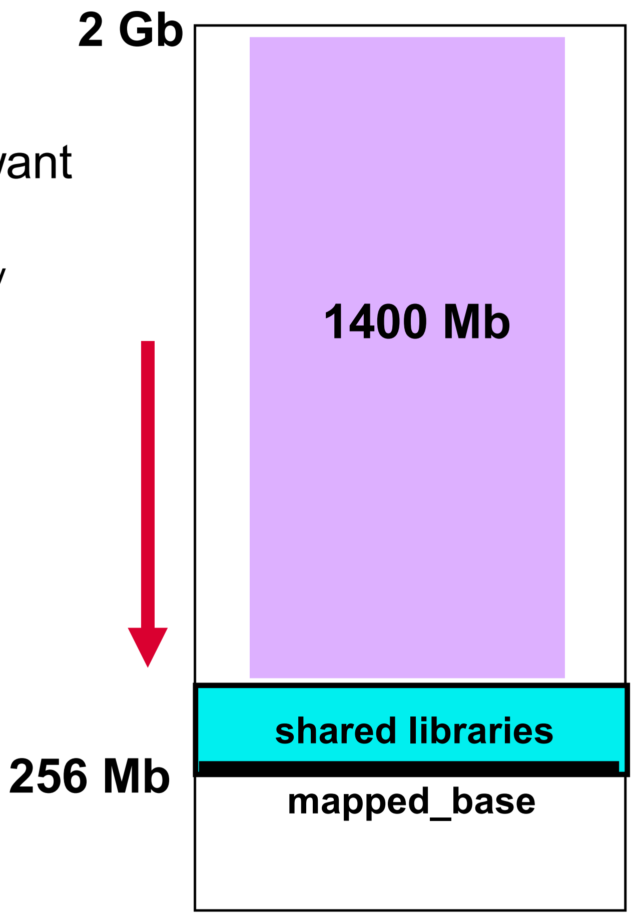
- Try to use latest Java version
  - Up to 20% release to release improvements
  - True as well for newer service releases (SR)
- Make sure that you've got enabled JIT
  - Verify Java output and look for “JIT enabled: jitc”
- Don't use Java in batch mode:
  - If you do 100 calls “java -jar myprogram.jar” you compile myprogram 100 times
    - can take more CPU power than the program itself
    - the JIT compiler can't do its optimization work
  - Instead pull the loop inside the Java program and call “java -jar myprogram100.jar” once

Java heap size

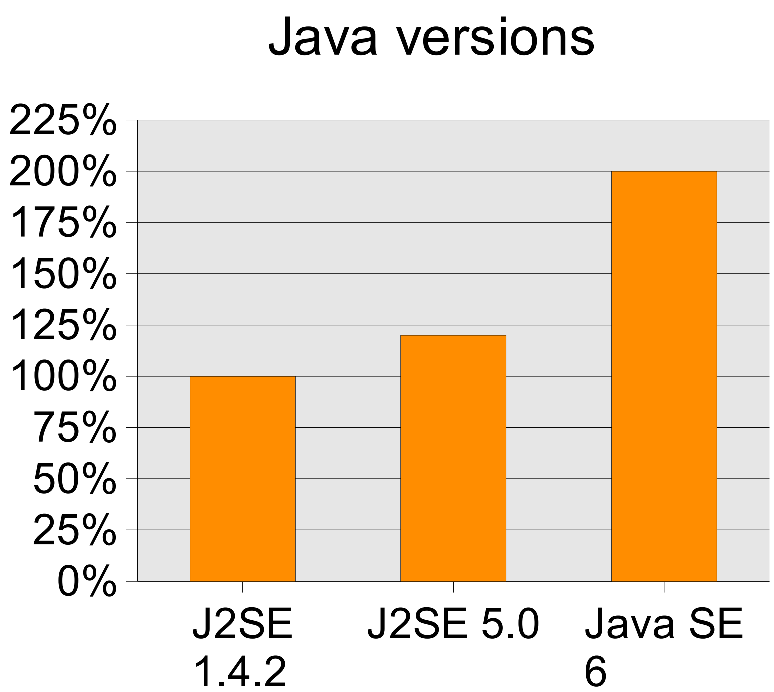
- Useful parameters
  - Setting heap size: -Xms (minimal), -Xmx (maximal), use min=max
  - -verbose:gc -- monitor GC
- Max heap <= available memory
  - Avoid paging - Linux and VM
  - remember: heap memory will be used eventually!
- Larger heap size usually implies better performance
  - in 31bit SLES8, SLES9 & SLES10 use /proc/<pid>/mapped_base to define heaps up to 1.7 GB
  - In 31bit RHEL4 environments use flex-mmap mechanism
    - Watch out for prelinked applications!
  - Works also in 31bit emulation on 64 bit distros

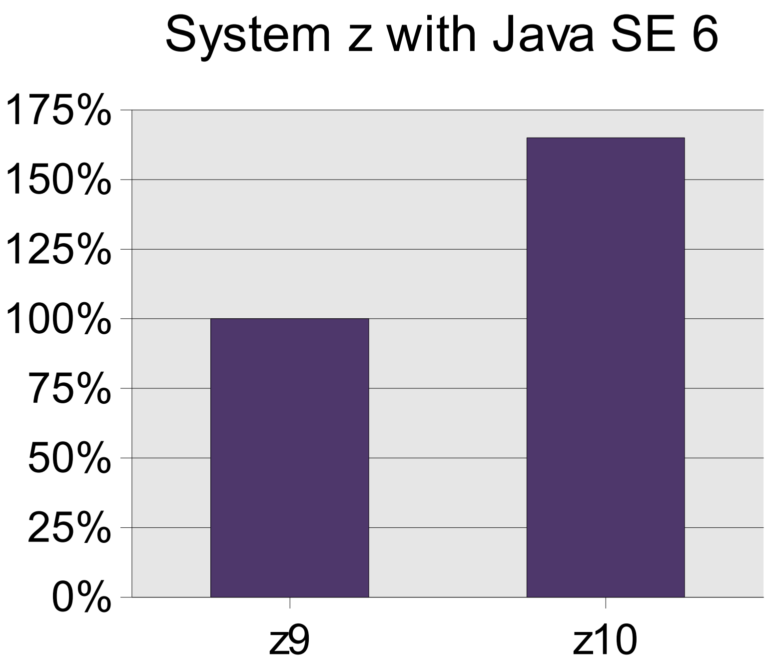
Mapped_base HowTo

- Only available for Novell distribution SLES8,9,10 (31 bit)
- PID is the process ID of the process you want to change
  - In bash $$ gives you the current process, from any process /proc/self/... works as well
- Display memory map of any PID by
  `cat /proc/PID/maps`
- Check the mapped_base value by
  `cat /proc/PID/mapped_base`
- Change value to e.g. 256 Mb by
  `echo 268435456 >/proc/PID/mapped_base`



Java Results 64-bit





- Java improvements through newer JVM and JIT
- improvements through new hardware
- 64-bit Java is production ready

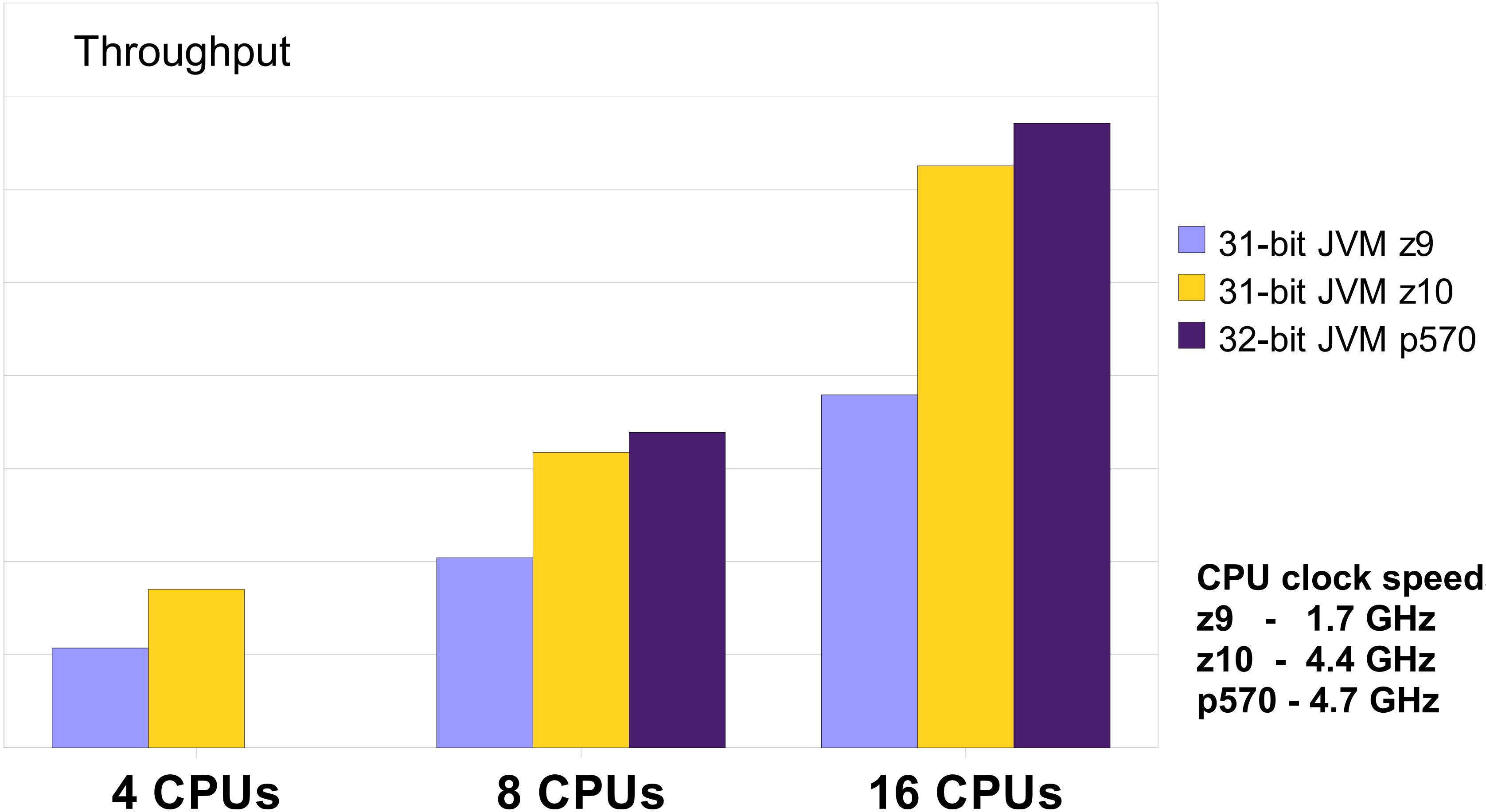
- Java 6: new option -Xcompressedref (stay tuned)

Java tuning exercise for z10 – workload specific

- Split workload so that multiple 31 bit JVMs can be used
- `-Xms1600m -Xmx1600m` : maximize heap, same value
- `-Xlp` : use large pages for the heap (new z10 feature)
- `-Xgcpolicy:gencon` : change garbage collection policy to treat long and short lived objects differently, results in shorter pause times
- `-Xmo800m -Xmn800m` : explicitly set the size for old and new objects (nursery too small by default)
- `-Xnoloa` : don't use special large object area in the heap
- Further reading:
  - GC: http://www-128.ibm.com/developerworks/java/library/j-ibmjava2/index.html, http://www-128.ibm.com/developerworks/java/library/j-ibmjava3/index.html

z10 Performance: Java workload

- System z versus System p



CPU clock speeds
z9 - 1.7 GHz
z10 - 4.4 GHz
p570 - 4.7 GHz

Networking performance

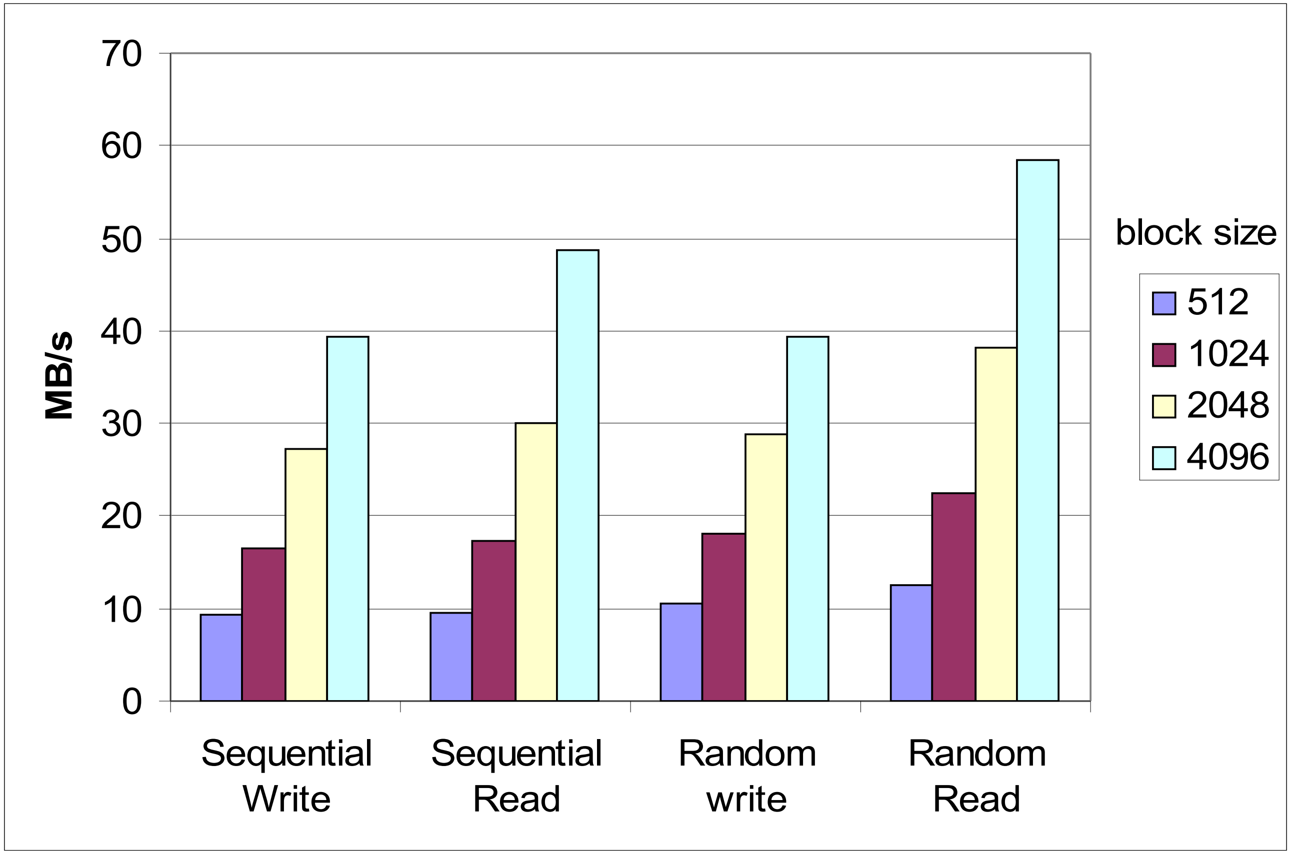
- Which connectivity to use:
  - External connectivity:
    - Use new 10 GbE cards with MTU 8992
    - Attach OSA directly to Linux guest image
  - Internal connectivity:
    - Hipersockets for LPAR-LPAR communication
    - VSwitch for guest-guest communication
- For really busy network devices consider to
  - use channel bonding
  - Increase the number of inbound buffers in the qeth driver
    - Device has to be offline
    - `# echo <number> > /sys/bus/ccwgroup/drivers/qeth/<device_bus_id>/buffer_count`
- Channel bonding for HA creates only a small overhead
- Choose your MTU size carefully
  - Avoid fragmentation, lots of small packages can drive up CPU utilization

How to improve disk performance

- Hardware choices
  - Use SCSI instead of ECKD
  - Use FICON instead of ESCON
    - 4Gb FICON > 2Gb FICON > 1Gb FICON
- Utilize your hardware
  - Use “striped” logical volumes from different ranks
  - Consider using HiperPAV
  - Carefully set up your storage system
  - With D8000 – new option to stripe on storage server (see Session 2590)
  - http://www.ibm.com/developerworks/linux/linux390/perf/tuning_rec_dasd_optimizedisk.shtml

Effect of dasdfmt block size on throughput and capacity

- Use 4k block size on ECKD DASDs whenever possible !



dasdfmt blocksize	disk space
512b	3.5G
1024b	4.7G
2048b	6G
4096b	6.8G

“On Demand Timer” patch

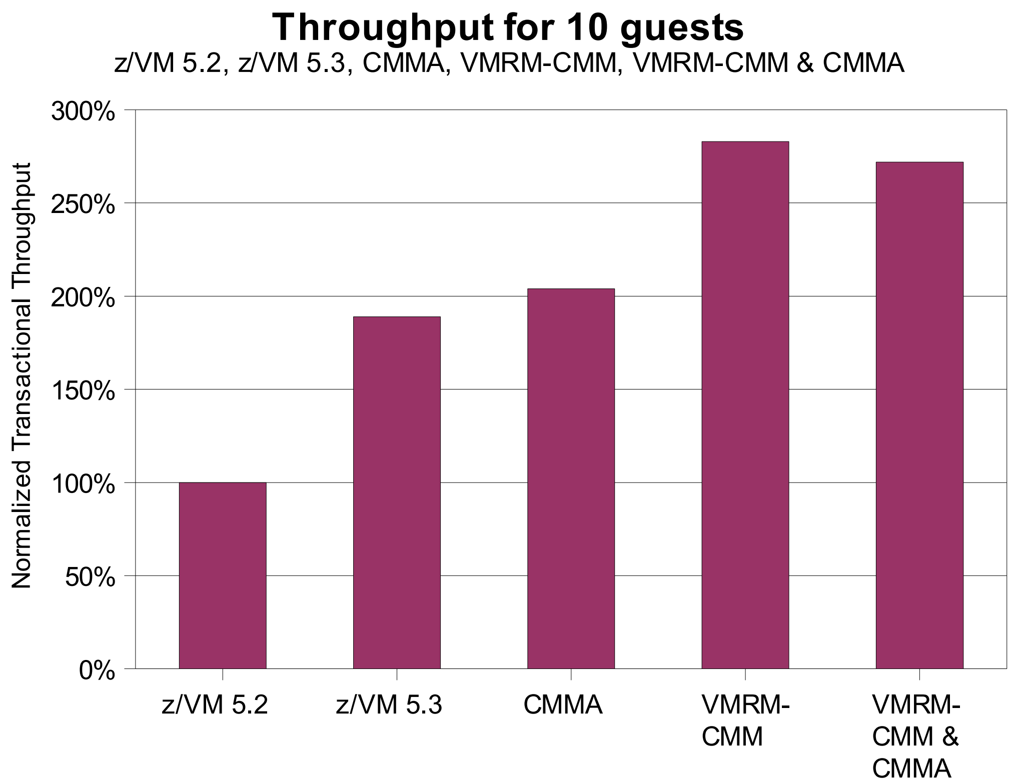
- Linux uses HZ based timer interrupts
- Timer interrupts for idle guests create unnecessary overhead
- Starting with SLES8: enable & disable on the fly
  - /proc/sys/kernel/hz_timer
  - 1 = timer interrupts occurring every 10 ms
  - 0 = timer interrupts generated on demand only
- Included in SLES9, SLES10 and RHEL4, RHEL5 s390/s390x distributions

CMM

- 2 methods available:
  - VMRM-CMM (VM Resource Manager – Cooperative Memory Management) aka CMM1
    - Resource manager controls the size of the guests
  - CMMA (Collaborative Memory Management Assist) aka CMM2
    - Linux indicates which pages don't need to be saved
- Both methods show performance improvements when z/VM hits a system memory constraint.

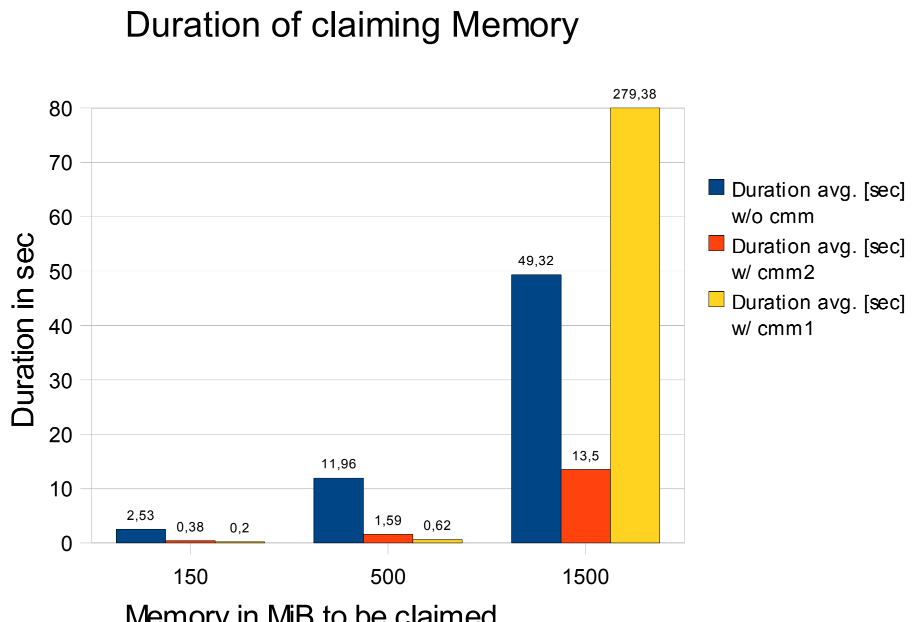
CMM1 scenario

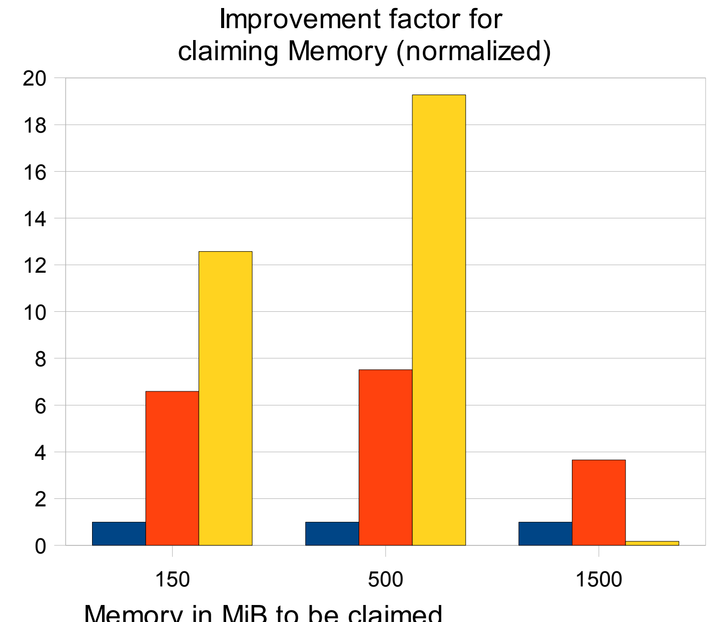
- Large Oracle guests, total used Linux memory = 2x of z/VM central storage, OLTP workload
- Advantages with CMM1
- Guests did not suffer from smaller page cache



CMM2 scenario

- Workload
  - 15 guests, touching all their memory, all z/VM storage used. A guest orders now 150MB, 500MB, 1.5GB of memory. We measure the duration of this operation
- Result
  - In case of sudden memory claims CMM2 is the best choice





of CPUs per Linux image

- Use as few virtual CPUs as possible
- For LPAR definitions:
  - # all virtual CPUs : # real CPUs <= 4:1
- For z/VM:
  - #of guest CPUs <= #of CPUs for VM (LPAR)
  - Don't define more CPUs than you really need!
- You don't get done more by defining more CPUs!
- Automatic adaption with cpuhotplugd (see session 2590)

Linux command 'top' – the snapshot tool

- Adds new field “CPU steal time”
  - Is time Linux wanted to run, but the hipervisor was not able to schedule CPU
  - Is included in SLES10 and RHEL5

```
top - 09:50:20 up 11 min,  3 users,  load average: 8.94, 7.17, 3.82
Tasks:  78 total,   8 running,  70 sleeping,   0 stopped,   0 zombie
 Cpu0 : 38.7%us,  4.2%sy,  0.0%ni,  0.0%id,  2.4%wa,  1.8%hi,  0.0%si, 53.0%st
 Cpu1 : 38.5%us,  0.6%sy,  0.0%ni,  5.1%id,  1.3%wa,  1.9%hi,  0.0%si, 52.6%st
 Cpu2 : 54.0%us,  0.6%sy,  0.0%ni,  0.6%id,  4.9%wa,  1.2%hi,  0.0%si, 38.7%st
 Cpu3 : 49.1%us,  0.6%sy,  0.0%ni,  1.2%id,  0.0%wa,  0.0%hi,  0.0%si, 49.1%st
 Cpu4 : 35.9%us,  1.2%sy,  0.0%ni, 15.0%id,  0.6%wa,  1.8%hi,  0.0%si, 45.5%st
 Cpu5 : 43.0%us,  2.1%sy,  0.7%ni,  0.0%id,  4.2%wa,  1.4%hi,  0.0%si, 48.6%st
Mem:    251832k total,   155448k used,    96384k free,     1212k buffers
Swap:   524248k total,    17716k used,   506532k free,    18096k cached
```

Sysstat – the 'long' term data collection

- Contains four parts
  - sadc: data gatherer - stores data in binary file
  - Sar: reporting tool - reads binary file and converts it to readable output
  - Mpstat: processor utilization
  - Iostat: I/O utilization
- “steal time” included starting version 7.0.0
- Install the sysstat package and configure it depending on your distribution (crontab)
  - by default data is collected in /var/log/sa
- More info at: http://perso.orange.fr/sebastien.godard
  and with “man sar” on your system

Oprofile – the Open Source sampling tool

- Oprofile offers profiling of all running code on Linux systems, providing a variety of statistics.
  - By default, kernel mode and user mode information is gathered for configurable events
- System z hardware currently does not have support for hardware performance counters, instead timer interrupt is used
  - Enable the hz_timer(!)
- The timer is set to whatever the jiffy rate is and is not user-settable
- Novell / SUSE: oprofile is on the SDK CDs
- More info at:
  - http://oprofile.sourceforge.net/docs/
  - http://www.redhat.com/docs/manuals/enterprise/RHEL-4-Manual/sysadmin-guide/ch

Oprofile – short how-to

- Example from
  http://www.ibm.com/developerworks/linux/linux390/perf/tuning_how_tools.html#

```
sysctl -w kernel.hz_timer=1
gunzip /boot/vmlinux-2.6.5-7.201-s390x.gz

opcontrol --vmlinux=/boot/vmlinux-2.6.5-7.201-s390x
opcontrol --start

<DO TEST>

opcontrol --shutdown
opreport
```

Oprofile – output example

```
CPU: CPU with timer interrupt, speed 0 MHz (estimated)
Profiling through timer interrupt
vma      samples  %        app name            symbol name
80002840 5862     34.8970  mcf_base.z_Linux    price_out_impl
800012c8 5221     31.0811  mcf_base.z_Linux    refresh_potential
80003cb4 4398     26.1817  mcf_base.z_Linux    primal_bea_mpp
80003b60 408       2.4289  mcf_base.z_Linux    sort_basket
0001a67c 345       2.0538  vmlinux             default_idle
800013d8 138       0.8215  mcf_base.z_Linux    flow_cost
800033bc 98        0.5834  mcf_base.z_Linux    update_tree
800020f8 88        0.5239  mcf_base.z_Linux    dual_feasible
800036a4 72        0.4286  mcf_base.z_Linux    primal_iminus
8000323c 40        0.2381  mcf_base.z_Linux    write_circulations
80002720 24        0.1429  mcf_base.z_Linux    insert_new_arc
```

SCSI statistics

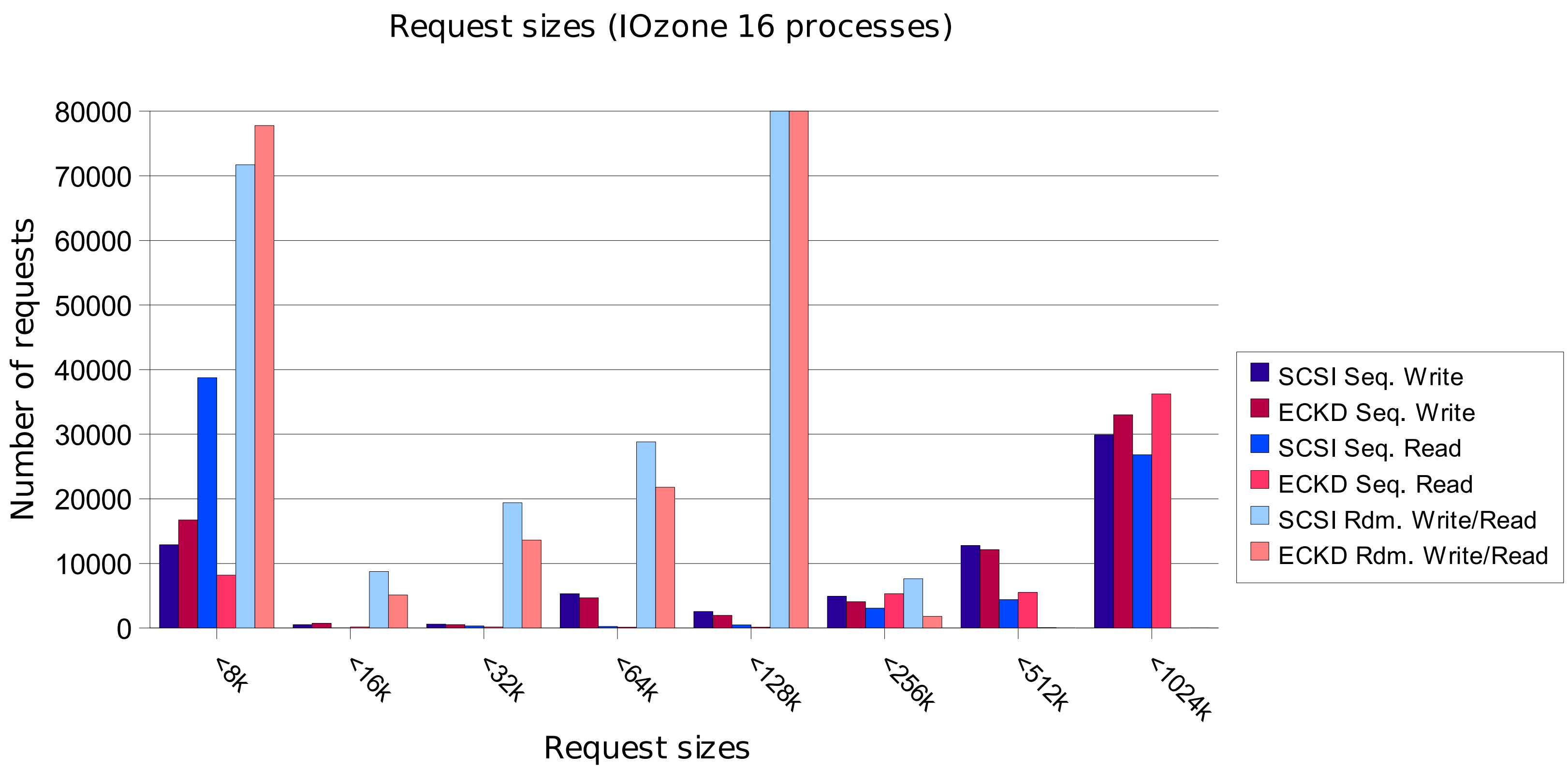
- In SLES9 and SLES10 SCSI statistics can be collected
- If debugfs is mounted at `/sys/kernel/debug/` , all the statistics data collected can be found at `/sys/kernel/debug/statistics/`
- The names of these subdirectories consist of
  - `zfcp-<device-bus-id>` for an adapter and
  - `zfcp-<device-bus-id>-<WWPN>-<LUN>` for a LUN.
- Each subdirectory contains two files
  - data file
  - definition file
- `echo on=1 > definition` enables the data gathering
- `echo on=0 > definition` disables the data gathering. By default data gathering is off
- `echo data=reset > definition` resets the counters to 0.

SCSI statistics example

```
cat /sys/kernel/debug/statistics/zfcp-0.0.1700-0x5005076303010482-0x4014400500000000/data
...
request_sizes_scsi_read 0x1000 1163
request_sizes_scsi_read 0x80000 805
request_sizes_scsi_read 0x54000 47
request_sizes_scsi_read 0x2d000 44
request_sizes_scsi_read 0x2a000 26
request_sizes_scsi_read 0x57000 25
request_sizes_scsi_read 0x1e000 25
request_sizes_scsi_read 0x63000 24
request_sizes_scsi_read 0x6f000 19
request_sizes_scsi_read 0x12000 19
...
latencies_scsi_read <=1 1076
latencies_scsi_read <=2 205
latencies_scsi_read <=4 575
latencies_scsi_read <=8 368
latencies_scsi_read <=16 0
...
channel_latency_read <=16000 0
channel_latency_read <=32000 983
channel_latency_read <=64000 99
channel_latency_read <=128000 115
channel_latency_read <=256000 753
channel_latency_read <=512000 106
channel_latency_read <=1024000 141
channel_latency_read <=2048000 27
channel_latency_read <=4096000 0
...
fabric_latency_read <=1000000 1238
fabric_latency_read <=2000000 328
fabric_latency_read <=4000000 522
fabric_latency_read <=8000000 136
fabric_latency_read <=16000000 0
...
```

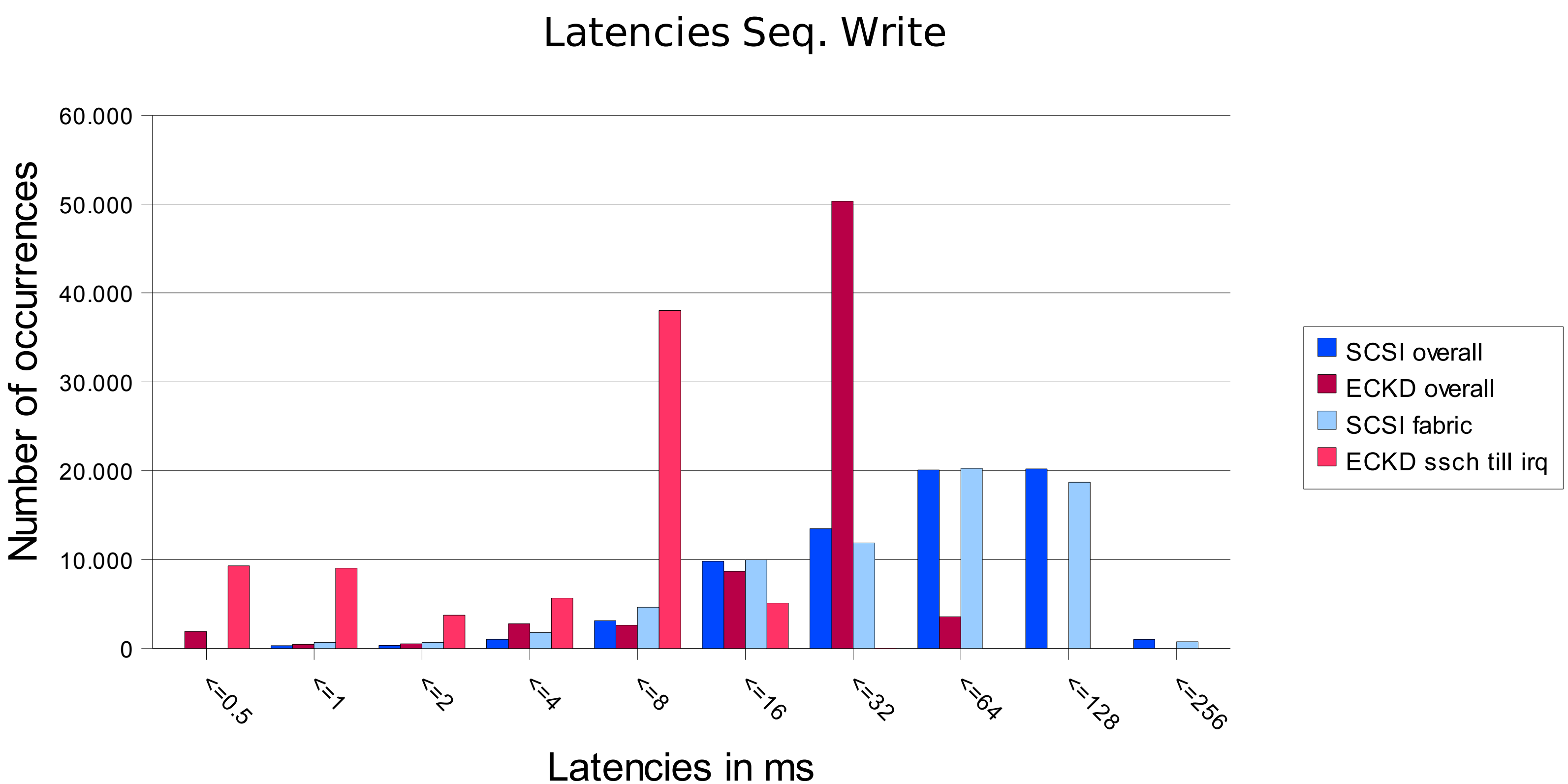
Comparing SCSI and ECKD request sizes

- Similar request sizes for sequential and random I/O



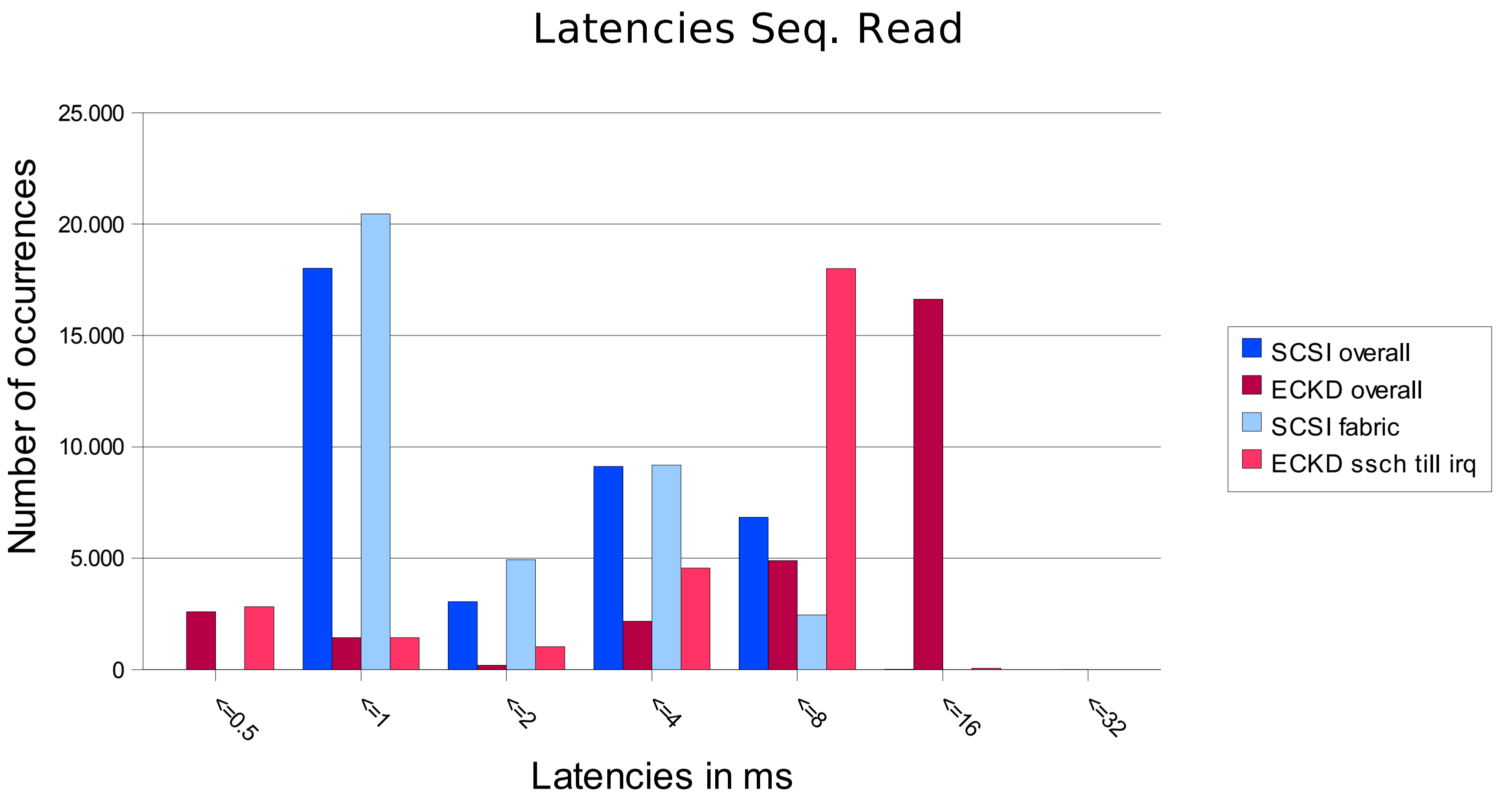
Comparing SCSI and ECKD latencies (1)

- SCSI sequential write latencies are longer



Comparing SCSI and ECKD latencies (2)

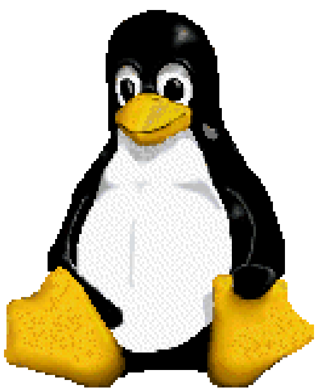
- SCSI sequential read latencies are shorter

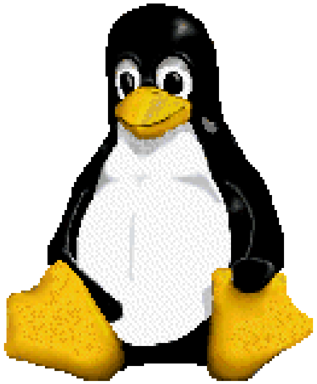


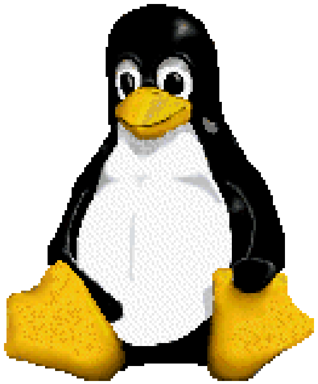
Visit us !

- Linux on zSeries Tuning Hints and Tips
  - http://www.ibm.com/developerworks/linux/linux390/perf/
- Linux-VM Performance Website:
  - http://www.vm.ibm.com/perf/tips/linuxper.html
- WAS 6.1 tuning guide
  - ftp://ftp.software.ibm.com/software/webserver/appserv/library/v61/wasv610exp_tune.pdf

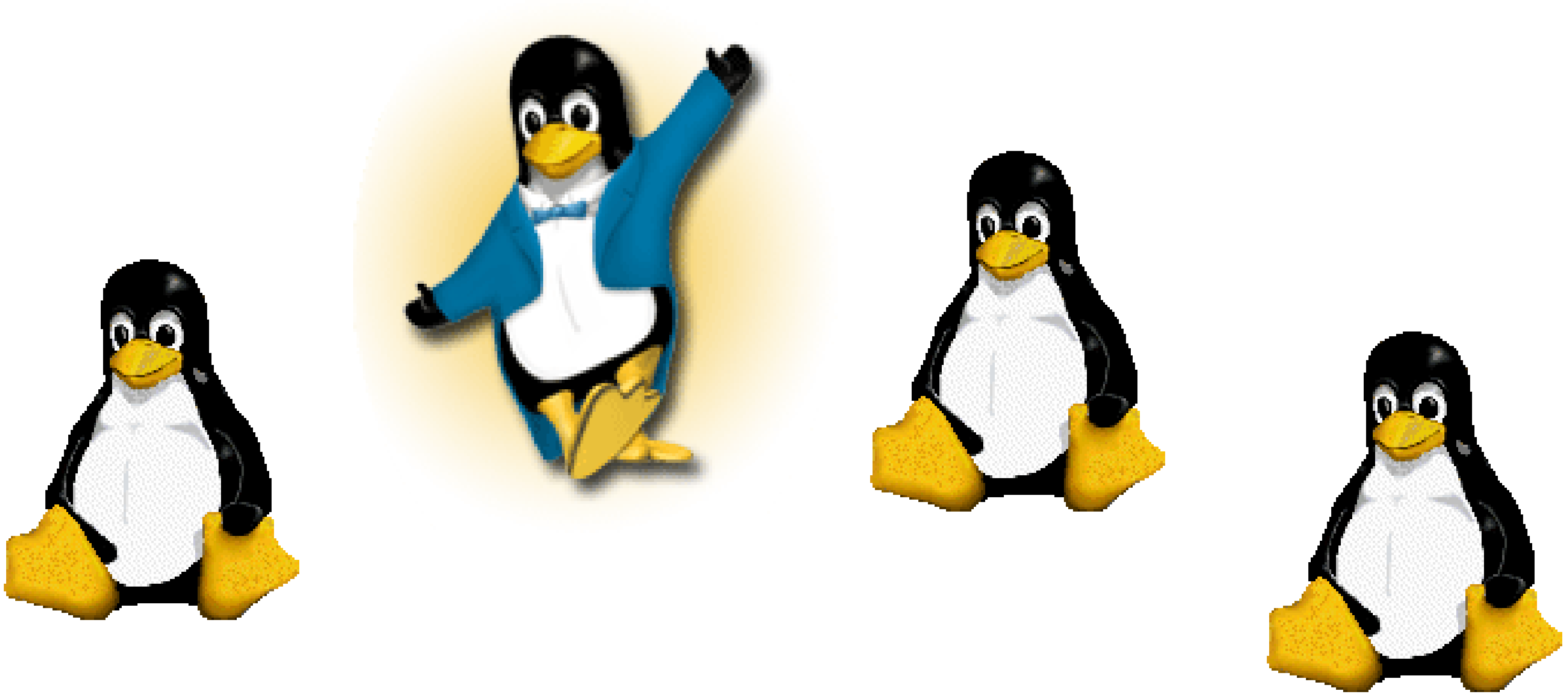
Questions







Backup – older but still valid topics for reference

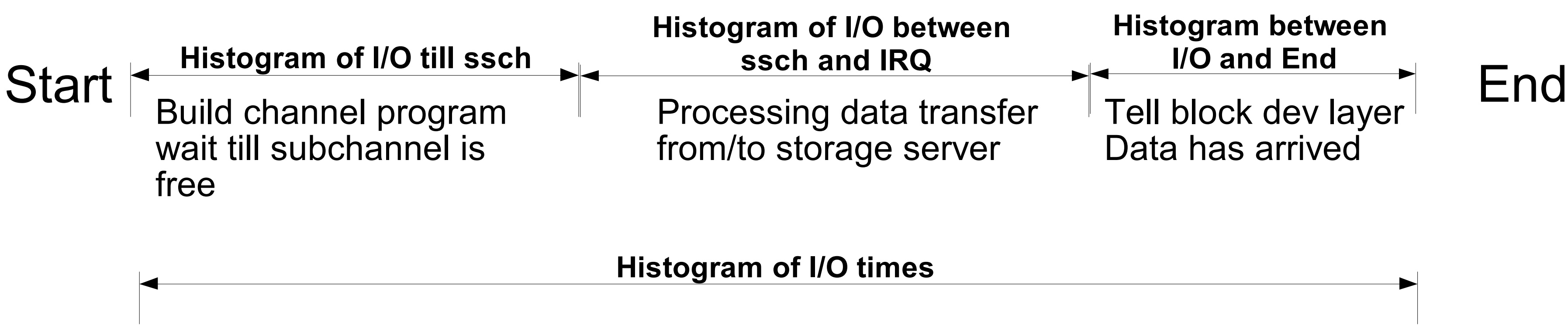


/proc/dasd/statistics (1)

- Linux can collect performance stats on DASD activity as seen by Linux(!)
- Turn on with
  `echo on > /proc/dasd/statistics`
- Turn off with
  `echo off > /proc/dasd/statistics`
- To reset: turn off and then on again
- Can be read for the whole system by
  `cat /proc/dasd/statistics`
- Can be read for individual DASDs by
  `tunedasd -P /dev/dasda`

/proc/dasd/statistics (2)

- Collects statistics (mostly processing times) of IO operations
- Each line represents a histogram of times for a certain operation
- Operations split up into the following :



http://www.ibm.com/developerworks/linux/linux390/perf/tuning_how_tools_dasd.html

/proc/dasd/statistics (3)

```
Tue Jan 18 20:52:50 EST 2005
21155901 dasd I/O requests
with 433275376 sectors(512B each)
   __<4    ___8    __16    __32    __64    _128    _256    _512    __1k    __2k    __4k    __8k    _16k    _32k    _64k    128k
   _256    _512    __1M    __2M    __4M    __8M    _16M    _32M    _64M    128M    256M    512M    __1G    __2G    __4G    _>4G
Histogram of sizes (512B secs)
      0       0 3774298  838941  352193  232188   43222   30563   16163    1403       0       0       0       0       0       0
      0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0
Histogram of I/O times (microseconds)
      0       0       0       0       0       0       0       2 3005329  352056  726353  671293  355198  147238   29245    2201
     51       3       0       0       0       0       0       0       0       0       0       0       0       0       0       0
Histogram of I/O times per sector
      0       0   24686  204678  524222 2803252  500319  537993  249088  316175  111592   15932    1005      26       3       0
      0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0
Histogram of I/O time till ssch
3498191   51615   86168   21601    2756    1927    4348   22793  177758  138465  955964  214188   61200   42284    9075     621
     14       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0
Histogram of I/O time between ssch and irq
      0       0       0       0       0       0       0       4 4252115  408592   78374  122000  309317  108290    9848     416
     13       3       0       0       0       0       0       0       0       0       0       0       0       0       0       0
Histogram of I/O time between ssch and irq per sector
      0       0   41819  517428  890743 3323127   21897   23329  103966  280533   79777    6056     282      10       2       0
      0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0
Histogram of I/O time between irq and end
4531949  633301   75411   41903    4984     791     516      48      40       3       3      20       0       0       0       0
      0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0
# of req in chanq at enqueuing (1..32)
      0 3658672  277906  128989   97542 1125789      27       0       0       0       0       0       0       0       0       0
      0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0
```

How to collect z/VM monitor data

- Cheat Sheet at: http://www.vm.ibm.com/perf/tips/collect.html
- 5 basic steps
  - Create monitor DCSS
  - Setup userid to issue monwrite command
  - Start and configure monitor
  - Start monwrite
  - Stop monwrite and save data

How to insert Linux data in z/VM monitor stream

- Enable your guest for inserting data into the monitor stream
  - set APPLMON option to user direct
- Insert Linux modules
  - `modprobe appldata_mem`
  - `modprobe appdata_os`
  - `modprobe appldata_net_sum`
- Turn on monitoring
  - `echo 1 > /proc/sys/appldata/timer`
  - `echo 1 > /proc/sys/appldata/mem`
  - `echo 1 > /proc/sys/appldata/os`
  - `echo 1 > /proc/sys/appldata/net_sum`

- Details can be found in chapter 15 of Device Drivers, Features, and Commands (SC33-8281-02)
  http://download.boulder.ibm.com/ibmdl/pub/software/dw/linux390/docu/l26bdd02.pdf

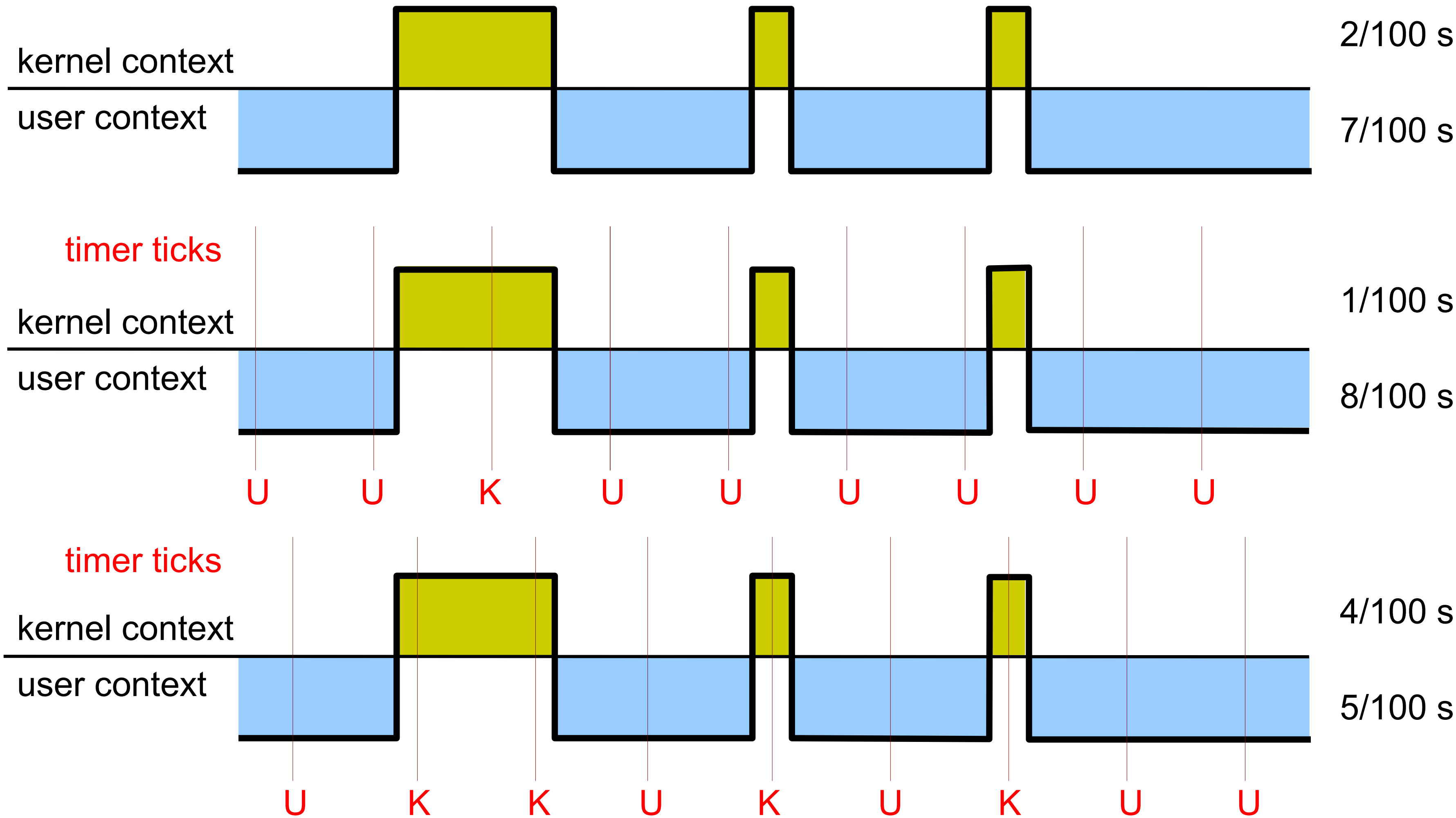
z/VM 2 GB considerations

- Solution: upgrade z/VM to 5.2 or 5.3 level
- Read at
  - http://www.vm.ibm.com/perf/tips/2gstorag.html
  - http://www.vm.ibm.com/perf/reports/zvm/html/64bit.html
  - http://www.ibm.com/developerworks/linux/linux390/perf/tuning_rec_fixed_io_
- Old workarounds
  - **C**ooperative **M**emory **M**anagement
  - fixed I/O buffers with kernel 2.6 and ECKD
  - distribute your guests to multiple z/VMs
  - Move large guest to LPAR

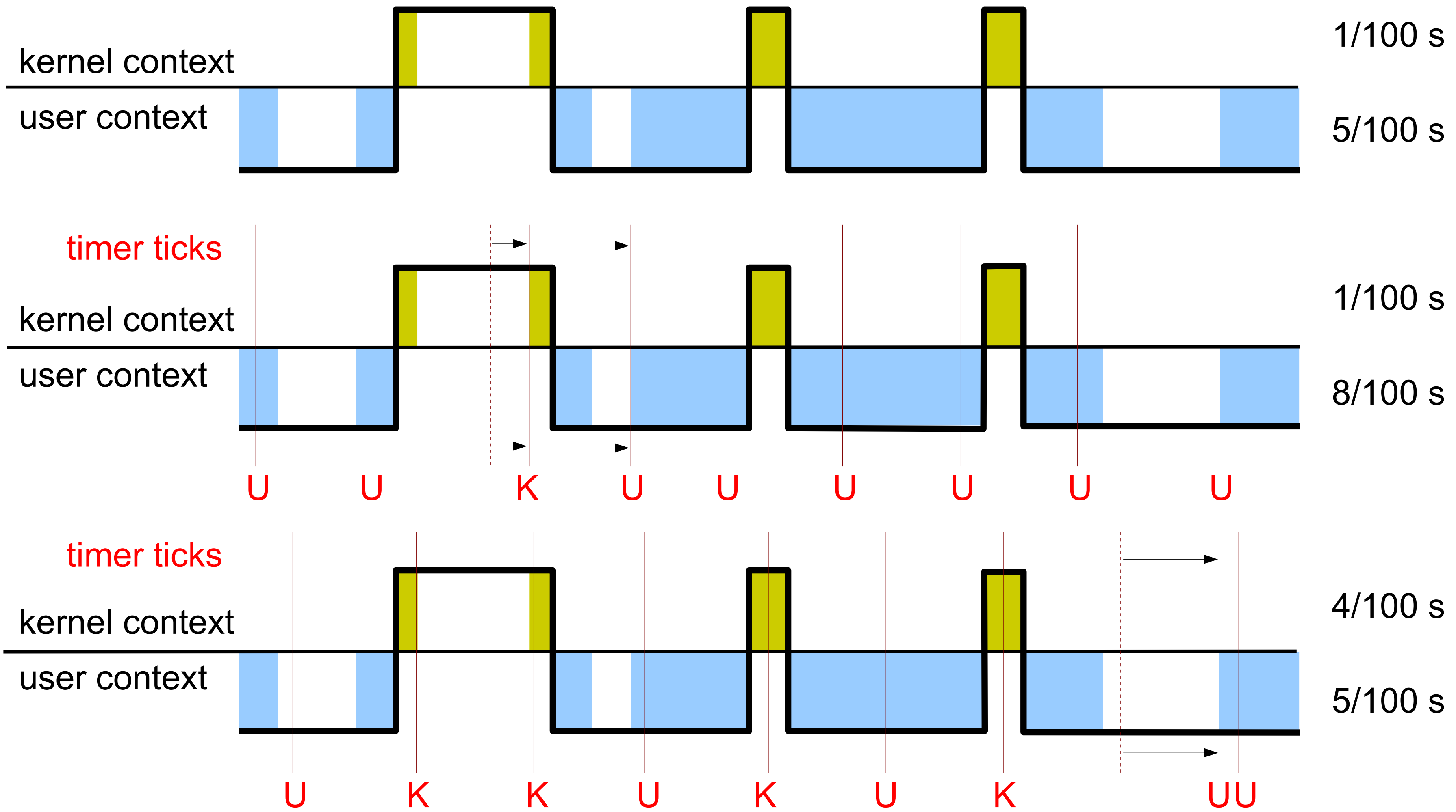
spin_retry

- Problem:
  - with many guests in z/VM it can happen that CP is busy executing diagnose instructions for the guest
- What's behind it:
  - in a so-called spin lock, Linux guests give their CPU share back to the hipervisor using DIAG 44
  - Hipervisor can be overloaded
- Solution:
  - Linux tries to get a lock n times before issuing a DIAG
  - Value of n is adjustable in /proc/sys/kernel/spin_retry (default 1000)
  - Included in latest SLES9 + SLES10 + RHEL4 + RHEL5

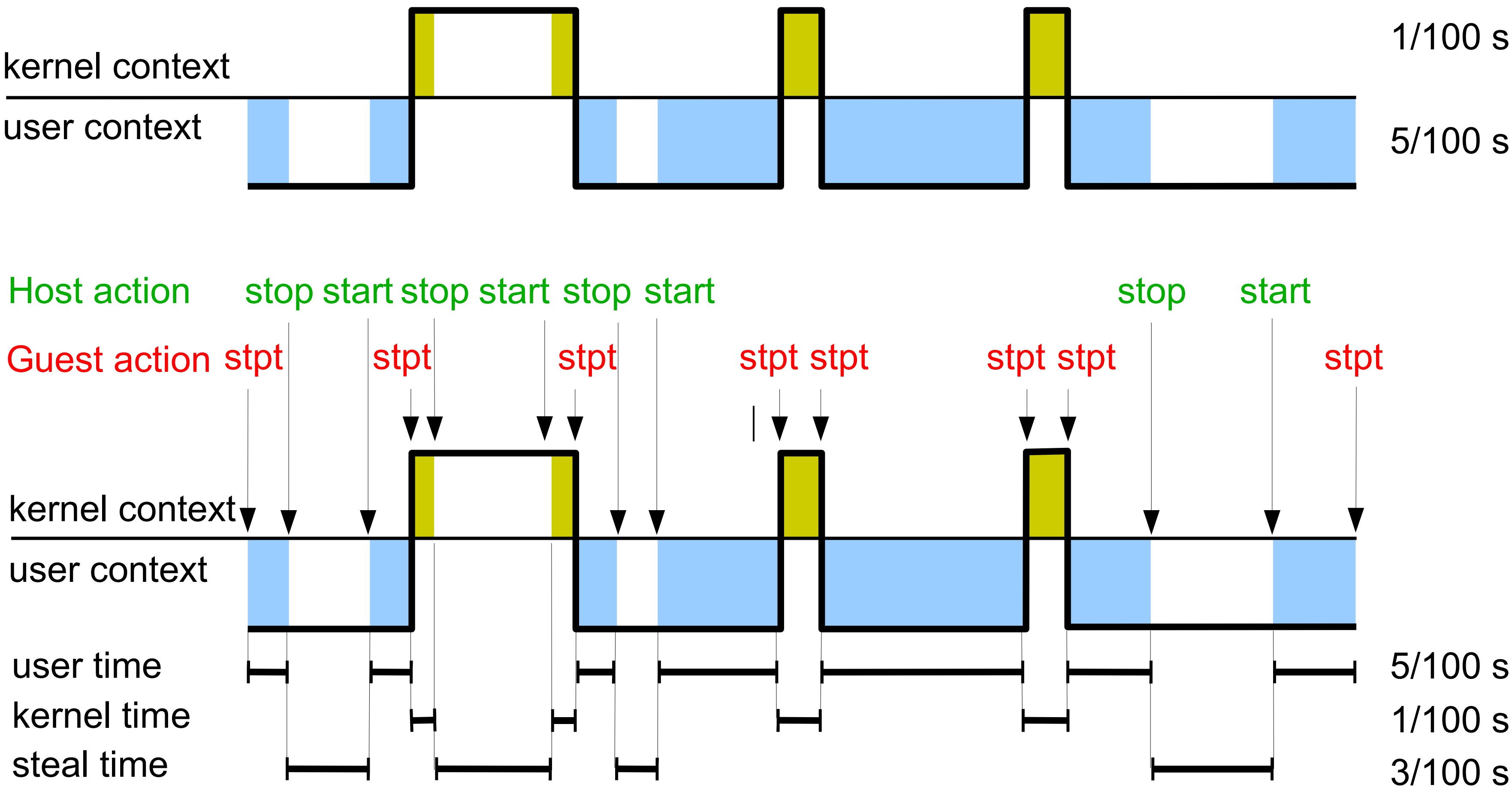
Tick based CPU Time inaccuracy



Tick based CPU accounting on virtual systems



New Virtual CPU time accounting



stpt = Store CPU Timer