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How to Surprise by being a Linux Performance "know-it-all"

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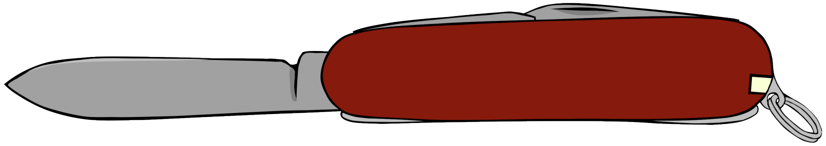
SHARE in Anaheim 2012

Agenda

- Tools are your swiss army knife
  - ps
  - top
  - sadc/sar
  - iostat
  - vmstat
  - netstat



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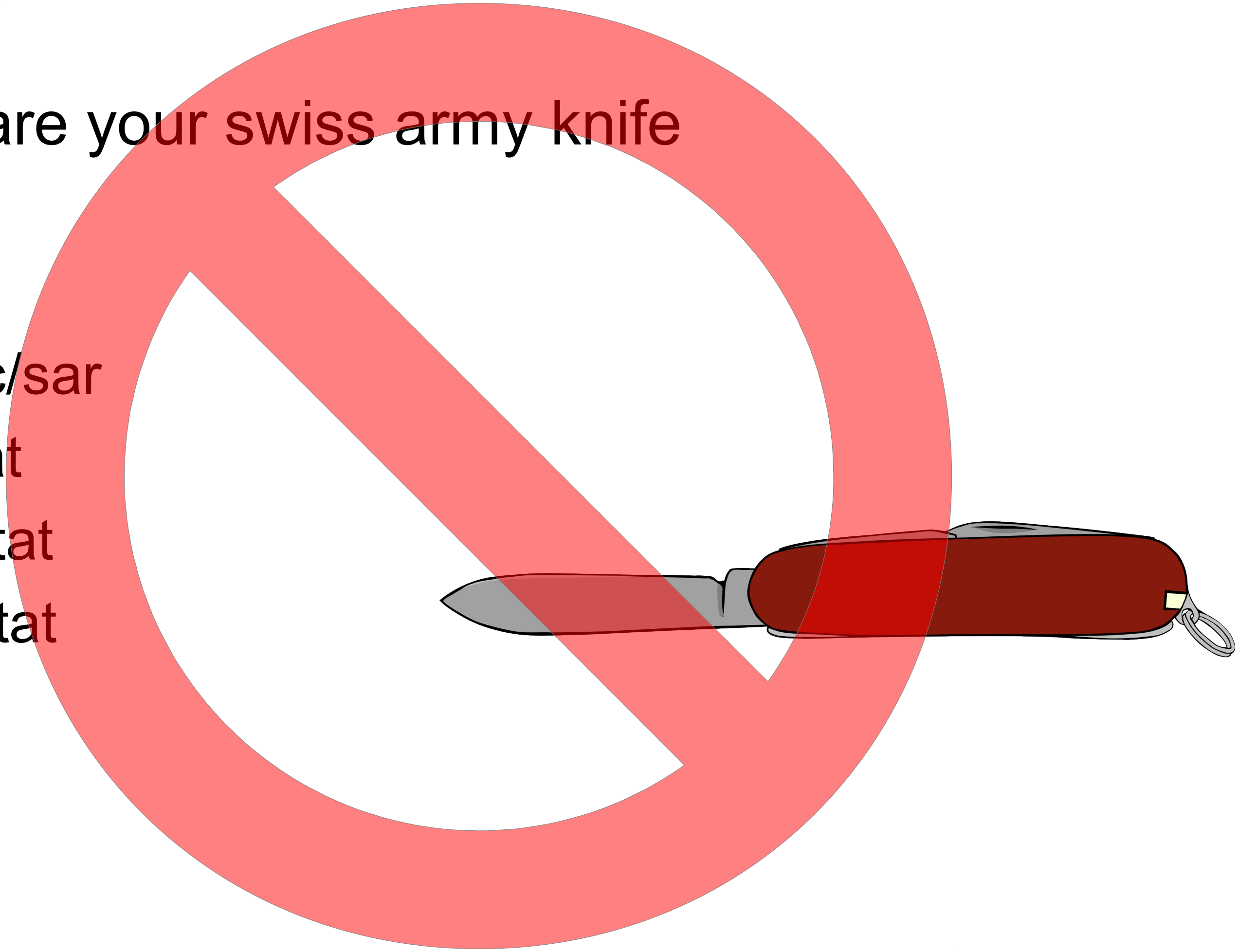


Agenda

- Your swiss army knife for the complex cases
  - htop
  - dstat
  - pidstat
  - irqstats
  - strace/ltrace
  - blktrace
  - hyptop
  - profiling
  - valgrind
  - iptraf
  - tracepoints

General thoughts on performance tools

- Things that are always to consider
  - Monitoring can impact the system
  - Most data gathering averages over a certain period of time
    → this flattens peaks
  - Start with defining the problem
    - which parameter(s) from the application/system indicates the problem
    - which range is considered as bad, what is considered as good
  - monitor the good case and save the results
    - comparisons when a problem occurs can save days and weeks

- Staged approach saves a lot of work
  - Try to use general tools to isolate the area of the issue
  - Create theories and try to quickly verify/falsify them
  - Use advanced tools to debug the identified area

Orientation - where to go

Tool	1st overview	CPU consumption	latencies	Hot spots	Disk I/O	Memory	Network
top / ps	x	x					
sysstat	x	x			x	x	
vmstat	x	x				x	
iostat	x				x		
dasdstat					x		
scsistat					x		
netstat	x						x
htop / dstat / pidstat	x	x	x		x		
irqstats	x	x	x				
strace / ltrace			x				
hyptop		x					
profiling		x		x			
blktrace					x		
valgrind						x	
iptraf	x						x
tracepoints			x	x	x	x	x

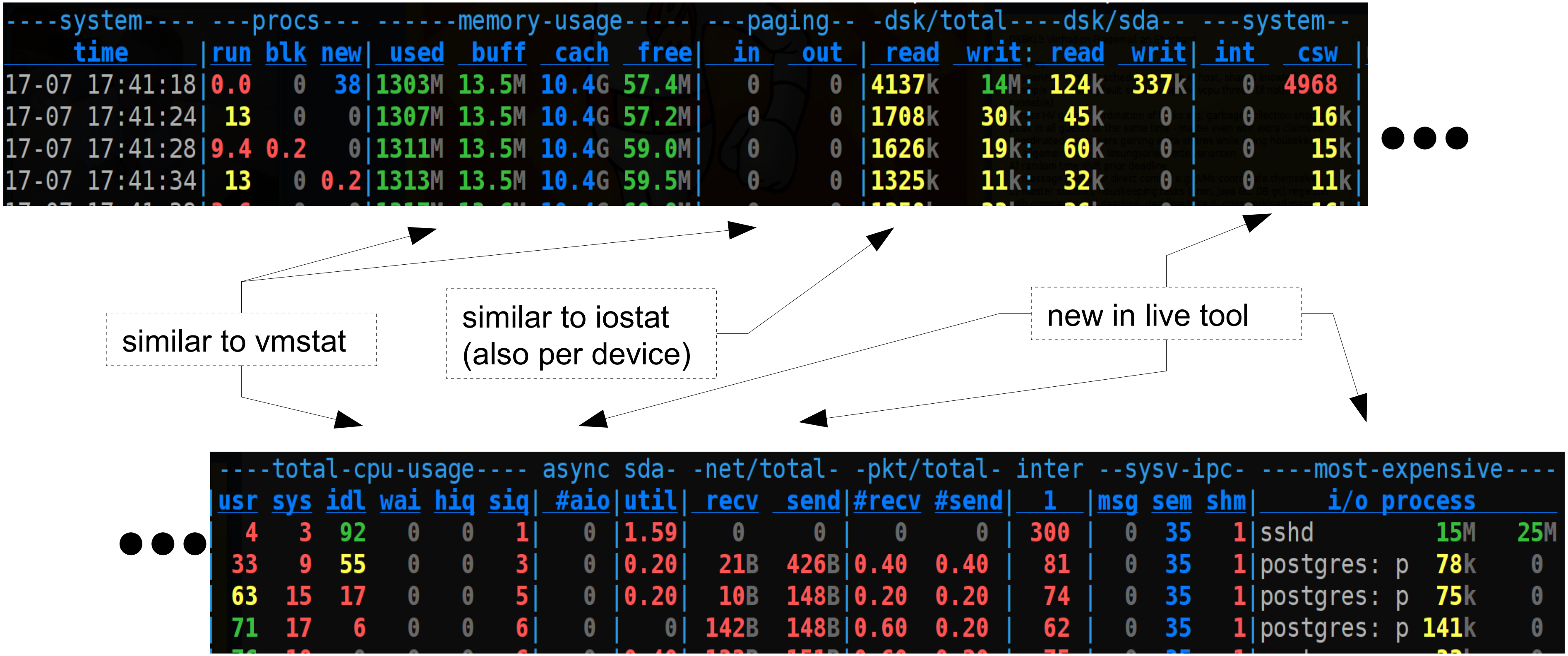
DSTAT

- Characteristics: Live easy to use full system information
- Objective: Flexible set of statistics
- Usage: `dstat -tv –aio –disk-util -n –net-packets -i –ipc -D total,[diskname] –top-io [...] [interval]`
- Short: `dstat -tinv`

- Shows
  - Throughput
  - Utilization
  - Summarized and per Device queue information
  - Much more … it more or less combines several classic tools like iostat and vmstat

- Hints
  - Powerful plugin concept
    - “`--top-io`” for example identifies the application causing the most I/Os
  - Colorization allows fast identification of deviations

Dstat – the limit is your screen width



```
----system---- ---procs--- ------memory-usage----- ---paging-- -dsk/total----dsk/sda-- ---system--
     time     |run blk new| used  buff  cach  free|  in   out | read  writ: read  writ| int   csw |
17-07 17:41:18|0.0   0  38|1303M 13.5M 10.4G 57.4M|   0     0 |4137k   14M: 124k  337k|   0  4968 |
17-07 17:41:24| 13   0   0|1307M 13.5M 10.4G 57.2M|   0     0 |1708k   30k:  45k    0 |   0    16k|
17-07 17:41:28|9.4 0.2   0|1311M 13.5M 10.4G 59.0M|   0     0 |1626k   19k:  60k    0 |   0    15k|
17-07 17:41:34| 13   0 0.2|1313M 13.5M 10.4G 59.5M|   0     0 |1325k   11k:  32k    0 |   0    11k|
```

•••

similar to vmstat

similar to iostat
(also per device)

new in live tool

•••

```
----total-cpu-usage---- async sda- -net/total- -pkt/total- inter --sysv-ipc- ----most-expensive----
|usr sys idl wai hiq siq| #aio|util| recv  send|#recv #send|  1  |msg sem shm|     i/o process
|  4   3  92   0   0   1|   0 |1.59|   0     0 |   0     0 | 300 |  0  35   1|sshd          15M   25M
| 33   9  55   0   0   3|   0 |0.20|  21B  426B|0.40  0.40 |  81 |  0  35   1|postgres: p  78k     0
| 63  15  17   0   0   5|   0 |0.20|  10B  148B|0.20  0.20 |  74 |  0  35   1|postgres: p  75k     0
| 71  17   6   0   0   6|   0 |   0| 142B  148B|0.60  0.20 |  62 |  0  35   1|postgres: p 141k     0
```

HTOP

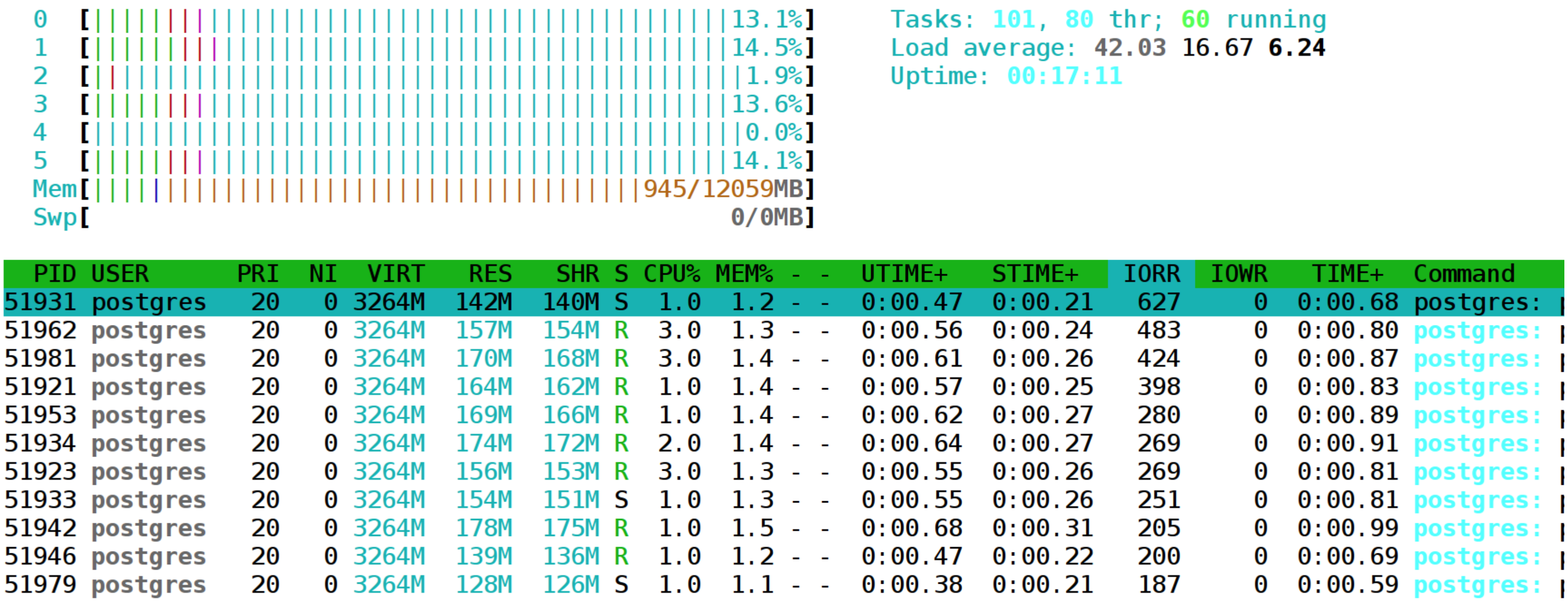
- Characteristics: Process overview with extra features
- Objective: Get a understanding about your running processes
- Usage: `htop`

- Shows
  - Running processes
  - CPU and memory utilization
  - Accumulated times
  - I/O rates
  - System utilization visualization

- Hints
  - Htop can display more uncommon fields (in menu)
  - Able to send signals out of its UI for administration purposes
  - Processes can be sorted/filtered for a more condensed view

htop

Configurable utilization visualization



```
0  [|||||||||||||||||||||||||||||||||||||||||||13.1%]   Tasks: 101, 80 thr; 60 running
1  [|||||||||||||||||||||||||||||||||||||||||||14.5%]   Load average: 42.03 16.67 6.24
2  [||||||||||||||||||||||||||||||||||||||||||||1.9%]   Uptime: 00:17:11
3  [|||||||||||||||||||||||||||||||||||||||||||13.6%]
4  [||||||||||||||||||||||||||||||||||||||||||||0.0%]
5  [|||||||||||||||||||||||||||||||||||||||||||14.1%]
Mem[|||||||||||||||||||||||||||||||||||||945/12059MB]
Swp[                                           0/0MB]

  PID USER      PRI  NI  VIRT   RES   SHR S CPU% MEM% - -  UTIME+   STIME+  IORR  IOWR   TIME+  Command
51931 postgres   20   0 3264M  142M  140M S  1.0  1.2 - -  0:00.47  0:00.21  627     0  0:00.68 postgres:
51962 postgres   20   0 3264M  157M  154M R  3.0  1.3 - -  0:00.56  0:00.24  483     0  0:00.80 postgres:
51981 postgres   20   0 3264M  170M  168M R  3.0  1.4 - -  0:00.61  0:00.26  424     0  0:00.87 postgres:
51921 postgres   20   0 3264M  164M  162M R  1.0  1.4 - -  0:00.57  0:00.25  398     0  0:00.83 postgres:
51953 postgres   20   0 3264M  169M  166M R  1.0  1.4 - -  0:00.62  0:00.27  280     0  0:00.89 postgres:
51934 postgres   20   0 3264M  174M  172M R  2.0  1.4 - -  0:00.64  0:00.27  269     0  0:00.91 postgres:
51923 postgres   20   0 3264M  156M  153M R  3.0  1.3 - -  0:00.55  0:00.26  269     0  0:00.81 postgres:
51933 postgres   20   0 3264M  154M  151M S  1.0  1.3 - -  0:00.55  0:00.26  251     0  0:00.81 postgres:
51942 postgres   20   0 3264M  178M  175M R  1.0  1.5 - -  0:00.68  0:00.31  205     0  0:00.99 postgres:
51946 postgres   20   0 3264M  139M  136M R  1.0  1.2 - -  0:00.47  0:00.22  200     0  0:00.69 postgres:
51979 postgres   20   0 3264M  128M  126M S  1.0  1.1 - -  0:00.38  0:00.21  187     0  0:00.59 postgres:
```

Common process info

Accumulated Usage and IO rates

Hierarchy

PIDSTAT

- Characteristics: Easy to use extended per process statistics
- Objective: Identify processes with peak activity
- Usage: `pidstat [-w|-r|-d]`

- Shows
  - `-w` context switching activity and if it was voluntary
  - `-r` memory statistics, especially minor/major faults per process
  - `-d` disk throughput per process

- Hints
  - Also useful if run as background log due to its low overhead
    - Good extension to sadc in systems running different applications/services
  - `-p <pid>` can be useful to track activity of a specific process

Pidstat examples

```
12:46:18 PM       PID   cswch/s nvcswch/s  Command
12:46:18 PM         3      2.39      0.00  ksoftirqd/0
12:46:18 PM         4      0.04      0.00  migration/0
12:46:18 PM      1073    123.42    180.18  Xorg
```

Voluntarily / Involuntary

```
12:47:51 PM       PID  minflt/s  majflt/s     VSZ    RSS   %MEM  Command
12:47:51 PM       985      0.06      0.00   15328   3948   0.10  smbd
12:47:51 PM       992      0.04      0.00    5592   2152   0.05  sshd
12:47:51 PM      1073    526.41      0.00 1044240 321512   7.89  Xorg
```

Faults per process

```
12:49:18 PM       PID   kB_rd/s   kB_wr/s kB_ccwr/s  Command
12:49:18 PM       330      0.00      1.15      0.00  kjournald
12:49:18 PM      2899      4.35      0.09      0.04  notes2
12:49:18 PM      3045     23.43      0.01      0.00  audacious2
```

How much KB disk I/O per process

IRQ Statistics

- Characteristics: Low overhead IRQ information
- Objective: Condensed overview of IRQ activity
- Usage: `cat /proc/interrupts`

- Shows
  - Which interrupts happen on which cpu

- Hints
  - Recent Versions (SLES11-SP2) much more useful
  - If interrupts are unintentionally unbalanced
  - If the amount of interrupts matches I/O
    - This can point to non-working IRQ avoidance

IRQ Statistics

- Example
  - Network focus on CPU zero (in this case unwanted)
  - Scheduler covered most of that avoiding idle CPU 1-3
  - But caused a lot migrations, IPI's and cache misses

```
           CPU0       CPU1       CPU2       CPU3
EXT:      21179      24235      22217      22959
I/O:    1542959     340076     356381     325691
CLK:      15995      16718      15806      16531   [EXT] Clock Comparator
EXC:        255        325        332        227   [EXT] External Call
EMS:       4923       7129       6068       6201   [EXT] Emergency Signal
TMR:          0          0          0          0   [EXT] CPU Timer
TAL:          0          0          0          0   [EXT] Timing Alert
PFL:          0          0          0          0   [EXT] Pseudo Page Fault
DSD:          0          0          0          0   [EXT] DASD Diag
VRT:          0          0          0          0   [EXT] Virtio
SCP:          6         63         11          0   [EXT] Service Call
IUC:          0          0          0          0   [EXT] IUCV
CPM:          0          0          0          0   [EXT] CPU Measurement
CIO:        163        310        269        213   [I/O] Common I/O Layer Interrupt
QAI:  1 541 773    338 857    354 728    324 110   [I/O] QDIO Adapter Interrupt
DAS:       1023        909       1384       1368   [I/O] DASD
[…] 3215, 3270, Tape, Unit Record Devices, LCS, CLAW, CTC, AP Bus, Machine Check
```

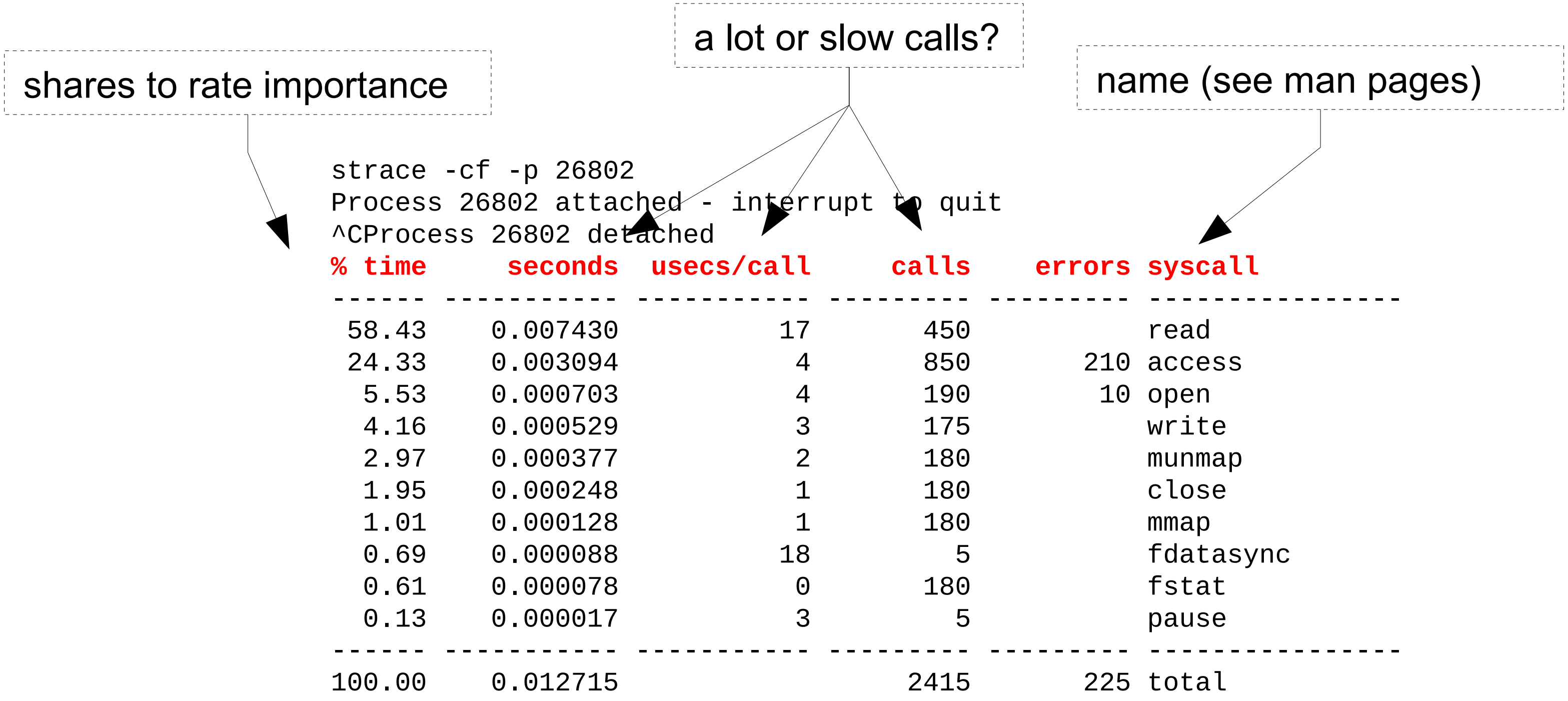
STRACE

- Characteristics: High overhead, high detail tool
- Objective: Get insights about the ongoing system calls of a program
- Usage: `strace -p [pid of target program]`

- Shows
  - Identify kernel entries called more often or taking too long
    - Can be useful if you search for increased system time
  - Time in call (`-T`)
  - Relative timestamp (`-r`)

- Hints
  - The option "`-c`" allows medium overhead by just tracking counters and durations

strace - example



shares to rate importance

a lot or slow calls?

name (see man pages)

```
strace -cf -p 26802
Process 26802 attached - interrupt to quit
^CProcess 26802 detached
% time     seconds  usecs/call     calls    errors syscall
------ ----------- ----------- --------- --------- ----------------
 58.43    0.007430          17       450           read
 24.33    0.003094           4       850       210 access
  5.53    0.000703           4       190        10 open
  4.16    0.000529           3       175           write
  2.97    0.000377           2       180           munmap
  1.95    0.000248           1       180           close
  1.01    0.000128           1       180           mmap
  0.69    0.000088          18         5           fdatasync
  0.61    0.000078           0       180           fstat
  0.13    0.000017           3         5           pause
------ ----------- ----------- --------- --------- ----------------
100.00    0.012715                  2415       225 total
```

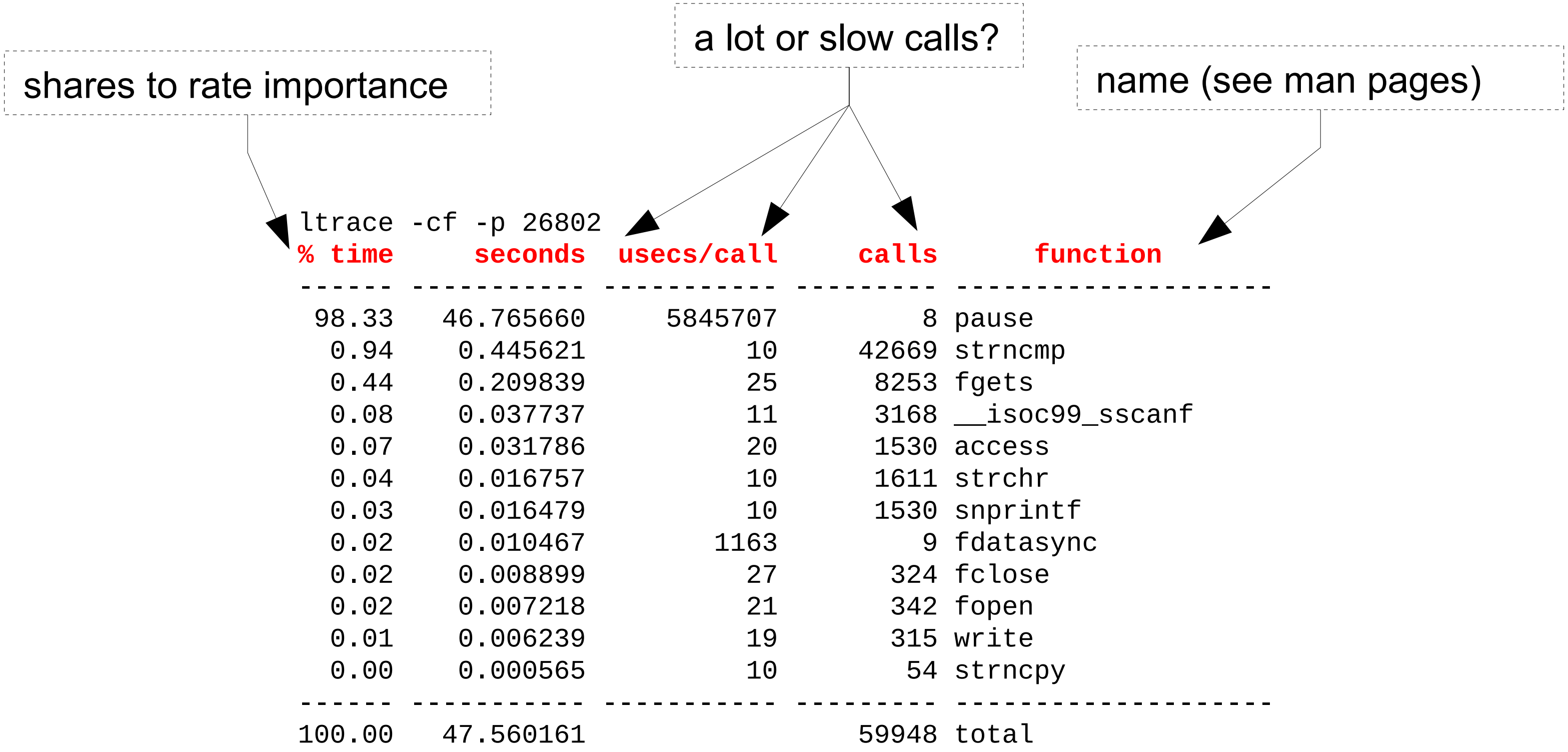
LTRACE

- Characteristics: High overhead, high detail tool
- Objective: Get insights about the ongoing library calls of a program
- Usage: `ltrace -p [pid of target program]`

- Shows
  - Identify library calls that are too often or take too long
    - Good if you search for additional user time
    - Good if things changed after upgrading libs
  - Time in call (`-T`)
  - Relative timestamp (`-r`)

- Hints
  - The option “`-c`” allows medium overhead by just tracking counters and durations
  - The option -S allows to combine ltrace and strace

ltrace - example



shares to rate importance

a lot or slow calls?

name (see man pages)

```
ltrace -cf -p 26802
% time     seconds  usecs/call     calls      function
------ ----------- ----------- --------- --------------------
 98.33   46.765660     5845707         8 pause
  0.94    0.445621          10     42669 strncmp
  0.44    0.209839          25      8253 fgets
  0.08    0.037737          11      3168 __isoc99_sscanf
  0.07    0.031786          20      1530 access
  0.04    0.016757          10      1611 strchr
  0.03    0.016479          10      1530 snprintf
  0.02    0.010467        1163         9 fdatasync
  0.02    0.008899          27       324 fclose
  0.02    0.007218          21       342 fopen
  0.01    0.006239          19       315 write
  0.00    0.000565          10        54 strncpy
------ ----------- ----------- --------- --------------------
100.00   47.560161                 59948 total
```

strace / ltrace – full trace

- Without -c both tools produce a full detail log
  - Via -f child processes can be traced as well
  - Extra options "`-Tr`" are useful to search for latencies follow time in call / relative timestamp
  - Useful to "read" what exactly goes on when

```
Example strace'ing a sadc data gatherer
0.000028 write(3, "\0\0\0\0\0\0\0\17\0\0\0\0\0\0\0\17\0\0\0\0\0\0\0\0\0\0\0\0\0\0\0\0"..., 680) = 680 <0.000007>
0.000027 write(3, "\0\0\0\0\0\0\0\17\0\0\0\0\0\0\0\17\0\0\0\0\0\0\0\0\0\0\0\0\0\0\0\0"..., 680) = 680 <0.000007>
0.000026 fdatasync(3)              = 0 <0.002673>
0.002688 pause()                   = 0 <3.972935>
3.972957 --- SIGALRM (Alarm clock) @ 0 (0) ---
0.000051 rt_sigaction(SIGALRM, {0x8000314c, [ALRM], SA_RESTART}, {0x8000314c, [ALRM], SA_RESTART}, 8) = 0 <0.000005>
0.000038 alarm(4)                  = 0 <0.000005>
0.000031 sigreturn()               = ? (mask now []) <0.000005>
0.000024 stat("/etc/localtime", {st_mode=S_IFREG|0644, st_size=2309, ...}) = 0 <0.000007>
0.000034 open("/proc/uptime", O_RDONLY) = 4 <0.000009>
0.000024 fstat(4, {st_mode=S_IFREG|0444, st_size=0, ...}) = 0 <0.000005>
0.000029 mmap(NULL, 4096, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_ANONYMOUS, -1, 0) = 0x3fffd20a000 <0.000006>
0.000028 read(4, "11687.70 24836.04\n", 1024) = 18 <0.000010>
0.000027 close(4)                  = 0 <0.000006>
0.000020 munmap(0x3fffd20a000, 4096) = 0 <0.000009>
```

BLKTRACE

- Characteristics: High detail info of the block device layer actions
- Objective: Understand whats going with your I/O in the kernel and devices
- Usage: `blktrace -d [device(s)]`
  Then: `blkparse -st [commontracefilepart]`

- Shows
  - Events like merging, request creation, I/O submission, I/O completion, ...
  - Timestamps and disk offsets for each event
  - Associated task and executing CPU
  - Application and CPU summaries

- Hints
  - Filter masks allow lower overhead if only specific events are of interest
  - Has an integrated client/server mode to stream data away
    - Avoids extra disk I/O on a system with disk I/O issues

Blktrace – when is it useful

- Often its easy to identify that I/O is slow, but
  → Where?
  → Because of what?

- Blocktrace allows to
  - Analyze Disk I/O characteristics like sizes and offsets
    - Maybe your I/O is split in a layer below
  - Analyze the timing with details about all involved Linux layers
    - Often useful to decide if HW or SW causes stalls
  - Summaries per CPU / application can identify imbalances

Blktrace - events

Common:
A -- remap For stacked devices, incoming i/o is remapped to device below it in the i/o stack. The remap action details what exactly is being remapped to what.
Q -- queued This notes intent to queue i/o at the given location. No real requests exists yet.
G -- get request To send any type of request to a block device, a struct request container must be allocated first.
I -- inserted A request is being sent to the i/o scheduler for addition to the internal queue and later service by the driver. The request is fully formed at this time.
D -- issued A request that previously resided on the block layer queue or in the i/o scheduler has been sent to the driver.
C -- complete A previously issued request has been completed. The output will detail the sector and size of that request, as well as the success or failure of it.

Plugging & Merges:
P -- plug When i/o is queued to a previously empty block device queue, Linux will plug the queue in anticipation of future I/Os being added before this data is needed.
U -- unplug Some request data already queued in the device, start sending requests to the driver. This may happen automatically if a timeout period has passed (see next entry) or if a number of requests have been added to the queue.
Recent kernels associate the queue with the submitting task and unplug also on a context switch.
T -- unplug due to timer If nobody requests the i/o that was queued after plugging the queue, Linux will automatically unplug it after a defined period has passed.
M -- back merge A previously inserted request exists that ends on the boundary of where this i/o begins, so the i/o scheduler can merge them together.
F -- front merge Same as the back merge, except this i/o ends where a previously inserted requests starts.

Special:
B -- bounced The data pages attached to this bio are not reachable by the hardware and must be bounced to a lower memory location. This causes a big slowdown in i/o performance, since the data must be copied to/from kernel buffers. Usually this can be fixed with using better hardware -- either a better i/o controller, or a platform with an IOMMU.
S -- sleep No available request structures were available, so the issuer has to wait for one to be freed.
X -- split On raid or device mapper setups, an incoming i/o may straddle a device or internal zone and needs to be chopped up into smaller pieces for service. This may indicate a performance problem due to a bad setup of that raid/dm device, but may also just be part of normal boundary conditions. dm is notably bad at this and will clone lots of i/o.

Blktrace - events

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Good as documentation,
but hard to
understand/remember

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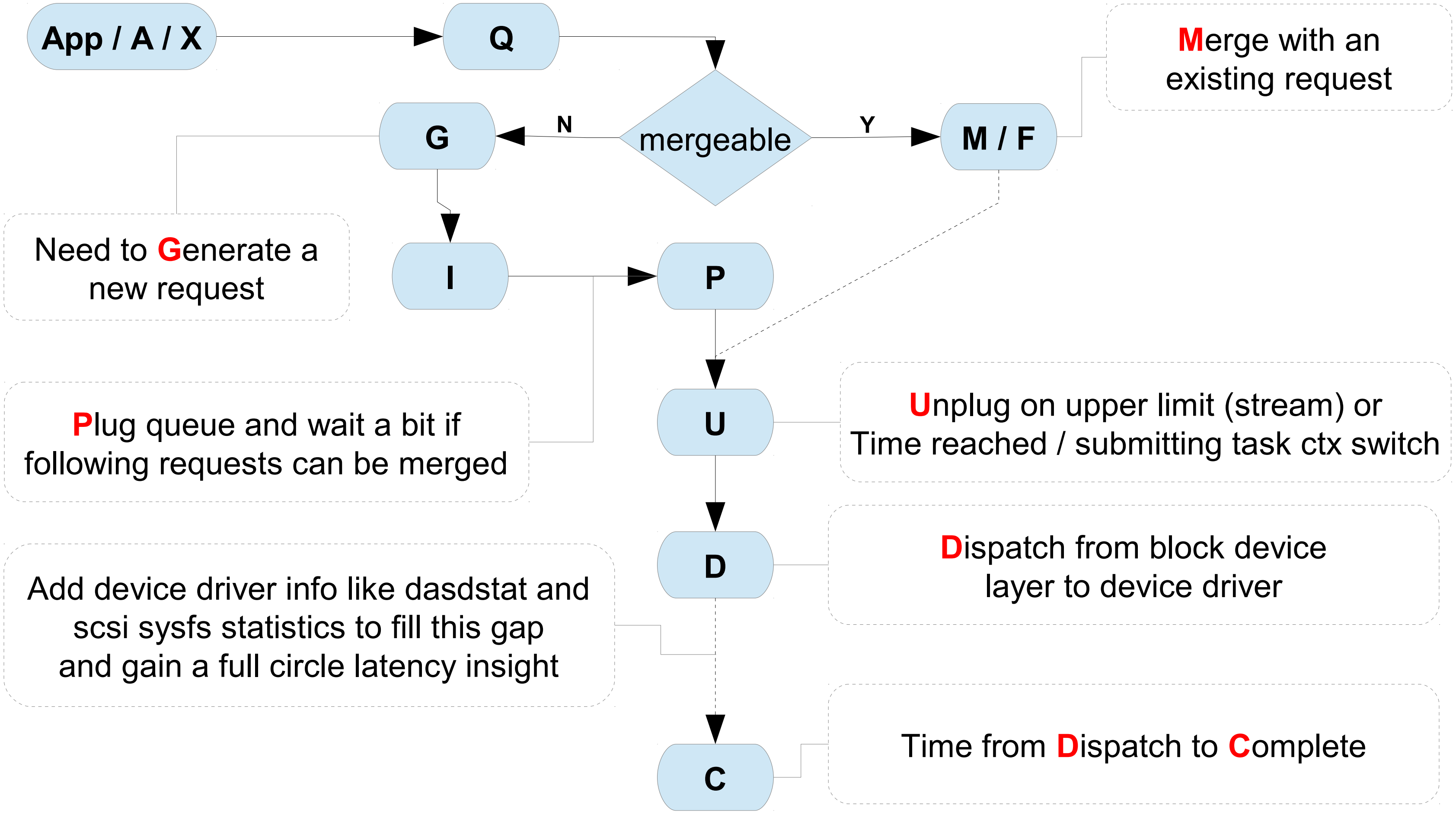
Block device layer – events (simplified)



Merge with an existing request

Need to Generate a new request

Plug queue and wait a bit if following requests can be merged

Unplug on upper limit (stream) or Time reached / submitting task ctx switch

Dispatch from block device layer to device driver

Add device driver info like dasdstat and scsi sysfs statistics to fill this gap and gain a full circle latency insight

Time from Dispatch to Complete

blktrace

- Example Case
  - The snippet shows a lot of 4k requests (8x512 byte sectors)
    - We expected the I/O to be 32k
  - Each one is dispatched separately (no merges)
    - This caused unnecessary overhead and slow I/O

```
Maj/Min CPU   Seq-nr       sec.nsec   pid Action RWBS sect + size  map source / task
94,4     27       21    0.059363692 18994      A    R 20472832 + 8 <- (94,5) 20472640
94,4     27       22    0.059364630 18994      Q    R 20472832 + 8 [qemu-kvm]
94,4     27       23    0.059365286 18994      G    R 20472832 + 8 [qemu-kvm]
94,4     27       24    0.059365598 18994      I    R 20472832 + 8 (     312) [qemu-kvm]
94,4     27       25    0.059366255 18994      D    R 20472832 + 8 (     657) [qemu-kvm]
94,4     27       26    0.059370223 18994      A    R 20472840 + 8 <- (94,5) 20472648
94,4     27       27    0.059370442 18994      Q    R 20472840 + 8 [qemu-kvm]
94,4     27       28    0.059370880 18994      G    R 20472840 + 8 [qemu-kvm]
94,4     27       29    0.059371067 18994      I    R 20472840 + 8 (     187) [qemu-kvm]
94,4     27       30    0.059371473 18994      D    R 20472840 + 8 (     406) [qemu-kvm]
```

blktrace

- Example Case
  - Analysis turned out that the I/O was from the swap code
    - Same offsets were written by kswapd
  - A recent code change there disabled the ability to merge
  - The summary below shows the difference after a fix

```
Total initially
 Reads Queued:      560,888,    2,243MiB  Writes Queued:      226,242,   904,968KiB
 Read Dispatches:   544,701,    2,243MiB  Write Dispatches:   159,318,   904,968KiB
 Reads Requeued:          0               Writes Requeued:          0
 Reads Completed:   544,716,    2,243MiB  Writes Completed:   159,321,   904,980KiB
 Read Merges:        16,187,   64,748KiB  Write Merges:        61,744,   246,976KiB
 IO unplugs:        149,614               Timer unplugs:        2,940

Total after Fix
 Reads Queued:      734,315,    2,937MiB  Writes Queued:      300,188,     1,200MiB
 Read Dispatches:   214,972,    2,937MiB  Write Dispatches:   215,176,     1,200MiB
 Reads Requeued:          0               Writes Requeued:          0
 Reads Completed:   214,971,    2,937MiB  Writes Completed:   215,177,     1,200MiB
 Read Merges:       519,343,    2,077MiB  Write Merges:        73,325,   293,300KiB
 IO unplugs:        337,130               Timer unplugs:       11,184
```

Hyptop

- Characteristics: Easy to use Guest/LPAR overview
- Objective: Check CPU and overhead statistics of your own and sibling images
- Usage: `hyptop`

- Shows
  - CPU load & Management overhead
  - Memory usage
  - Can show image overview or single image details

- Hints
  - Good "first view" tool for linux admins that want to look "out of their linux"
  - Requirements:
    - For z/VM the Guest needs Class B
    - For LPAR "Global performance data control" checkbox in HMC

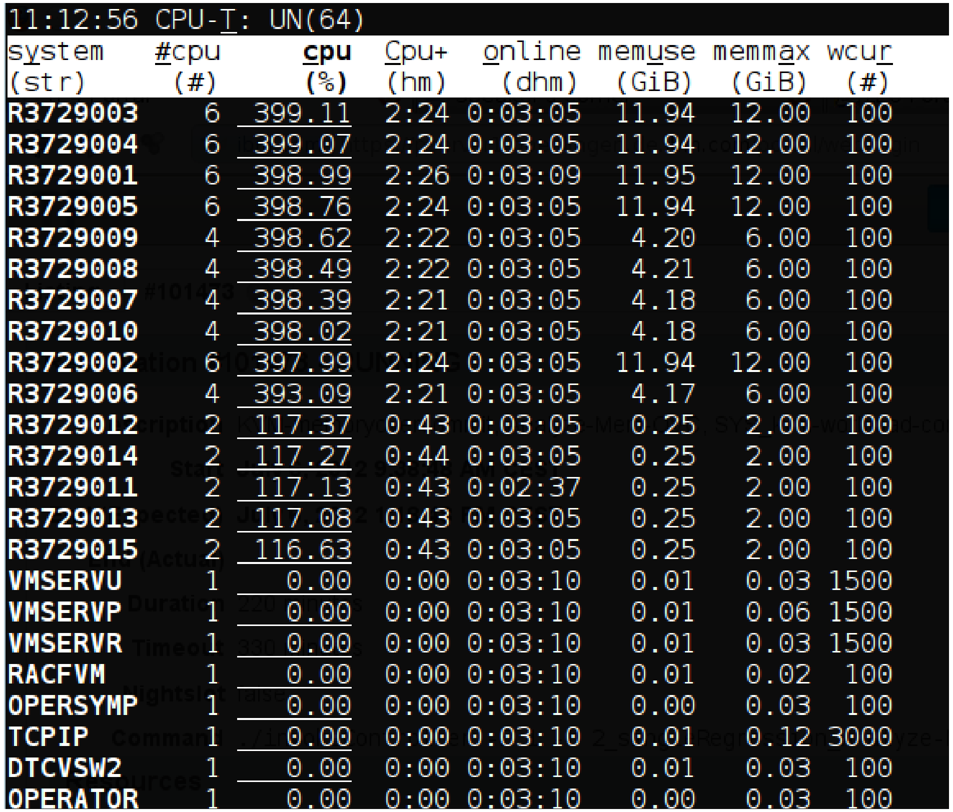
Hyptop

Why are exactly 4 CPUs used in all 6 CPU guests

All these do not fully utilize their 2 CPUs

No peaks in service guests

LPAR images would see other LPARs



```
11:12:56 CPU-T: UN(64)
system     #cpu      cpu   Cpu+  online memuse memmax wcur
(str)       (#)      (%)   (hm)   (dhm)  (GiB)  (GiB)  (#)
R3729003      6   399.11   2:24 0:03:05  11.94  12.00  100
R3729004      6   399.07   2:24 0:03:05  11.94  12.00  100
R3729001      6   398.99   2:26 0:03:09  11.95  12.00  100
R3729005      6   398.76   2:24 0:03:05  11.94  12.00  100
R3729009      4   398.62   2:22 0:03:05   4.20   6.00  100
R3729008      4   398.49   2:22 0:03:05   4.21   6.00  100
R3729007      4   398.39   2:21 0:03:05   4.18   6.00  100
R3729010      4   398.02   2:21 0:03:05   4.18   6.00  100
R3729002      6   397.99   2:24 0:03:05  11.94  12.00  100
R3729006      4   393.09   2:21 0:03:05   4.17   6.00  100
R3729012      2   117.37   0:43 0:03:05   0.25   2.00  100
R3729014      2   117.27   0:44 0:03:05   0.25   2.00  100
R3729011      2   117.13   0:43 0:02:37   0.25   2.00  100
R3729013      2   117.08   0:43 0:03:05   0.25   2.00  100
R3729015      2   116.63   0:43 0:03:05   0.25   2.00  100
VMSERVU       1     0.00   0:00 0:03:10   0.01   0.03 1500
VMSERVP       1     0.00   0:00 0:03:10   0.01   0.06 1500
VMSERVR       1     0.00   0:00 0:03:10   0.01   0.03 1500
RACFVM        1     0.00   0:00 0:03:10   0.01   0.02  100
OPERSYMP      1     0.00   0:00 0:03:10   0.00   0.03  100
TCPIP         1     0.00   0:00 0:03:10   0.01   0.12 3000
DTCVSW2       1     0.00   0:00 0:03:10   0.01   0.03  100
OPERATOR      1     0.00   0:00 0:03:10   0.00   0.03  100
```

Weights are equal

service guest weights

Profiling

- Characteristics: Easy to use profiling and kernel tracing
- Objective: Get detailed information where & why CPU is consumed
- Usage: `perf top` (to begin with)

- Shows
  - Sampling for CPU hotspots
    - Annotated source code along hotspot
  - CPU event counters
  - Further integrated non-sampling tools

- Hints
  - Without HW support only userspace can be reasonably profiled
  - “successor” of oprofile that is available with HW support (SLES11-SP2)
  - Perf HW support code upstream, wait for next distribution releases

Profiling

- What profiling can and what it can't
  - + Search hotspots of CPU consumption worth to optimize
  - + List functions according to their usage
  - - Search where time is lost (I/O, Stalls)

- Perf is not just a sampling tool
  - Integrated tools to evaluate tracepoints like
    “perf sched”, “perf timechart”, …
    - Opposite to real sampling this can help to search for stalls

Profiling

- Perf example howto
  - We had a case where new code caused cpus to scale badly
  - `perf record “workload”`
    - Creates a file called perf.data that can be analyzes
  - We used “`perf diff`” on both data files to get a comparison

- “Myriad” of further options/modules
  - Live view with perf top
  - Perf sched for an integrated analysis of scheduler tracepoints
  - Perf annotate to see samples alongside code
  - Perf stat for a counter based analysis
  - [...]

Profiling

- Perf example (perf diff)
  - found a locking issue causing increased cpu consumption

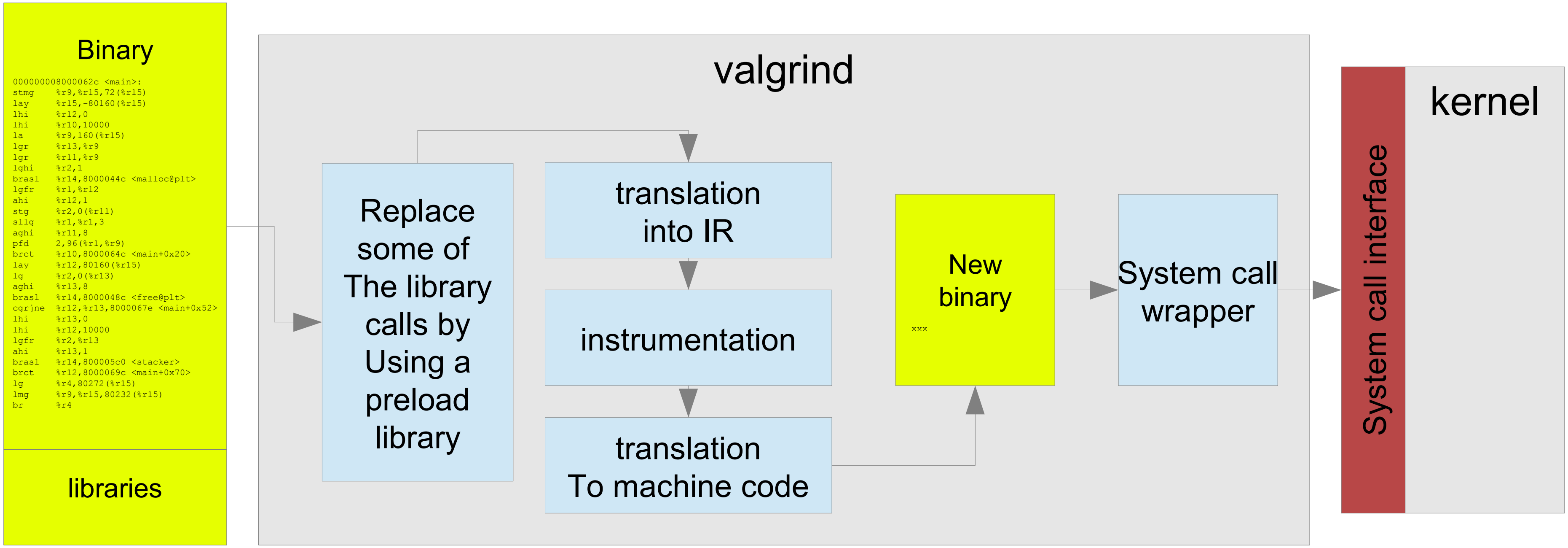
```
# Baseline  Delta                                 Symbol
# ........ ..........  .................... ......
#
     12.14%      +8.07%  [kernel.kallsyms]    [k] lock_acquire
      8.96%      +5.50%  [kernel.kallsyms]    [k] lock_release
      4.83%      +0.38%  reaim                [.] add_long
      4.22%      +0.41%  reaim                [.] add_int
      4.10%      +2.49%  [kernel.kallsyms]    [k] lock_acquired
      3.17%      +0.38%  libc-2.11.3.so       [.] msort_with_tmp
      3.56%      -0.37%  reaim                [.] string_rtns_1
      3.04%      -0.38%  libc-2.11.3.so       [.] strncat
```

Valgrind

- Characteristics: In depth memory analysis
- Objective: Find out where memory is leaked, sub-optimally cached, ...
- Usage: `valgrind [program]`
- Shows
  - Memory leaks
  - Cache profiling
  - Heap profiling
- Hints
  - Runs on binaries, therefore easy to use
  - Debug Info not required but makes output more useful

Valgrind Overview

- Technology is based on a JIT (Just-in-Time Compiler)
- Intermediate language allows debugging instrumentation



```
000000008000062c <main>:
stmg    %r9,%r15,72(%r15)
lay     %r15,-80160(%r15)
lhi     %r12,0
lhi     %r10,10000
la      %r9,160(%r15)
lgr     %r13,%r9
lgr     %r11,%r9
lghi    %r2,1
brasl   %r14,8000044c <malloc@plt>
lgfr    %r1,%r12
ahi     %r12,1
stg     %r2,0(%r11)
sllg    %r1,%r1,3
aghi    %r11,8
pfd     2,96(%r1,%r9)
brct    %r10,8000064c <main+0x20>
lay     %r12,80160(%r15)
lg      %r2,0(%r13)
aghi    %r13,8
brasl   %r14,8000048c <free@plt>
cgrjne  %r12,%r13,8000067e <main+0x52>
lhi     %r13,0
lhi     %r12,10000
lgfr    %r2,%r13
ahi     %r13,1
brasl   %r14,800005c0 <stacker>
brct    %r12,8000069c <main+0x70>
lg      %r4,80272(%r15)
lmg     %r9,%r15,80232(%r15)
br      %r4
```

Valgrind – sample output of “memcheck”

```
# valgrind buggy_program
==2799== Memcheck, a memory error detector
==2799== Copyright (C) 2002-2010, and GNU GPL'd, by Julian Seward et al.
==2799== Using Valgrind-3.6.1 and LibVEX; rerun with -h for copyright info
==2799== Command: buggy_program
==2799==
==2799== HEAP SUMMARY:
==2799==     in use at exit: 200 bytes in 2 blocks
==2799==   total heap usage: 2 allocs, 0 frees, 200 bytes allocated
==2799==
==2799== LEAK SUMMARY:
==2799==    definitely lost: 100 bytes in 1 blocks
==2799==    indirectly lost: 0 bytes in 0 blocks
==2799==      possibly lost: 0 bytes in 0 blocks
==2799==    still reachable: 100 bytes in 1 blocks
==2799==         suppressed: 0 bytes in 0 blocks
==2799== Rerun with --leak-check=full to see details of leaked memory
[...]
```

- Important parameters:
  - --leak-check=full
  - --track-origins=yes

Valgrind - Tools

- Several tools
  - Memcheck (default): detects memory and data flow problems
  - Cachegrind: cache profiling
  - Massif: heap profiling
  - Helgrind: thread debugging
  - DRD: thread debugging
  - None: no debugging (for valgrind JIT testing)
  - Callgrind: codeflow and profiling
- Tool can be selected with –tool=xxx
- System z support since version 3.7 (SLES-11-SP2)
- Backports into 3.6 (SLES-10-SP4, RHEL6-U1)

IPTRAF

- Characteristics: Live information on network devices / connections
- Objective: Filter and format network statistics
- Usage: `iptraf`

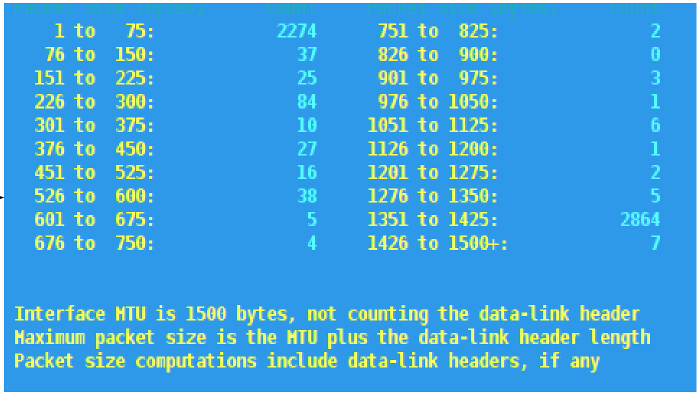
- Shows
  - Details per Connection / Interface
  - Statistical breakdown of ports / packet sizes
  - LAN station monitor

- Hints
  - Can be used for background logging as well
    - Use SIGUSR1 and logrotate to handle the growing amount of data
  - Knowledge of packet sizes important for the right tuning

iptraf

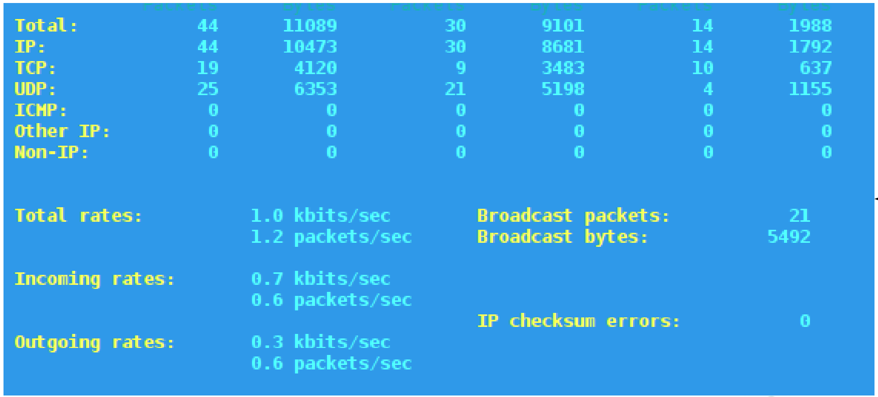
- Questions that usually can be addressed
  - Connection behavior overview
  - Do you have peaks in your workload characteristic
  - Who does your host really communicate with
- Comparison to wireshark
  - Not as powerful, but much easier and faster to use
  - Lower overhead and no sniffing needed (often prohibited)

Packet sizes



```
 Packet Size (bytes)       Count     Packet Size (bytes)       Count
    1 to   75:              2274       751 to  825:                2
   76 to  150:                37       826 to  900:                0
  151 to  225:                25       901 to  975:                3
  226 to  300:                84       976 to 1050:                1
  301 to  375:                10      1051 to 1125:                6
  376 to  450:                27      1126 to 1200:                1
  451 to  525:                16      1201 to 1275:                2
  526 to  600:                38      1276 to 1350:                5
  601 to  675:                 5      1351 to 1425:             2864
  676 to  750:                 4      1426 to 1500+:               7


 Interface MTU is 1500 bytes, not counting the data-link header
 Maximum packet size is the MTU plus the data-link header length
 Packet size computations include data-link headers, if any
```

IF details



```
                  Packets      Bytes     Packets      Bytes     Packets      Bytes
 Total:                44      11089          30       9101          14       1988
 IP:                   44      10473          30       8681          14       1792
 TCP:                  19       4120           9       3483          10        637
 UDP:                  25       6353          21       5198           4       1155
 ICMP:                  0          0           0          0           0          0
 Other IP:              0          0           0          0           0          0
 Non-IP:                0          0           0          0           0          0


 Total rates:            1.0 kbits/sec          Broadcast packets:          21
                         1.2 packets/sec        Broadcast bytes:          5492

 Incoming rates:         0.7 kbits/sec
                         0.6 packets/sec
                                                IP checksum errors:          0
 Outgoing rates:         0.3 kbits/sec
                         0.6 packets/sec
```

Tracepoints (Events)

- Characteristics: Complex interface, but a vast source of information
- Objective: In kernel latency and activity insights
- Usage: Access debugfs mount point /tracing

- Shows
  - Timestamp and activity name
  - Tracepoints can provide event specific context data
  - Infrastructure adds extra common context data like cpu, preempts depth, ...

- Hints
  - Very powerful and customizable, there are hundreds of tracepoints
    - Some tracepoints have tools to be accessed “perf sched”, “blktrace” both base on them
    - Others need custom postprocessing
  - There are much more things you can handle with tracepoints check out Kernel Documentation/trace/tracepoint-analysis.txt (via perf stat)

    Kernel Documentation/trace/events.txt (custom access)

Tracepoints – example I/III

- Here we use custom access since there was tool
  - We searched for 1.2ms extra latency
    - Target is it lost in HW, Userspace, Kernel or all of them
  - Workload was a simple 1 connection 1 byte←→1 byte load
  - Call “`perf list`” for a list of currently supported tracepoints
  - We used the following tracepoints

Abbreviation	Tracepoint	Meaning
R	netif_receive_skb	low level receive
P	napi_poll	napi work related to receive
Q	net_dev_queue	enqueue in the stack
S	net_dev_xmit	low level send

Tracepoints – example II/III

- (Simplified) Script
  - # full versions might tune buffer sizes, check files, and so on

```
echo latency-format > /sys/kernel/debug/tracing/trace_options            # enable tracing type
echo net:* >> /sys/kernel/debug/tracing/set_event                        # select specific events
echo napi:* >> /sys/kernel/debug/tracing/set_event                       # “
echo "name == ${dev}" > /sys/kernel/debug/tracing/events/net/filter      # set filters
echo "dev_name == ${dev}" > /sys/kernel/debug/tracing/events/napi/filter # “
cat /sys/kernel/debug/tracing/trace >> ${output}                         # synchronous
echo !*:* > /sys/kernel/debug/tracing/set_event                          # disable tracing
```

- Output

```
#                _------=> CPU#
#               / _-----=> irqs-off
#              | / _----=> need-resched
#              || / _---=> hardirq/softirq
#              ||| / _--=> preempt-depth
#              |||| /     delay
#  cmd     pid ||||| time  |   caller
#     \   /    |||||  \    |   /
   <...>-24116 0..s. 486183281us+: net_dev_xmit: dev=eth5 skbaddr=0000000075b7e3e8 len=67 rc=0
  <idle>-0     0..s. 486183303us+: netif_receive_skb: dev=eth5 skbaddr=000000007ecc6e00 len=53
  <idle>-0     0.Ns. 486183306us+: napi_poll: napi poll on napi struct 000000007d2479a8 fordevice eth
   <...>-24116 0..s. 486183311us+: net_dev_queue: dev=eth5 skbaddr=0000000075b7e3e8 len=67
   <...>-24116 0..s. 486183317us+: net_dev_xmit: dev=eth5 skbaddr=0000000075b7e3e8 len=67 rc=0
```

Tracepoints – example III/III

- Example postprocessed

```
               SUM        COUNT      AVERAGE      MIN     MAX   STD-DEV
P2Q:    8478724     1572635         5.39        4    2140      7.41
Q2S:   12188675     1572638         7.65        3      71      4.89
S2R:   38562294     1572636        24.42        1    2158      9.08
R2P:    4197486     1572633         2.57        1      43      2.39
SUM:   63427179     1572635        40.03
               SUM        COUNT      AVERAGE      MIN     MAX   STD-DEV
P2Q:    7191885     1300897         5.53        4     171      1.31
Q2S:   10622270     1300897         8.17        3      71      5.99
S2R:   32078550     1300898        24.66        2     286      5.88
R2P:    3707814     1300897         2.85        1     265      2.59
SUM:   53600519     1300897        41.20
```

- Confirmed that most of the 1.2 ms were list in our image
- Confirmed that it was not at/between a specific function
  - Eventually it was an interrupt locality issue causing bad caching

Orientation - where to go

Tool	1st overview	CPU consumption	latencies	Hot spots	Disk I/O	Memory	Network
top / ps	x	x					
sysstat	x	x			x	x	
vmstat	x	x				x	
iostat	x				x		
dasdstat					x		
scsistat					x		
netstat	x						x
htop / dstat / pidstat	x	x	x		x		
irqstats	x	x	x				
strace / ltrace			x				
hyptop		x					
profiling		x		x			
blktrace					x		
valgrind						x	
iptraf	**x**						x
tracepoints			x	x	x	x	x

Questions

- Further information is available at
  - Linux on System z – Tuning hints and tips
    http://www.ibm.com/developerworks/linux/linux390/perf/index.html
  - Live Virtual Classes for z/VM and Linux
    http://www.vm.ibm.com/education/lvc/

IBM

Christian Ehrhardt
Linux on System z
Performance Evaluation

Research & Development
Schönaicher Strasse 220
71032 Böblingen, Germany

ehrhardt@de.ibm.com

Backup

- Basic Tools
  - vmstat
  - systat
  - iostat
  - dasdstat / scsi statistics
  - netstat
  - ss
  - top / ps
- Further complex tools (no slides)
  - ftrace
  - systemtap

Valgrind - Good to know

- No need to recompile, but
    - Better results with debug info
    - Gcc option -O0 might result in more findings(the compiler might hide some errors)
    - Gcc option -fno-builtin might result in more findings
- --trace-children=yes will also debug child processes
- Setuid programs might cause trouble
    - Valgrind is the process container (→ no setuid)
    - Possible solution: remove setuid and start as the right user, check documentation for other ways
- The program will be slower
    - 5-30 times slower for memcheck

vmstat

- Characteristics: Easy to use, high-level information
- Objective: First and fast impression of the current state
- Usage: vmstat [interval in sec]

- Output sample:

```
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
 2  2      0 4415152  64068 554100    0    0     4 63144  350   55 29 64  0  3  4
 3  0      0 4417632  64832 551272    0    0     0   988  125   60 32 67  0  0  1
 3  1      0 4415524  68100 550068    0    0     0  5484  212   66 31 64  0  4  1
 3  0      0 4412672  68856 552408    0    0     0    40  109   48 32 68  0  0  0
 3  0      0 4414408  69656 549544    0    0     0     0  103   36 32 68  0  0  0
 3  0      0 4411184  70500 552312    0    0     0     0  104   37 33 67  0  0  0
 3  0      0 4411804  72188 549592    0    0     0  8984  230   42 32 67  0  0  1
 3  0      0 4405232  72896 555592    0    0     0    16  105   52 32 68  0  0  0
```

- Shows
  - Data per time interval
  - CPU utilization
  - Disk I/O
  - Memory usage/Swapping

- Hints
  - Shared memory usage is listed under 'cache'

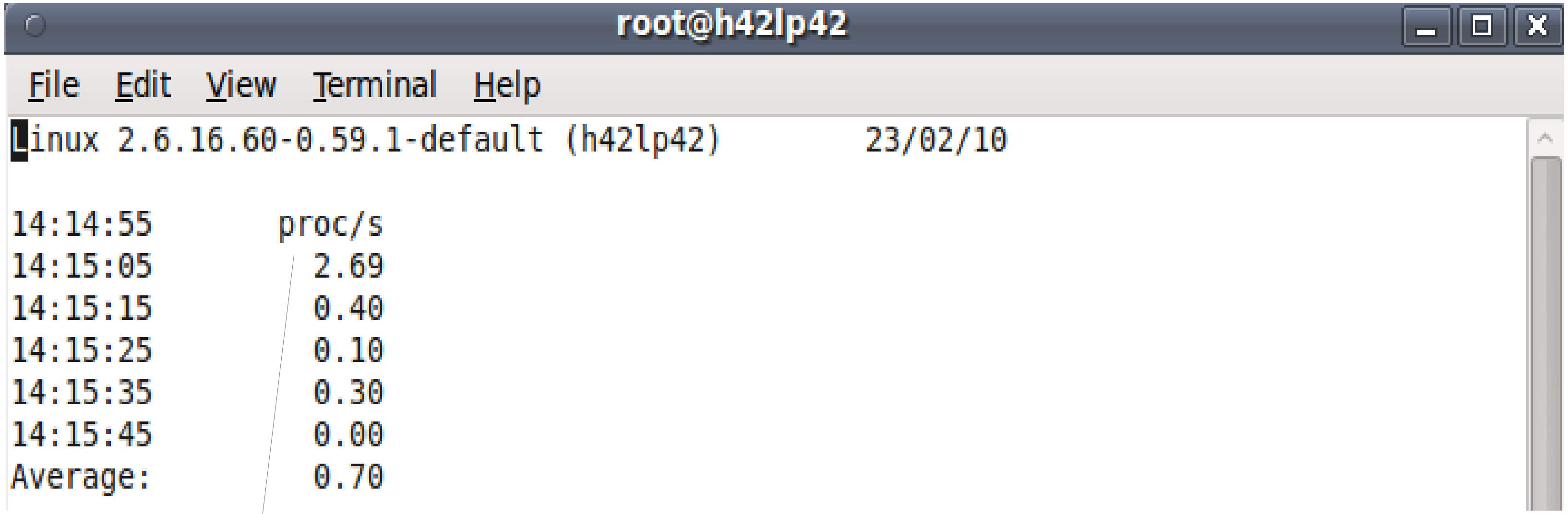
sadc/sar

- Characteristics: Very comprehensive, statistics data on device level
- Objective: Suitable for permanent system monitoring and detailed analysis
- Usage (recommended):
  - monitor /usr/lib64/sa/sadc -d [interval in sec] [outfile]
  - view sar -A -f [outfile]

- Shows
  - CPU utilization
  - Disk I/O overview and on device level
  - Network I/O and errors on device level
  - Memory usage/Swapping
  - … and much more
  - Reports statistics data over time and creates average values for each item

- Hints
  - Specify -d parameter to sadc to include disk device statistics (increase size of outfile)
  - Shared memory is listed under 'cache'
  - [outfile] is a binary file, which contains all values. It is formatted using sar
    - enables the creation of item specific reports, e.g. network only
    - enables the specification of a start and end time → time of interest

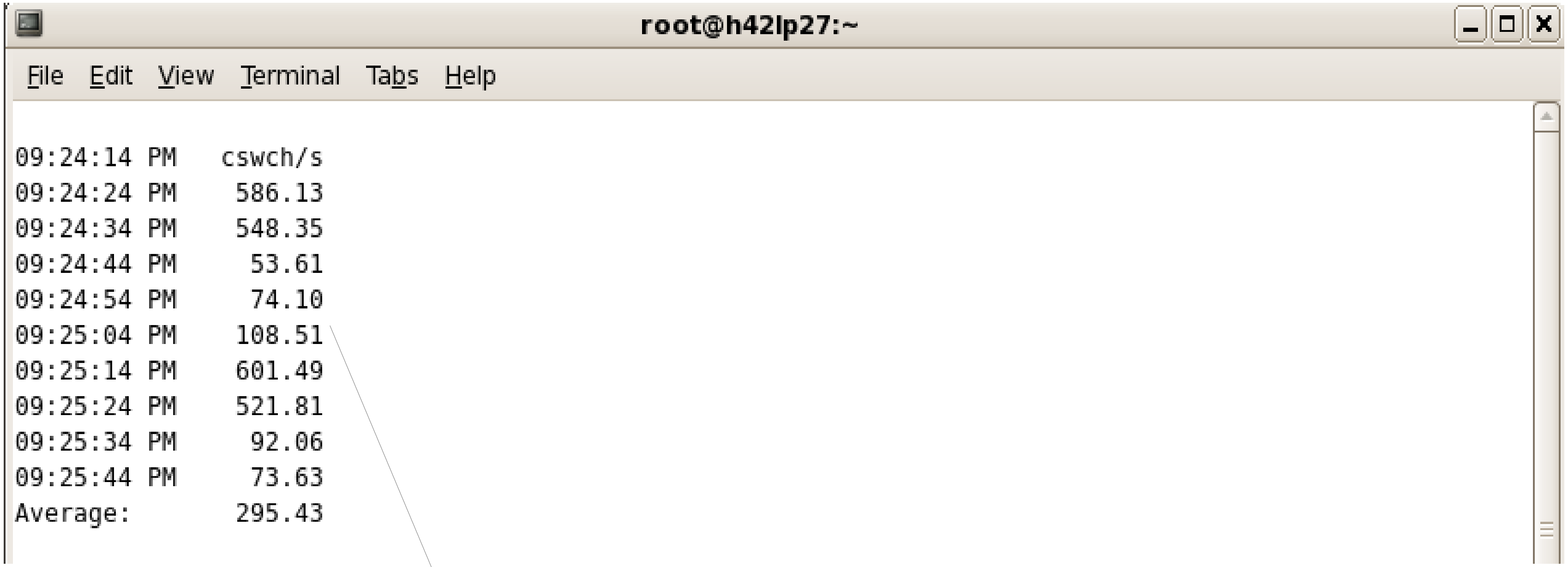
SAR - Processes created



```
Linux 2.6.16.60-0.59.1-default (h42lp42)        23/02/10

14:14:55        proc/s
14:15:05          2.69
14:15:15          0.40
14:15:25          0.10
14:15:35          0.30
14:15:45          0.00
Average:          0.70
```

Processes created per second usually small except during startup.
If constantly at a high rate your application likely has an issue.
Be aware – the numbers scale with your system size and setup.

SAR - Context Switch Rate

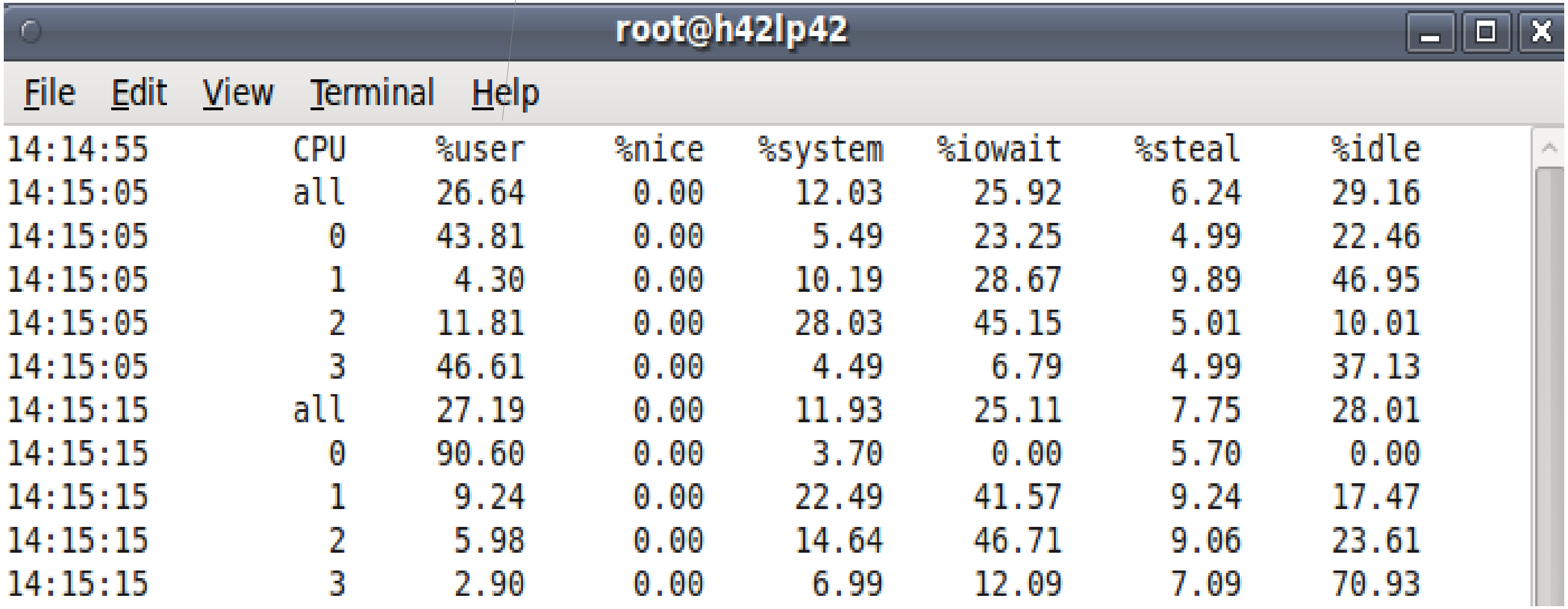


```
09:24:14 PM   cswch/s
09:24:24 PM    586.13
09:24:34 PM    548.35
09:24:44 PM     53.61
09:24:54 PM     74.10
09:25:04 PM    108.51
09:25:14 PM    601.49
09:25:24 PM    521.81
09:25:34 PM     92.06
09:25:44 PM     73.63
Average:       295.43
```

Context switches per second usually < 1000 per cpu except during startup or while running a benchmark if > 10000 your application might have an issue.

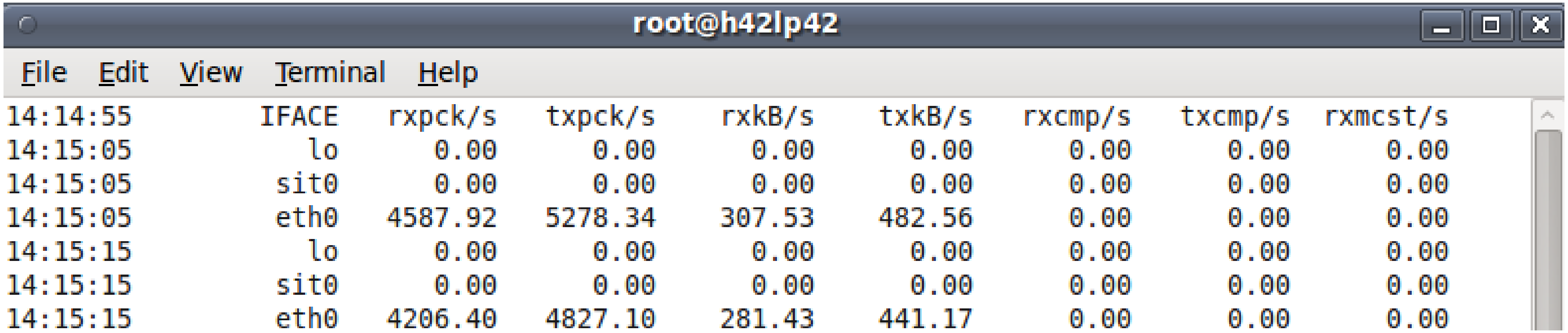
SAR - CPU utilization

Per CPU values:
watch out for
- system time (kernel)
- user (applications)
- irq/soft (kernel, interrupt handling)
- idle (nothing to do)
- iowait time (runnable but waiting for I/O)
- steal time (runnable but utilized somewhere else)



```
14:14:55        CPU     %user     %nice   %system   %iowait    %steal     %idle
14:15:05        all     26.64      0.00     12.03     25.92      6.24     29.16
14:15:05          0     43.81      0.00      5.49     23.25      4.99     22.46
14:15:05          1      4.30      0.00     10.19     28.67      9.89     46.95
14:15:05          2     11.81      0.00     28.03     45.15      5.01     10.01
14:15:05          3     46.61      0.00      4.49      6.79      4.99     37.13
14:15:15        all     27.19      0.00     11.93     25.11      7.75     28.01
14:15:15          0     90.60      0.00      3.70      0.00      5.70      0.00
14:15:15          1      9.24      0.00     22.49     41.57      9.24     17.47
14:15:15          2      5.98      0.00     14.64     46.71      9.06     23.61
14:15:15          3      2.90      0.00      6.99     12.09      7.09     70.93
```

SAR - Network traffic

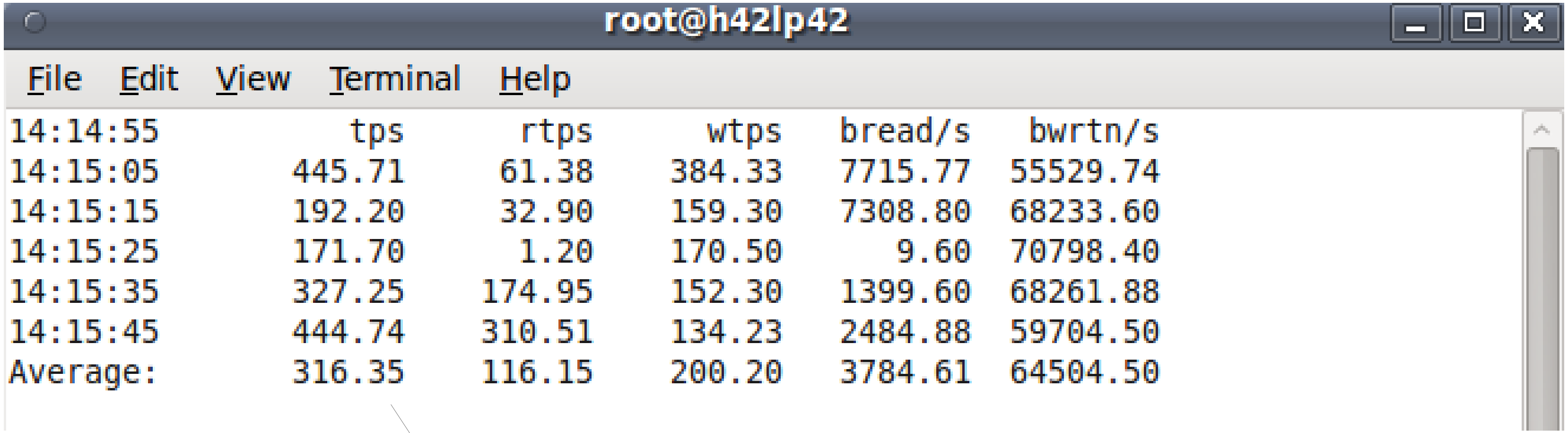


```
14:14:55        IFACE   rxpck/s   txpck/s    rxkB/s    txkB/s   rxcmp/s   txcmp/s  rxmcst/s
14:15:05           lo      0.00      0.00      0.00      0.00      0.00      0.00      0.00
14:15:05         sit0      0.00      0.00      0.00      0.00      0.00      0.00      0.00
14:15:05         eth0   4587.92   5278.34    307.53    482.56      0.00      0.00      0.00
14:15:15           lo      0.00      0.00      0.00      0.00      0.00      0.00      0.00
14:15:15         sit0      0.00      0.00      0.00      0.00      0.00      0.00      0.00
14:15:15         eth0   4206.40   4827.10    281.43    441.17      0.00      0.00      0.00
```

Per interface statistic of packets/bytes
You can easily derive average packet sizes from that.
Sometimes people expect - and planned for – different sizes.

Has another panel for errors, drops and such events.

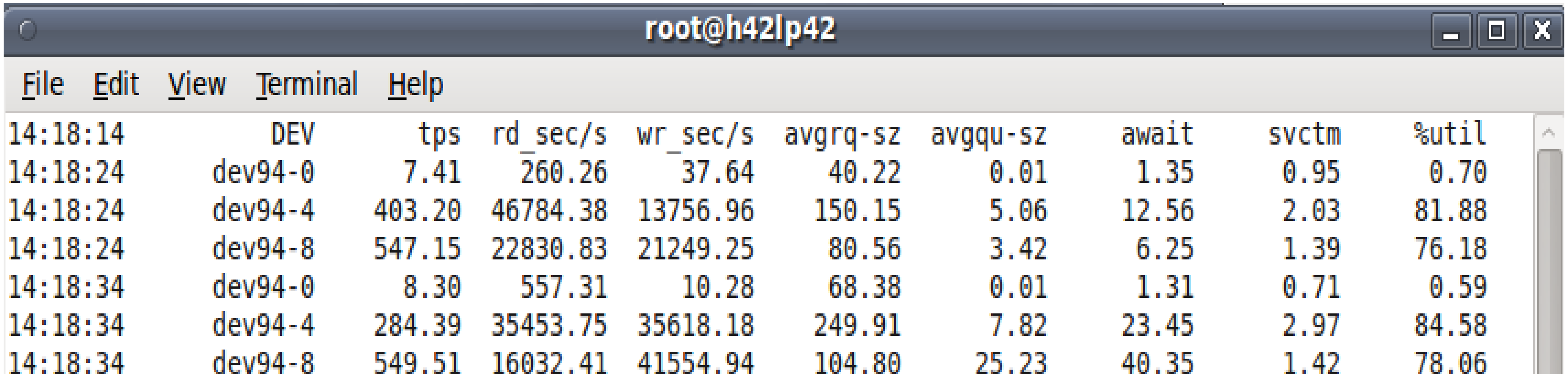
SAR – Disk I/O I – overall



```
14:14:55          tps      rtps      wtps   bread/s   bwrtn/s
14:15:05       445.71     61.38    384.33   7715.77  55529.74
14:15:15       192.20     32.90    159.30   7308.80  68233.60
14:15:25       171.70      1.20    170.50      9.60  70798.40
14:15:35       327.25    174.95    152.30   1399.60  68261.88
14:15:45       444.74    310.51    134.23   2484.88  59704.50
Average:       316.35    116.15    200.20   3784.61  64504.50
```

Overview of
- operations per second
- transferred amount

SAR – Disk I/O II – per device



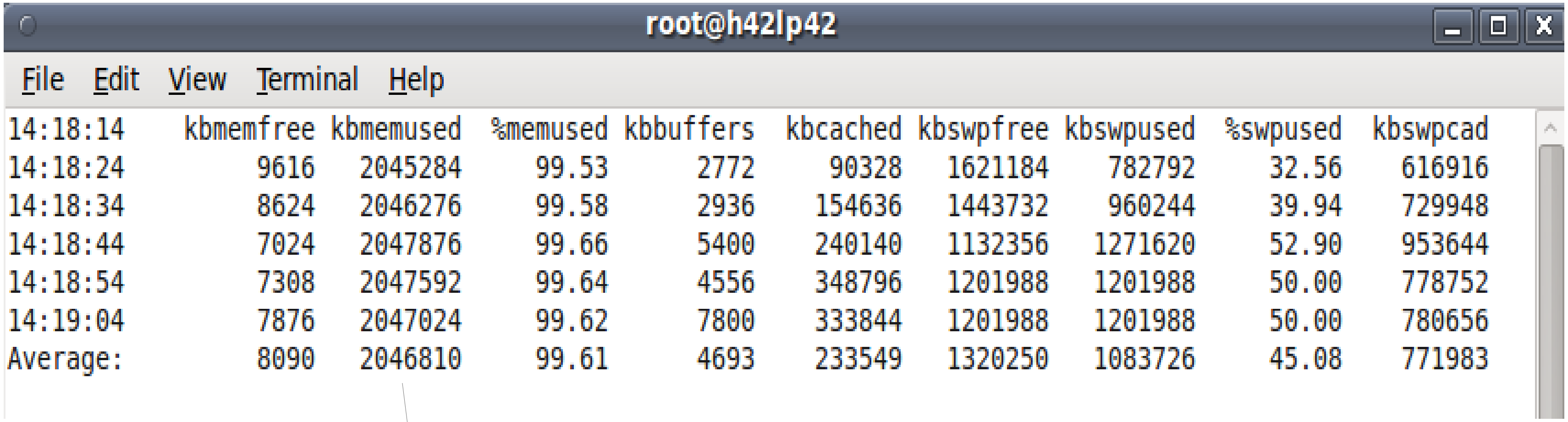
```
14:18:14          DEV       tps  rd_sec/s  wr_sec/s  avgrq-sz  avgqu-sz     await     svctm     %util
14:18:24      dev94-0      7.41    260.26     37.64     40.22      0.01      1.35      0.95      0.70
14:18:24      dev94-4    403.20  46784.38  13756.96    150.15      5.06     12.56      2.03     81.88
14:18:24      dev94-8    547.15  22830.83  21249.25     80.56      3.42      6.25      1.39     76.18
14:18:34      dev94-0      8.30    557.31     10.28     68.38      0.01      1.31      0.71      0.59
14:18:34      dev94-4    284.39  35453.75  35618.18    249.91      7.82     23.45      2.97     84.58
14:18:34      dev94-8    549.51  16032.41  41554.94    104.80     25.23     40.35      1.42     78.06
```

Is your I/O balanced across devices?
Imbalances can indicate issues wit a LV setup.

tps and avgrq-sz combined can be important.
Do they match your sizing assumptions?

Await shows the time the application has to wait.

SAR - Memory statistics - the false friend

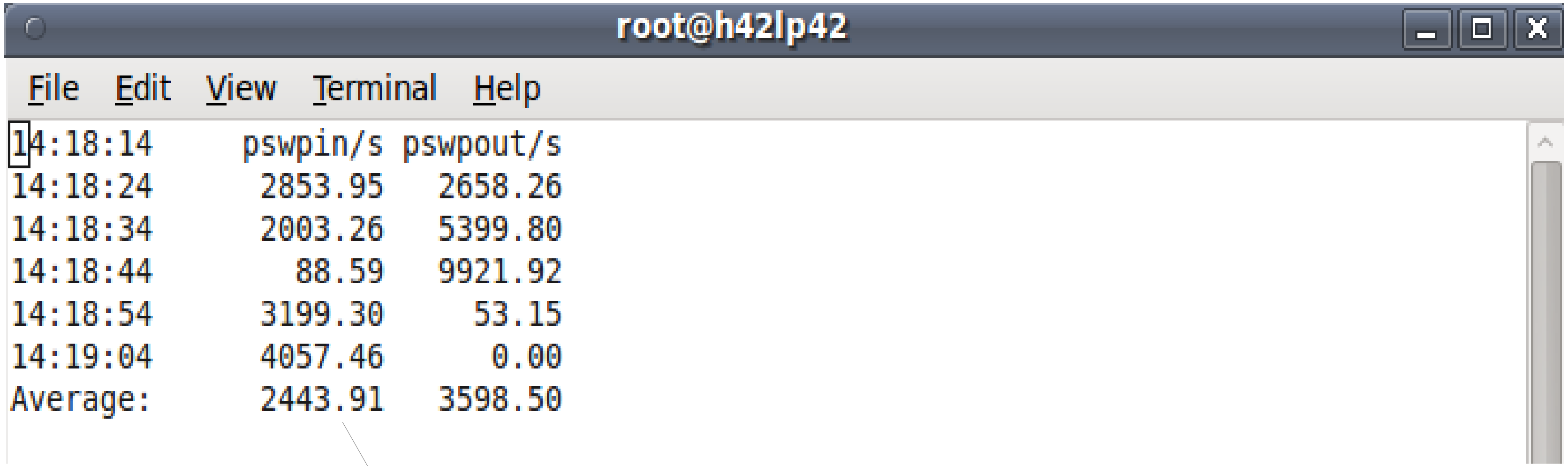


```
14:18:14    kbmemfree kbmemused  %memused kbbuffers  kbcached kbswpfree kbswpused  %swpused  kbswpcad
14:18:24         9616   2045284     99.53      2772     90328   1621184    782792     32.56    616916
14:18:34         8624   2046276     99.58      2936    154636   1443732    960244     39.94    729948
14:18:44         7024   2047876     99.66      5400    240140   1132356   1271620     52.90    953644
14:18:54         7308   2047592     99.64      4556    348796   1201988   1201988     50.00    778752
14:19:04         7876   2047024     99.62      7800    333844   1201988   1201988     50.00    780656
Average:         8090   2046810     99.61      4693    233549   1320250   1083726     45.08    771983
```

Be aware that high %memused and low kbmemfree
is no indication of a memory shortage (common mistake).

Same for swap – to use swap is actually good,
but to access it (swapin/-out) all the time is bad.

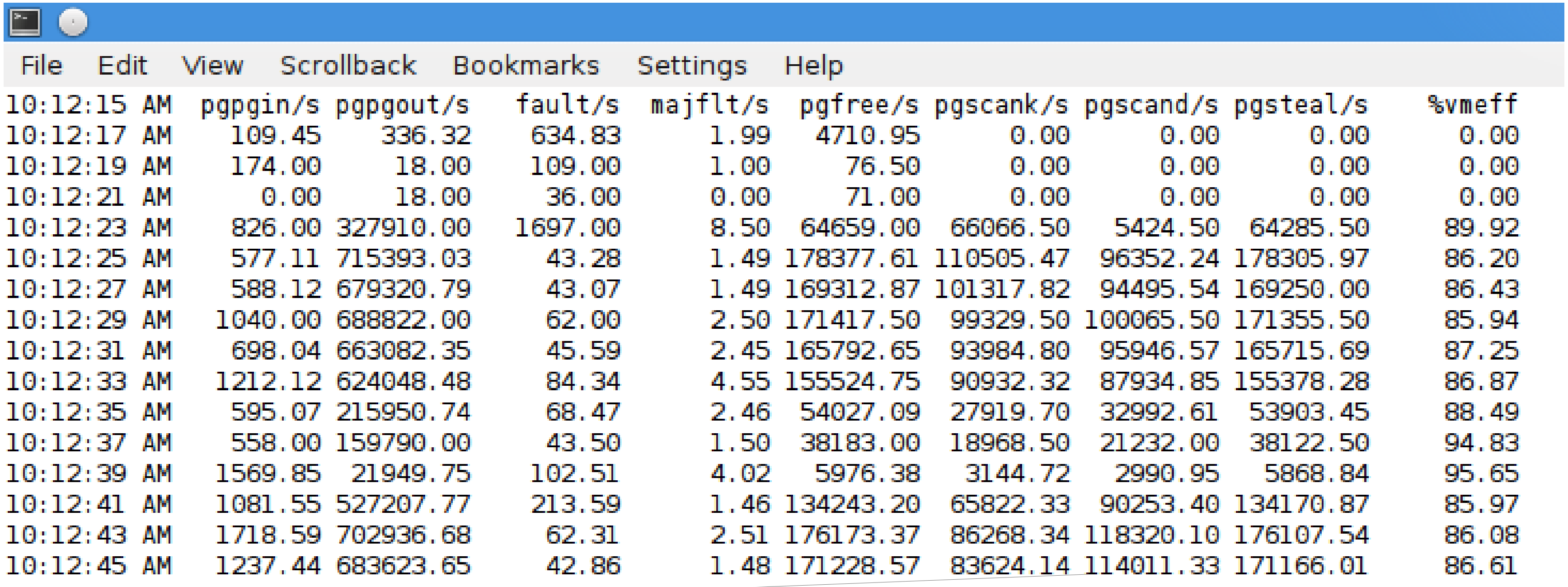
SAR - Memory pressure - Swap



```
14:18:14      pswpin/s pswpout/s
14:18:24       2853.95   2658.26
14:18:34       2003.26   5399.80
14:18:44         88.59   9921.92
14:18:54       3199.30     53.15
14:19:04       4057.46      0.00
Average:       2443.91   3598.50
```

The percentage seen before can be high,
But the swap rate shown here should be low.
Ideally it is near zero after a rampup time.
High rates can indicate memory shortages.

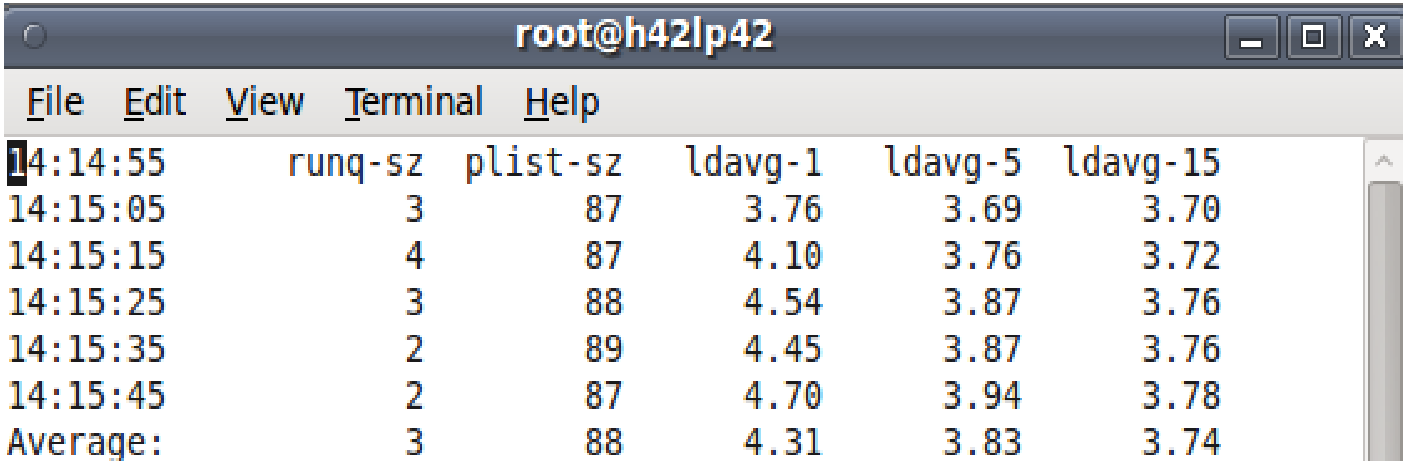
SAR - Memory pressure – faults and reclaim



```
10:12:15 AM  pgpgin/s pgpgout/s   fault/s  majflt/s  pgfree/s pgscank/s pgscand/s pgsteal/s    %vmeff
10:12:17 AM    109.45    336.32    634.83      1.99   4710.95      0.00      0.00      0.00      0.00
10:12:19 AM    174.00     18.00    109.00      1.00     76.50      0.00      0.00      0.00      0.00
10:12:21 AM      0.00     18.00     36.00      0.00     71.00      0.00      0.00      0.00      0.00
10:12:23 AM    826.00 327910.00   1697.00      8.50  64659.00  66066.50   5424.50  64285.50     89.92
10:12:25 AM    577.11 715393.03     43.28      1.49 178377.61 110505.47  96352.24 178305.97     86.20
10:12:27 AM    588.12 679320.79     43.07      1.49 169312.87 101317.82  94495.54 169250.00     86.43
10:12:29 AM   1040.00 688822.00     62.00      2.50 171417.50  99329.50 100065.50 171355.50     85.94
10:12:31 AM    698.04 663082.35     45.59      2.45 165792.65  93984.80  95946.57 165715.69     87.25
10:12:33 AM   1212.12 624048.48     84.34      4.55 155524.75  90932.32  87934.85 155378.28     86.87
10:12:35 AM    595.07 215950.74     68.47      2.46  54027.09  27919.70  32992.61  53903.45     88.49
10:12:37 AM    558.00 159790.00     43.50      1.50  38183.00  18968.50  21232.00  38122.50     94.83
10:12:39 AM   1569.85  21949.75    102.51      4.02   5976.38   3144.72   2990.95   5868.84     95.65
10:12:41 AM   1081.55 527207.77    213.59      1.46 134243.20  65822.33  90253.40 134170.87     85.97
10:12:43 AM   1718.59 702936.68     62.31      2.51 176173.37  86268.34 118320.10 176107.54     86.08
10:12:45 AM   1237.44 683623.65     42.86      1.48 171228.57  83624.14 114011.33 171166.01     86.61
```

Don't trust pgpgin/-out absolute values
Faults populate memory
Major faults need I/O
Scank/s is background reclaim by kswap/flush (modern)
Scand/s is reclaim with a “waiting” allocation
Steal is the amount reclaimed by those scans

SAR - System Load



```
14:14:55        runq-sz  plist-sz   ldavg-1   ldavg-5  ldavg-15
14:15:05              3        87      3.76      3.69      3.70
14:15:15              4        87      4.10      3.76      3.72
14:15:25              3        88      4.54      3.87      3.76
14:15:35              2        89      4.45      3.87      3.76
14:15:45              2        87      4.70      3.94      3.78
Average:              3        88      4.31      3.83      3.74
```

Runqueue size are the currently runnable programs.
It's not bad to have many, but if they exceed the amount
of CPUs you could do more work in parallel.

Plist-sz is the overall number of programs, if that is always
growing you have likely a process starvation or connection issue.

Load average is a runqueue length average for 1/5/15 minutes.

iostat

- Characteristics: Easy to use, information on disk device level
- Objective: Detailed input/output disk statistics
- Usage: iostat -xtdk [interval in sec]

- Shows
  - Throughput
  - Request merging
  - Device queue information
  - Service times

- Hints
  - Most critical parameter often is *await*
    - average time (in milliseconds) for I/O requests issued to the device to be served.
    - includes the time spent by the requests in queue and the time spent servicing them.
  - Also suitable for network file systems

iostat

- Output sample:

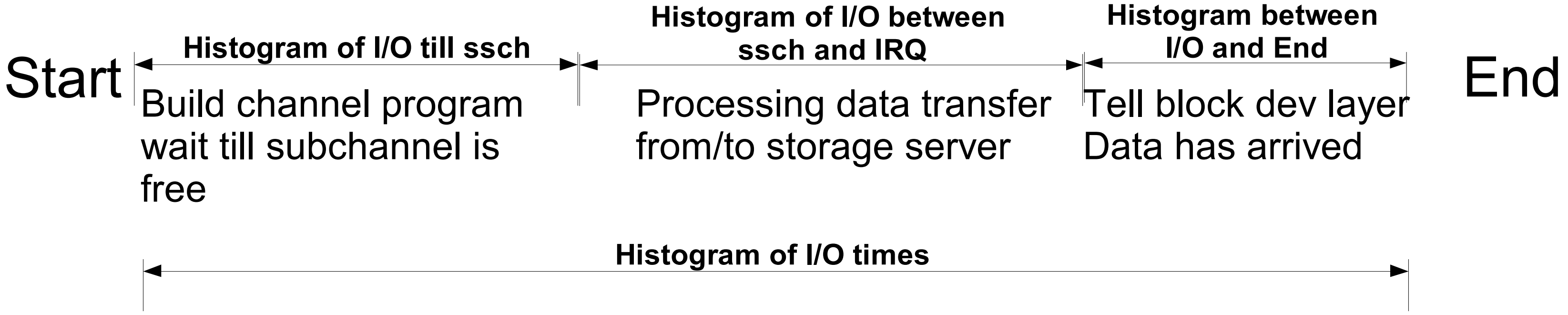
```
Time: 10:56:35 AM
Device:         rrqm/s   wrqm/s     r/s     w/s    rkB/s    wkB/s avgrq-sz avgqu-sz   await  svctm  %util
dasda             0.19     1.45    1.23    0.74    64.43     9.29    74.88     0.01    2.65   0.80   0.16
dasdb             0.02   232.93    0.03    9.83     0.18   975.17   197.84     0.98   99.80   1.34   1.33

Time: 10:56:36 AM
Device:         rrqm/s   wrqm/s     r/s     w/s    rkB/s    wkB/s avgrq-sz avgqu-sz   await  svctm  %util
dasda             0.00     0.00    0.00    0.00     0.00     0.00     0.00     0.00    0.00   0.00   0.00
dasdb             0.00  1981.55    0.00  339.81     0.00  9495.15    55.89     0.91    2.69   1.14  38.83

Time: 10:56:37 AM
Device:         rrqm/s   wrqm/s     r/s     w/s    rkB/s    wkB/s avgrq-sz avgqu-sz   await  svctm  %util
dasda             0.00     0.00    0.00    0.00     0.00     0.00     0.00     0.00    0.00   0.00   0.00
dasdb             0.00  2055.00    0.00  344.00     0.00  9628.00    55.98     1.01    2.88   1.19  41.00
```

DASD statistics

- Characteristics: Easy to use, very detailed
- Objective: Collects statistics of I/O operations on DASD devices
- Usage:
  - enable: echo on > /proc/dasd/statistics
  - show:
    - overall cat /proc/dasd/statistics
    - for individual DASDs tunedasd -P /dev/dasda

New Tool “dasdstat” available to handle that all-in-one

- Shows:
  - various processing times:



Start

Histogram of I/O till ssch

Build channel program wait till subchannel is free

Histogram of I/O between ssch and IRQ

Processing data transfer from/to storage server

Histogram between I/O and End

Tell block dev layer Data has arrived

End

Histogram of I/O times

DASD statistics - report

- Sample:

4KB <= request size < 8 KB

1ms <= response time < 2 ms

```
29432 dasd I/O requests
with 6227424 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    9925    3605    1866    4050    4102     933    2700    2251       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    1283    1249    6351    7496    3658    8583     805       7       0
      0       0       0       0       0       0       0       0       0       0       0       0       0       0       0       0

Histogram of I/O time till ssch
   2314     283      98      34      13       5      16     275     497    8917    5567    4232    7117      60       4       0
      0       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   14018    7189    2402    1031    4758      27       4       3       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
   2733       6    5702    9376    5781     940    1113    3781       0       0       0       0       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    2740     628    1711    1328   23024       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       0
```

- Hints
  - Also shows data per sector

FCP statistics

- Characteristics: Detailed latency information (SLES9 and SLES10)
- Objective: Collects statistics of I/O operations on FCP devices on request base, separate for read/write

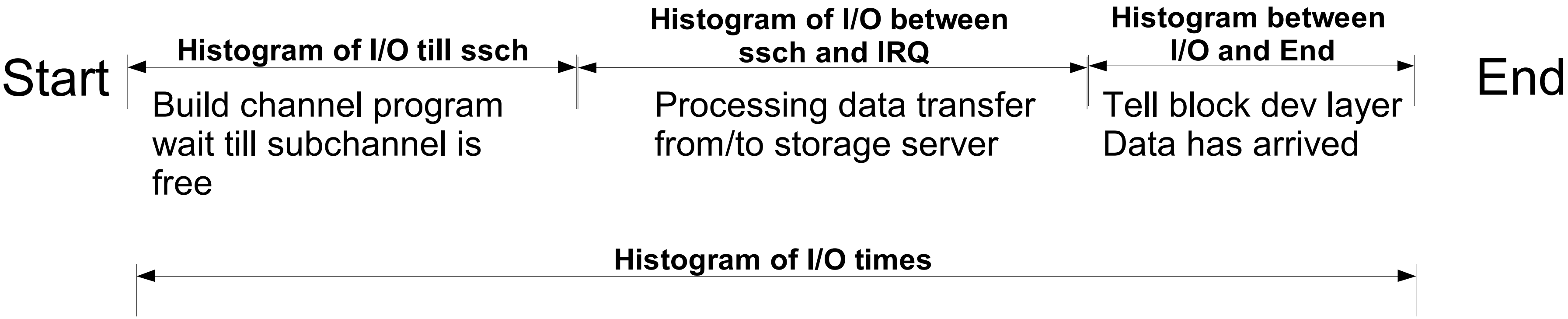
- Usage:
  - enable
    - CONFIG_STATISTICS=y must be set in the kernel config file
    - debugfs is mounted at /sys/kernel/debug/
    - For a certain LUN in directory `/sys/kernel/debug/statistics/zfcp-<device-bus-id>-<WWPN>-<LUN>` issue `echo on=1 > definition` (turn off with on=0, reset with data=reset)
  - view
    - `cat /sys/kernel/debug/statistics/zfcp-<device-bus-id>-<WWPN>-<LUN>/data`

- Hint
  - FCP and DASD statistics are not directly comparable, because in the FCP case many I/O requests can be sent to the same LUN before the first response is given. There is a queue at FCP driver entry and in the storage server

FCP statistics

- Shows:
  - Request sizes in bytes (hexadecimal)
  - Channel latency Time spent in the FCP channel in nanoseconds
  - Fabric latency processing data transfer from/to storage server incl. SAN in nanoseconds
  - (Overall) latencies whole time spent in the FCP layer in milliseconds

  - Calculate the pass through time for the FCP layer as
    `pass through time = overall latency – (channel latency + fabric latency)`
    → Time spent between the Linux device driver and FCP channel adapter inclusive in Hypervisor


Start
Histogram of I/O till ssch
Build channel program wait till subchannel is free
Histogram of I/O between ssch and IRQ
Processing data transfer from/to storage server
Histogram between I/O and End
Tell block dev layer Data has arrived
End
Histogram of I/O times

FCP 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 size 4KB, 1163 occurrences

```
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
...
```

response time <= 1ms

```
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
...
```

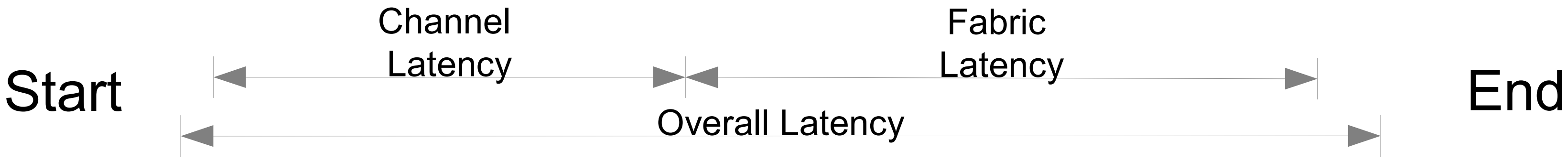
Channel response time <= 32µs
= all below driver

```
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
...
```

Fabric response time <= 1ms
= once leaving the card

FCP statistics explained

- Shows:
  - The channel latency roughly corresponds to the time a request spent in the channel. (µsec)
  - The fabric latency is the time a request spent outside the system z machine. This includes latencies caused by the SAN and the SCSI device (storage server). (µsec)
  - The passthrough latency is the delay caused by QDIO (the FCP transport between Linux device driver and FCP channel adapter) and, if applicable, a hypervisor which makes FCP subchannels available to a hosted Linux system.
  - The passthrough latency can be estimated as
    passthrough latency = overall latency – (channel latency + fabric latency)



netstat

- Characteristics: Easy to use, connection information
- Objective: Lists connections
- Usage: `netstat -eeapn`

- Shows
  - Information about each connection
  - Various connection states

- Hints
  - Inodes and program names are useful to reverse-map ports to applications

netstat -s

- Characteristics: Easy to use, very detailed information
- Objective: Display summary statistics for each protocol
- Usage: `netstat -s`

- Shows
  - Information to each protocol
  - Amount of incoming and outgoing packages
  - Various error states, for example TCP segments retransmitted!

- Hints
  - Shows accumulated values since system start, therefore mostly the differences between two snapshots are needed
  - There is always a low amount of packets in error or resets
  - Retransmits occurring only when the system is sending data
    When the system is not able to receive, then the sender shows retransmits
  - Use sadc/sar to identify the device

netstat -s

- Output sample:

```
Tcp:
  15813 active connections openings
  35547 passive connection openings
  305 failed connection attempts
  0 connection resets received
  6117 connections established
  81606342 segments received
  127803327 segments send out
  288729 segments retransmitted
  0 bad segments received.
  6 resets sent
```

Socket statistics

- Characteristics: Information on socket level
- Objective: Check socket options and weird connection states
- Usage: `ss -aempi`

- Shows
  - Socket options
  - Socket receive and send queues
  - Inode, socket identifiers

- Sample output

```
ss -aempi
 State        Recv-Q Send-Q    Local Address:Port       Peer Address:Port
 LISTEN       0      128                    :::ssh                  :::*
     users:(("sshd",959,4)) ino:7851 sk:ef858000  mem:(r0,w0,f0,t0)
```

- Hints
  - Inode numbers can assist reading strace logs
  - Check long outstanding queue elements

Top

- Characteristics: Easy to use
- Objective: Shows resource usage on process level
- Usage: `top -b -d [interval in sec]  > [outfile]`

- Shows
  - CPU utilization
  - Detailed memory usage

- Hints
  - Parameter -b enables to write the output for each interval into a file
  - Use -p [pid1, pid2,...] to reduce the output to the processes of interest
  - Configure displayed columns using 'f' key on the running top program
  - Use the 'W' key to write current configuration to ~/.toprc
    → becomes the default

top (cont.)

- See ~/.toprc file in backup

- Output sample:

```
top - 11:12:52 up  1:11,  3 users,  load average: 1.21, 1.61, 2.03
Tasks:  53 total,   5 running,  48 sleeping,   0 stopped,   0 zombie
Cpu(s):  3.0%us,  5.9%sy,  0.0%ni, 79.2%id,  9.9%wa,  0.0%hi,  1.0%si,  1.0%st
Mem:   5138052k total,   801100k used,  4336952k free,   447868k buffers
Swap:       88k total,        0k used,       88k free,   271436k cached

 PID USER      PR  NI  VIRT  RES  SHR S %CPU %MEM    TIME+  P SWAP DATA WCHAN     COMMAND
3224 root      18   0  1820  604  444 R  2.0  0.0   0:00.56 0 1216  252 -         dbench
3226 root      18   0  1820  604  444 R  2.0  0.0   0:00.56 0 1216  252 -         dbench
2737 root      16   0  9512 3228 2540 R  1.0  0.1   0:00.46 0 6284  868 -         sshd
3225 root      18   0  1820  604  444 R  1.0  0.0   0:00.56 0 1216  252 -         dbench
3230 root      16   0  2652 1264  980 R  1.0  0.0   0:00.01 0 1388  344 -         top
   1 root      16   0   848  304  256 S  0.0  0.0   0:00.54 0  544  232 select    init
   2 root      RT   0     0    0    0 S  0.0  0.0   0:00.00 0    0    0 migration migration/0
   3 root      34  19     0    0    0 S  0.0  0.0   0:00.00 0    0    0 ksoftirqd ksoftirqd/0
   4 root      10  -5     0    0    0 S  0.0  0.0   0:00.13 0    0    0 worker_th events/0
   5 root      20  -5     0    0    0 S  0.0  0.0   0:00.00 0    0    0 worker_th khelper
```

- Hints
  - virtual memory: VIRT = SWAP + RES unit KB
  - physical memory used: RES = CODE + DATA unit KB
  - shared memory SHR unit KB

Linux ps command

- Characteristics: very comprehensive, statistics data on process level
- Objective: reports a snapshot of the current processes
- Usage

  often recommended: “`ps -eo pid,tid,nlwp,policy,user,tname,ni,pri,psr,sgi_p, stat,wchan:12,start_time,time,pcpu,pmem,vsize,size, rss,share,command`”

  recommended for starters and easier to memorize “`ps axlf`”

```
 PID   TID NLWP POL USER     TTY       NI PRI PSR P STAT WCHAN        START     TIME %CPU %MEM    VSZ    SZ   RSS - COMMAND
 871   871    1 TS  root     ?         -5  29   0 * S<   kauditd_thre 10:01 00:00:00  0.0  0.0      0     0     0 - [kauditd]
2319  2319    1 TS  root     ?          0  23   0 * Ss   poll         10:01 00:00:00  0.0  0.0   2332   264   756 - /sbin/syslog-ng
2322  2322    1 TS  root     ?          0  23   0 * Ss   syslog       10:01 00:00:00  0.0  0.0   1940   376   588 - /sbin/klogd -c 7 -x -x
2324  2324    1 TS  daemon   ?          0  23   0 * Ss   poll         10:01 00:00:00  0.0  0.0   4524   288  1168 - /usr/sbin/slpd
2766  2766    1 TS  root     ?          0  23   0 * Ss   select       10:35 00:00:00  0.0  0.0   9364   720  3136 - sshd: root@pts/1
2768  2768    1 TS  root     pts/1      0  23   0 * Ss   wait4        10:35 00:00:00  0.0  0.0   5140   824  2680 - -bash
2833  2833    1 TS  root     ?          0  23   0 * Ss   select       10:38 00:00:00  0.0  0.0   9512   868  3152 - sshd: root@pts/2
2835  2835    1 TS  root     pts/2      0  23   0 * Ss+  read_chan    10:38 00:00:00  0.0  0.0   5140   824  2644 - -bash
3437  3437    1 TS  root     pts/1      0  23   0 * S+   wait4        11:39 00:00:00  0.0  0.0   1816   248   644 - dbench 3
3438  3438    1 TS  root     pts/1      0  20   0 0 R+   -            11:39 00:00:24 33.1  0.0   1820   252   604 - dbench 3
3439  3439    1 TS  root     pts/1      0  20   0 0 R+   -            11:39 00:00:23 32.8  0.0   1820   252   604 - dbench 3
3440  3440    1 TS  root     pts/1      0  20   0 0 R+   -            11:39 00:00:23 31.8  0.0   1820   252   604 - dbench 3
…
```

- Hints
  - Do not specify blanks inside the -o format string
  - Many more options available

Questions

- Further information is available at
  - Linux on System z – Tuning hints and tips
    http://www.ibm.com/developerworks/linux/linux390/perf/index.html
  - Live Virtual Classes for z/VM and Linux
    http://www.vm.ibm.com/education/lvc/

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