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

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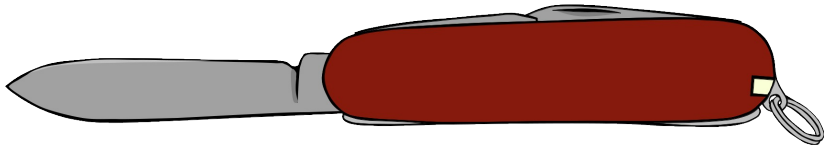
13521 & 13533

SHARE in Boston

Agenda

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



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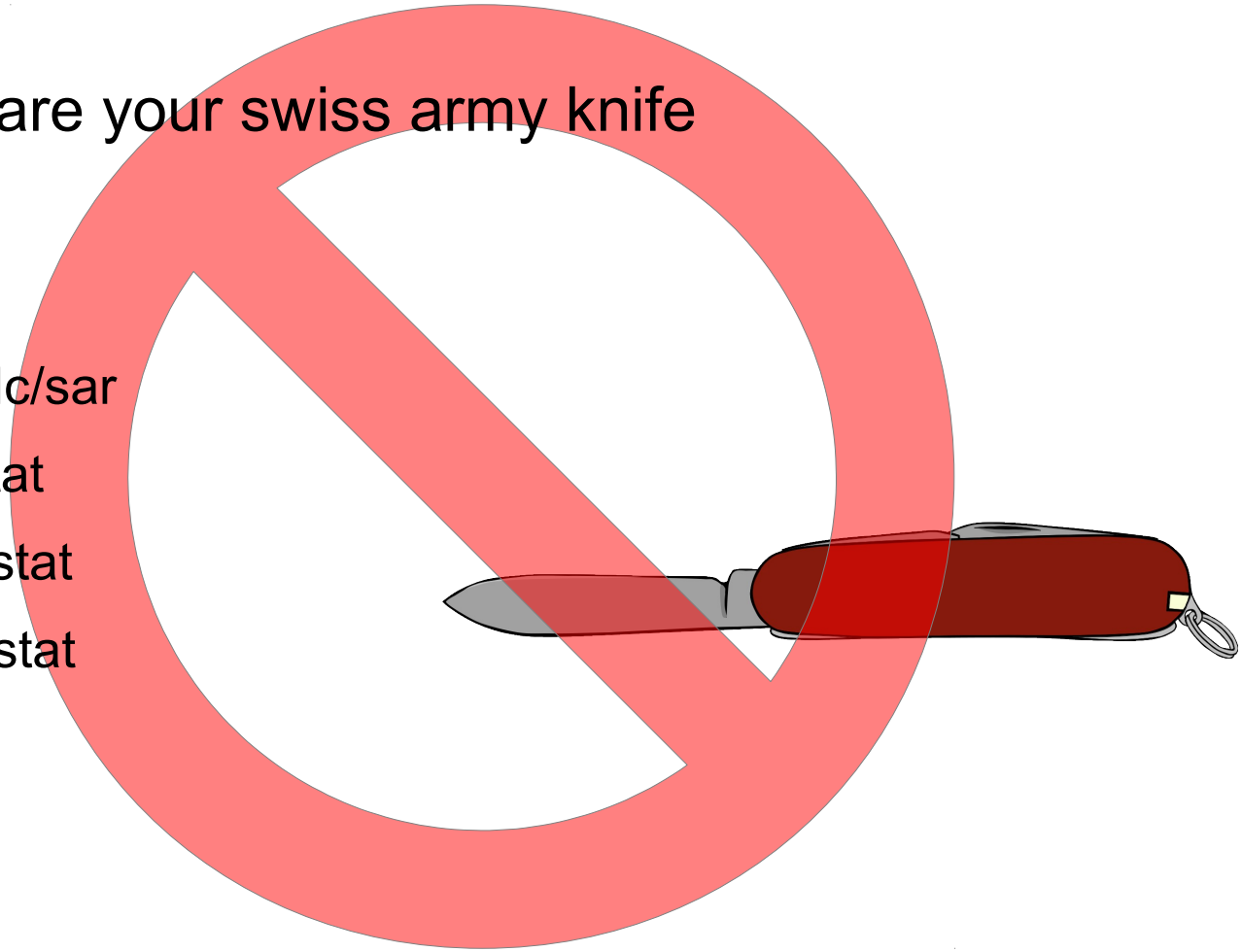
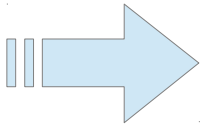


Ready for Takeoff



Agenda

- Your swiss army knife for the complex cases

Part I

- pidstat
- Strace
- Ltrace
- smem
- slabtop
- lsof
- Blktrace
- hyptop
- perf

Part II

- Dstat
- Htop
- Iptraf
- Valgrind
- Irqstats
- Java Health Center
- Java Garbage Collection and Memory visualizer
- Jinsight
- Kernel Tracepoints
- Cachestat

Non-legal Disclaimer

- This is an introduction and cheat sheet
  - To know what is out there
  - What could be useful in which case
  - How could I debug even further
- These descriptions are not full explanations
  - Most tools could get at least 1-2 presentations on their own
  - Don't start using them without reading howtos / man pages
- This is not about monitoring
  - Some tools used to start performance analysis CAN be monitors, but thats not part of the presentation

General thoughts on performance tools

- Things that are always to be considered
  - 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*

General thoughts on performance tools

- 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

  - Try to identify an issue the first time it appears
  - Or even better, avoid it completely

Orientation - where to go

Tool	1st overview	CPU cons.	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 / ss	x						x
htop / dstat / pidstat	x	x	x		x		
irqstats	x	x	x				
strace / ltrace			x				
hyptop		x					
perf		x	x	x	x	x	x
jinsight		x	x				
Health Center	x						
GMVC			x			x	
blktrace					x		
lsof					x		
valgrind						x	
smem						x	
slabtop						x	
iptraf	x						x
tracepoints			x	x	x	x	x

PIDSTAT

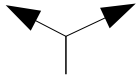
- Characteristics: Easy to use extended per process statistics
- Objective: Identify processes with peak activity
- Usage: `pidstat [-w|-r|-d]`
- Package: RHEL: sysstat SLES: sysstat

- 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

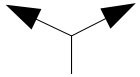
Pidstat examples

```
12:46:18 PM       PID   cswch/s nvcswch/s  Command
12:46:18 PM         3      2.39      0.00  smbd
12:46:18 PM         4      0.04      0.00  sshd
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  sshd
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

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]`
- Package: RHEL: strace SLES: strace

- 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

a lot, slow or failing calls?

shares to rate importance

name (see man pages)

```
strace -cf -p 26802
Process 26802 attached - interrupt to quit
^Process 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]`
- Package: RHEL: ltrace SLES: ltrace

- 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\17\0\0\0\0\0\0\0"..., 680) = 680 <0.000007>
0.000027 write(3, "\0\0\0\0\0\0\17\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}, 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, 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>
```

smem

- Characteristics: Memory usage details per process/mapping
- Objective: Where is userspace memory really used
- Usage: smem -tk -c "pid user command swap vss uss pss rss”
- smem -m -tk -c "map count pids swap vss uss rss pss avgrss avgpss"

- Package: RHEL: n/a SLES: n/a WWW http://www.selenic.com/smem/
- Shows
  - Pid, user, Command or Mapping, Count, Pid
  - Memory usage in categories vss, uss, rss, pss and swap

- Hints
  - Has visual output (pie charts) and filtering options as well
  - No support for huge pages or transparent huge pages (no kernel interface)

smem – process overview

```
smem -tk -c "pid user command swap vss uss pss rss”
```

PID	User	Command	Swap	VSS	USS	PSS	RSS
1860	root	/sbin/agetty -s sclp_line0	0	2.1M	92.0K	143.0K	656.0K
1861	root	/sbin/agetty -s ttysclp0 11	0	2.1M	92.0K	143.0K	656.0K
493	root	/usr/sbin/atd -f	0	2.5M	172.0K	235.0K	912.0K
1882	root	/sbin/udevd	0	2.8M	128.0K	267.0K	764.0K
1843	root	/usr/sbin/crond -n	0	3.4M	628.0K	693.0K	1.4M
514	root	/bin/dbus-daemon --system -	0	3.2M	700.0K	771.0K	1.5M
524	root	/sbin/rsyslogd -n -c 5	0	219.7M	992.0K	1.1M	1.9M
2171	root	./hhhptest	0	5.7G	1.0M	1.2M	3.2M
1906	root	-bash	0	103.8M	1.4M	1.5M	2.1M
2196	root	./hhhptest	0	6.2G	2.0M	2.2M	3.9M
1884	root	sshd: root@pts/0	0	13.4M	1.4M	2.4M	4.2M
1	root	/sbin/init	0	5.8M	2.9M	3.0M	3.9M
2203	root	/usr/bin/python /usr/bin/sm	0	109.5M	6.1M	6.2M	6.9M

- How much of a process is:
  - Swap - Swapped out
  - VSS - Virtually allocated
  - USS - Really unique
  - RSS - Resident
  - PSS - Resident accounting a proportional part of shared memory

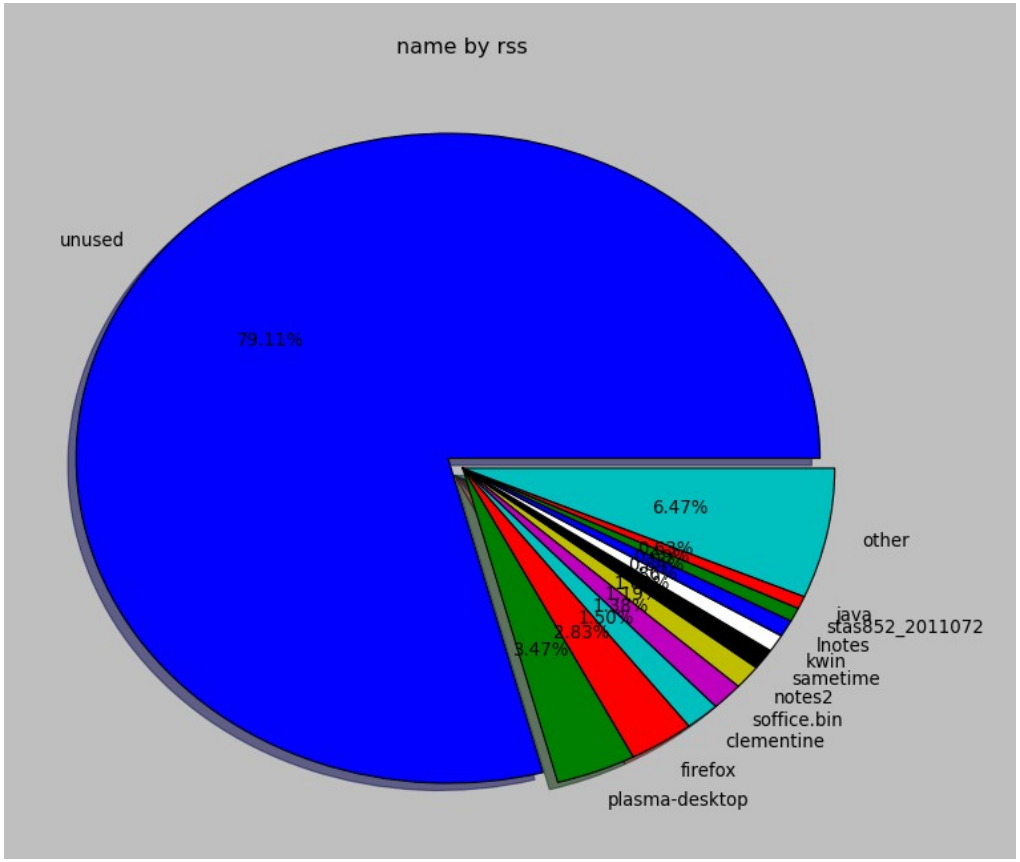
smem – mappings overview

```
smem -m -tk -c "map count pids swap vss uss rss pss avgrss avgpss"

Map                                    Count  PIDs      Swap       VSS       USS       RSS       PSS   AVGRSS   AVGPSS
[stack:531]                                1     1         0      8.0M         0         0         0        0        0
[vdso]                                    25    25         0    200.0K         0    132.0K         0     5.0K        0
/dev/zero                                  2     1         0      2.5M      4.0K      4.0K      4.0K     4.0K     4.0K
/usr/lib64/sasl2/libsasldb.so.2.0.23       2     1         0     28.0K      4.0K      4.0K      4.0K     4.0K     4.0K
/bin/dbus-daemon                           3     1         0    404.0K    324.0K    324.0K    324.0K   324.0K   324.0K
/usr/sbin/sshd                             6     2         0      1.2M    248.0K    728.0K    488.0K   364.0K   244.0K
/bin/systemd                               2     1         0    768.0K    564.0K    564.0K    564.0K   564.0K   564.0K
/bin/bash                                  2     1         0      1.0M    792.0K    792.0K    792.0K   792.0K   792.0K
[stack]                                   25    25         0      4.1M    908.0K    976.0K    918.0K    39.0K    36.0K
/lib64/libc-2.14.1.so                     75    25         0     40.8M    440.0K      9.3M      1.2M   382.0K    48.0K
/lib64/libcrypto.so.1.0.0j                 8     4         0      7.0M    572.0K      2.0M      1.3M   501.0K   321.0K
[heap]                                    16    16         0      8.3M      6.4M      6.9M      6.6M   444.0K   422.0K
<anonymous>                              241    25         0     55.7G     20.6M     36.2M     22.3M     1.4M   913.0K
```

- How much of a mapping is:
  - Swap - Swapped out
  - VSS - Virtually allocated
  - USS - Really unique
  - RSS - Resident
  - PSS - Resident accounting a proportional part of shared memory
  - Averages as there can be multiple mappers

smem - visualizations



- Not often needed, but handy for discussions

slabtop

- Characteristics: live profiling of kernel memory pools
- Objective: Analyze kernel memory consumption
- Usage: `slabtop`
- Package: RHEL: procps SLES: procps

- Shows
  - Active / Total object number/size
  - Objects per Slab
  - Object Name and Size
  - Objects per Slab

- Hints
  - -o is one time output e.g. to gather debug data
  - Despite slab/slob/slub in kernel its always slabtop

Slabtop - example

```
 Active / Total Objects (% used)    : 2436408 / 2522983 (96.6%)
 Active / Total Slabs (% used)      : 57999 / 57999 (100.0%)
 Active / Total Caches (% used)     : 75 / 93 (80.6%)
 Active / Total Size (% used)       : 793128.19K / 806103.80K (98.4%)
 Minimum / Average / Maximum Object : 0.01K / 0.32K / 8.00K

  OBJS ACTIVE  USE OBJ SIZE  SLABS OBJ/SLAB CACHE SIZE NAME
578172 578172 100%    0.19K  13766       42    110128K dentry
458316 458316 100%    0.11K  12731       36     50924K sysfs_dir_cache
368784 368784 100%    0.61K   7092       52    226944K proc_inode_cache
113685 113685 100%    0.10K   2915       39     11660K buffer_head
113448 113448 100%    0.55K   1956       58     62592K inode_cache
111872  44251  39%    0.06K   1748       64      6992K kmalloc-64
 54688  50382  92%    0.25K   1709       32     13672K kmalloc-256
 40272  40239  99%    4.00K   5034        8    161088K kmalloc-4096
 39882  39882 100%    0.04K    391      102      1564K ksm_stable_node
 38505  36966  96%    0.62K    755       51     24160K shmem_inode_cache
 37674  37674 100%    0.41K    966       39     15456K dm_rq_target_io
```

- How is kernel memory managed by the sl[auo]b allocator used
  - Named memory pools or Generic kmalloc pools
  - Active/total objects and their size
  - growth/shrinks of caches due to workload adaption

lsof

- Characteristics: list of open files plus extra details
- Objective: which process accesses which file in which mode
- Usage: `lsof +fg`
- Package: RHEL: lsof SLES: lsof

- Shows
  - List of files including sockets, directories, pipes
  - User, Command, Pid, Size, Device
  - File Type and File Flags

- Hints
  - +fg reports file flags which can provide a good cross check opportunity

lsof - example

```
COMMAND     PID   TID   USER   FD      TYPE         FILE-FLAG              DEVICE  SIZE/OFF       NODE NAME
crond     16129         root  mem       REG                                94,1    165000     881893
/usr/lib64/ld-2.16.so
crond     16129         root    0r      CHR              LG                1,3       0t0       2051 /dev/null
crond     16129         root    1u     unix              RW 0x0000001f1ba02000       0t0     106645 socket
crond     16129         root    2u     unix              RW 0x0000001f1ba02000       0t0     106645 socket
crond     16129         root    4r  a_inode         0x80000                0,9         0       6675 inotify
crond     16129         root    5u     unix        RW,0x80000 0x0000001f5d3ad000       0t0      68545 socket
dd        17617         root  cwd       DIR                                94,1      4096      16321 /root
dd        17617         root  rtd       DIR                                94,1      4096          2 /
dd        17617         root  txt       REG                                94,1     70568    1053994 /usr/bin/dd
dd        17617         root  mem       REG                                94,1    165000     881893
/usr/lib64/ld-2.16.so
dd        17617         root    0r      CHR              LG                1,9       0t0       2055 /dev/urandom
dd        17617         root    1w      REG          W,DIR,LG               94,1   5103616      16423 /root/test
dd        17617         root    2u      CHR             RW,LG             136,2       0t0          5 /dev/pts/2
```

- You can filter that per application or per file
  - Fd holds fdnumber, type, characteristic and lock information
    - *File descriptors can help to read strace/ltrace output*
  - Flags can be good to confirm e.g. direct IO, async IO
  - Size (e.g. mem) or offset (fds), name, ...

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]
- Package: RHEL: blktrace SLES: blktrace
- 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.

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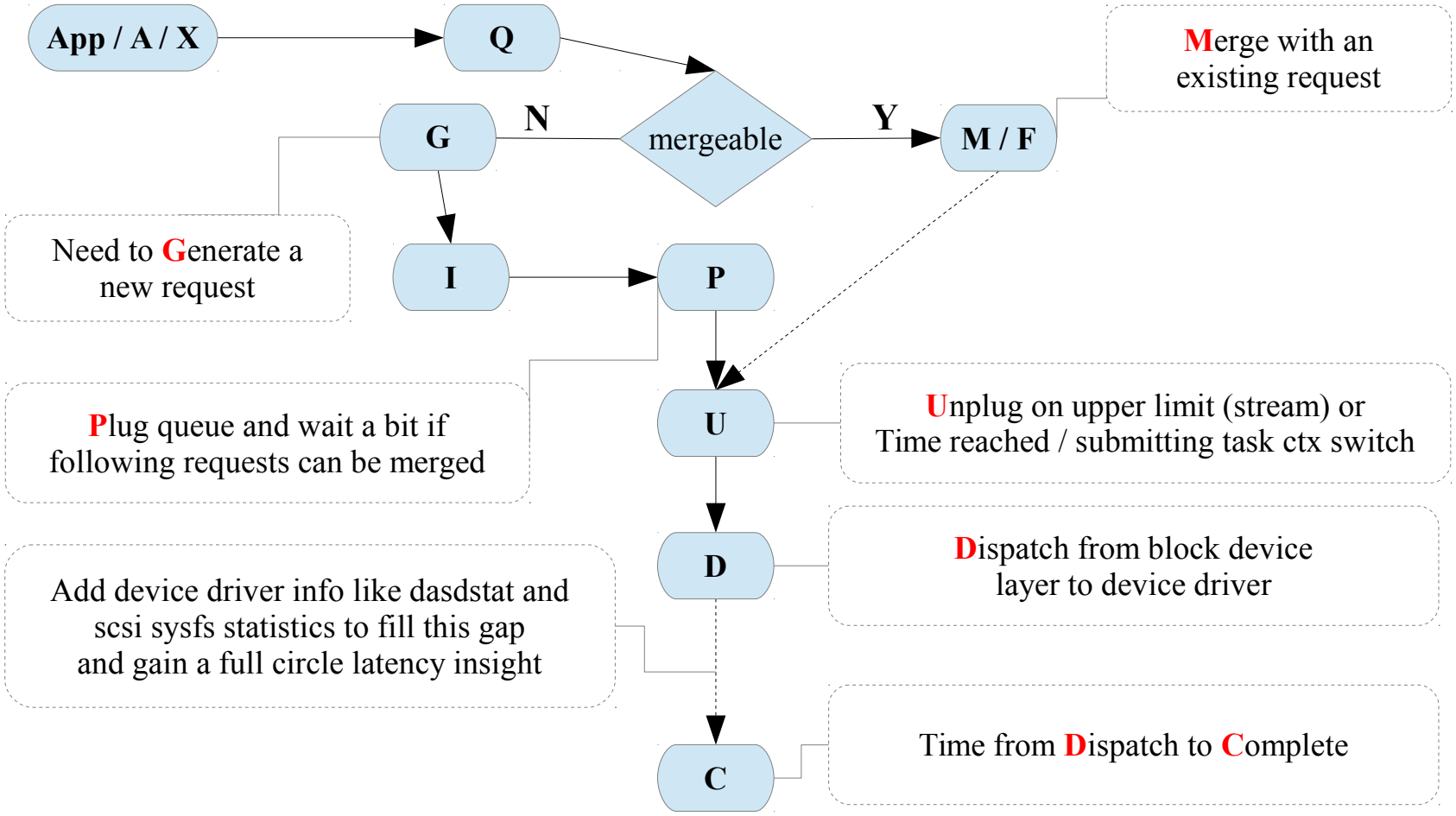
S -- sleep No available request structures were available, so the issuer has to wait for one to be freed.
X -- split On raid or device mapper setups, an incoming i/o may straddle a device or internal zone and needs to be chopped up into smaller pieces for service. This may indicate a performance problem 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.

Block device layer – events (simplified)



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 I/O
  - 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 and sibling images
- Usage: `hyptop`
- Package: RHEL: s390utils-base SLES: s390-tools

- Shows
  - CPU load & Management overhead
  - Memory usage (only under zVM)
  - 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

memuse = resident

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

service guest weights

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
RSCS	1	0.00	0:00	0:03:09	0.00	0.03	100
RSCSDNS	1	0.00	0:00	0:03:10	0.00	0.03	100
AUTOVM	1	0.00	0:00	0:03:10	0.00	0.03	100
GCS	1	0.00	0:00	0:03:10	0.00	0.02	100
LGLOPR	1	0.00	0:00	0:03:10	0.00	0.03	100
DIRMAINT	1	0.00	0:00	0:03:10	0.01	0.03	100
DTCVSW1	1	0.00	0:00	0:03:10	0.01	0.03	100
VMSERVS	1	0.00	0:00	0:03:10	0.01	0.06	1500

Perf

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

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

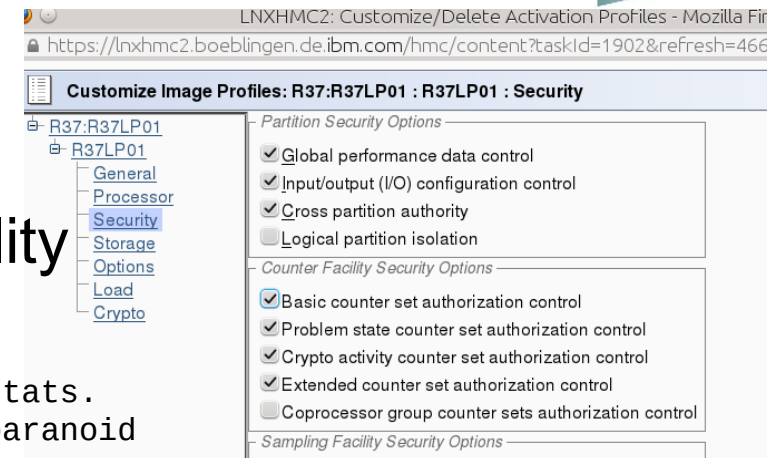
- Hints
  - Without HW support only userspace can be reasonably profiled
  - “successor” of Oprofile that is available with HW support (SLES11-SP2)
  - Perf HW support partially upstream, wait for next distribution releases

Perf

- 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*
  - Counters provide even lower overhead and report HW and Software events

Perf stat - preparation



- Activate the cpu measurement facility
  - If not you'll encounter this

```
Error: You may not have permission to collect stats.
Consider tweaking /proc/sys/kernel/perf_event_paranoid
Fatal: Not all events could be opened.
```

  - Check if its activated

```
echo p > /proc/sysrq-trigger
dmesg
[...]
SysRq : Show Regs
perf.ee05c5: CPU[0] CPUM_CF: ver=1.2 A=000F E=0000 C=0000
[…]
```

  - A = authorized, E=enabled (ready for use), C=controlled (currently running)
  - F = last four bits for basic, problem, crypto and extended set

Perf stat - usage

```
perf stat -B --event=cycles,instructions,r20,r21,r3,r5,sched:sched_wakeup  find /
-iname "*foobar*"
 Performance counter stats for 'find / -iname *foobar*':
     3,623,031,935 cycles                    #    0.000 GHz
     1,515,404,340 instructions              #    0.42  insns per cycle
     1,446,545,776 r20
       757,589,098 r21
       705,740,759 r3
       576,226,424 r5
            40,675 sched:sched_wakeup
       6.156288957 seconds time elapsed
```

- Events
  - Cycles/Instructions globally
  - R20,R21 – Cycles/Instructions of Problem state
  - R3/R5 – Penalty cycles due for L1 instruction/data cache
  - Not only HW events, you can use any of the currently 163 tracepoints

Perf stat - usage

```
perf stat -B --event=cycles,instructions,r20,r21,r3,r5,sched:sched_wakeup
 find / -iname "*foobar*"

 Performance counter stats for 'find / -iname *foobar*':
     3,623,031,935 cycles                    #    0.000 GHz
     1,515,404,340 instructions              #    0.42  insns per cycle
     1,446,545,776 r20
       757,589,098 r21
       705,740,759 r3
       576,226,424 r5
            40,675 sched:sched_wakeup
       6.156288957 seconds time elapsed
```

- Further releases will make that readable and work with few arguments
  - Until then you can refer to this document to get the event numbers

    The Load-Program-Parameter and CPU-Measurement Facilities

End of Part I

- One you should always have → IBM System z Enterprise

Orientation - where to go

Tool	1st overview	CPU cons.	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 / ss	x						x
htop / dstat / pidstat	x	x	x		x		
irqstats	x	x	x				
strace / ltrace			x				
hyptop		x					
perf		x	x	x	x	x	x
jinsight		x	x				
Health Center	x						
GMVC			x			x	
blktrace					x		
lsof					x		
valgrind						x	
smem						x	
slabtop						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/

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#SHAREorg

SHARE

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

Christian Ehrhardt, System Performance Analyst
IBM R&D Germany

12th and 15th August 2013
13521 & 13533

SHARE in Boston

Agenda

- Your swiss army knife for the complex cases

Part I

- pidstat
- Strace
- Ltrace
- smem
- slabtop
- lsof
- Blktrace
- hyptop
- perf

Part II

- Dstat
- Htop
- Iptraf
- Valgrind
- Irqstats
- Java Health Center
- Java Garbage Collection and Memory visualizer
- Jinsight
- Kernel Tracepoints
- Cachestat

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`
- Package: RHEL: dstat SLES: n/a WWW: http://dag.wieers.com/home-made/dstat/
- 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 plug-in 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

```
[root@r3729001 ~]# nice -n 1 dstat -tv --aio --disk-util -n --net-packets -i --ipc -D total,sda --top-io
----system---- ---procs--- ------memory-usage----- ---paging-- -dsk/total----dsk/sda-- ---system-- ----to
     time     |run blk new| used  buff  cach  free|  in   out | read  writ: read  writ| int   csw |usr sy
17-07 17:41:18|0.0   0  38|1303M 13.5M 10.4G 57.4M|   0     0 |4137k   14M: 124k  337k|   0  4968 |  4
17-07 17:41:24| 13   0   0|1307M 13.5M 10.4G 57.2M|   0     0 |1708k   30k:  45k    0 |   0    16k| 33
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| 63  1
17-07 17:41:34| 13   0 0.2|1313M 13.5M 10.4G 59.5M|   0     0 |1325k   11k:  32k    0 |   0    11k| 71  1
17-07 17:41:39|3.6   0   0|1317M 13.6M 10.4G 60.8M|   0     0 |1258k   23k:  26k    0 |   0    16k| 76  1
17-07 17:41:44| 13   0   0|1318M 13.6M 10.4G 53.1M|   0     0 |1601k   16k:  37k    0 |   0    14k| 75  1
17-07 17:41:49| 11   0 0.2|1322M 13.6M 10.4G 82.2M|   0     0 | 811k   16k:  31k    0 |   0    13k| 67  2
17-07 17:41:53| 12 0.4   0|1324M 13.6M 10.4G 68.7M|   0     0 | 909k 3277B:  40k    0 |   0  9820 | 26
17-07 17:41:58|0.6   0 0.2|1326M 13.6M 10.4G 59.6M|   0     0 |1386k   33k:  50k    0 |   0    14k| 25
```

similar to vmstat

similar to iostat
(also per device)

new in live tool

```
sda --top-io --noupdate 5
stem-- ----total-cpu-usage---- async sda- -net/total- -pkt/total- inter --sysv-ipc- ----most-expensive----
 csw  |usr sys idl wai hiq siq| #aio|util| recv  send|#recv #send|  1   |msg sem shm|      i/o process
4968  |  4   3  92   0   0   1|   0 |1.59|   0     0 |   0     0 | 300  |  0  35   1|sshd            15M   25M
  16k|  33   9  55   0   0   3|   0 |0.20|  21B  426B|0.40  0.40 |  81  |  0  35   1|postgres: p   78k     0
  15k|  63  15  17   0   0   5|   0 |0.20|  10B  148B|0.20  0.20 |  74  |  0  35   1|postgres: p   75k     0
  11k|  71  17   6   0   0   6|   0 |   0|  142B 148B|0.60  0.20 |  62  |  0  35   1|postgres: p  141k     0
  16k|  76  18   0   0   0   6|   0 |0.40|  133B 151B|0.60  0.20 |  75  |  0  35   1|postgres: p   32k     0
  14k|  75  19   0   0   0   6|   0 |0.40|  10B  151B|0.20  0.20 |  73  |  0  35   1|postgres: p  152k     0
  13k|  67  28   0   0   0   5|   0 |0.20|  162B 161B|0.80  0.40 |  53  |  0  35   1|postgres: p   22k     0
 9820|  26   6  65   0   0   2|   0 |0.20|  10B  151B|0.20  0.20 |  41  |  0  35   1|postgres: p  110k     0
```

htop

- Characteristics: Process overview with extra features
- Objective: Get an understanding about your running processes
- Usage: `htop`
- Package: RHEL: n/a SLES: n/a WWW: http://htop.sourceforge.net/
- 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

Hierarchy

Accumulated Usage and IO rates

IPTRAF

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

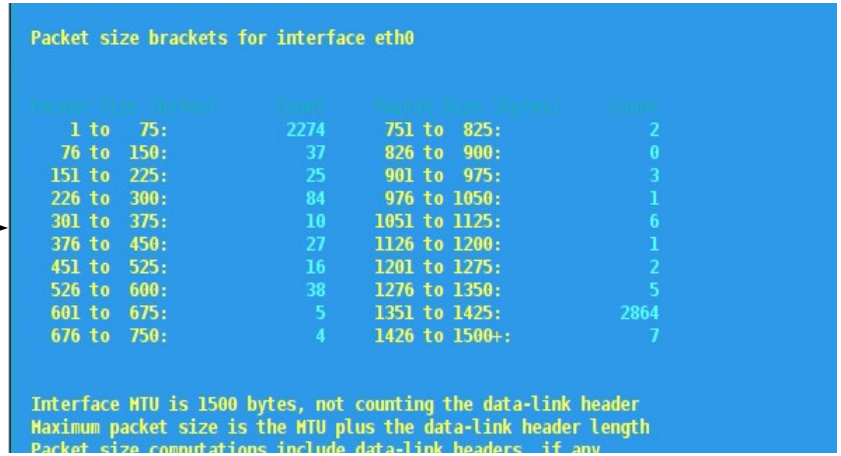
- Shows
  - Details per Connection / Interface
  - Statistical breakdown of ports / packet sizes
  - LAN station monitor

- 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

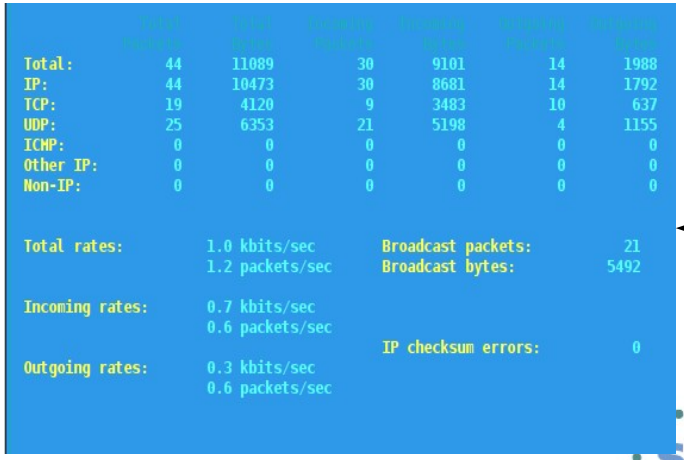
iptraf

- 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



IF details



Valgrind

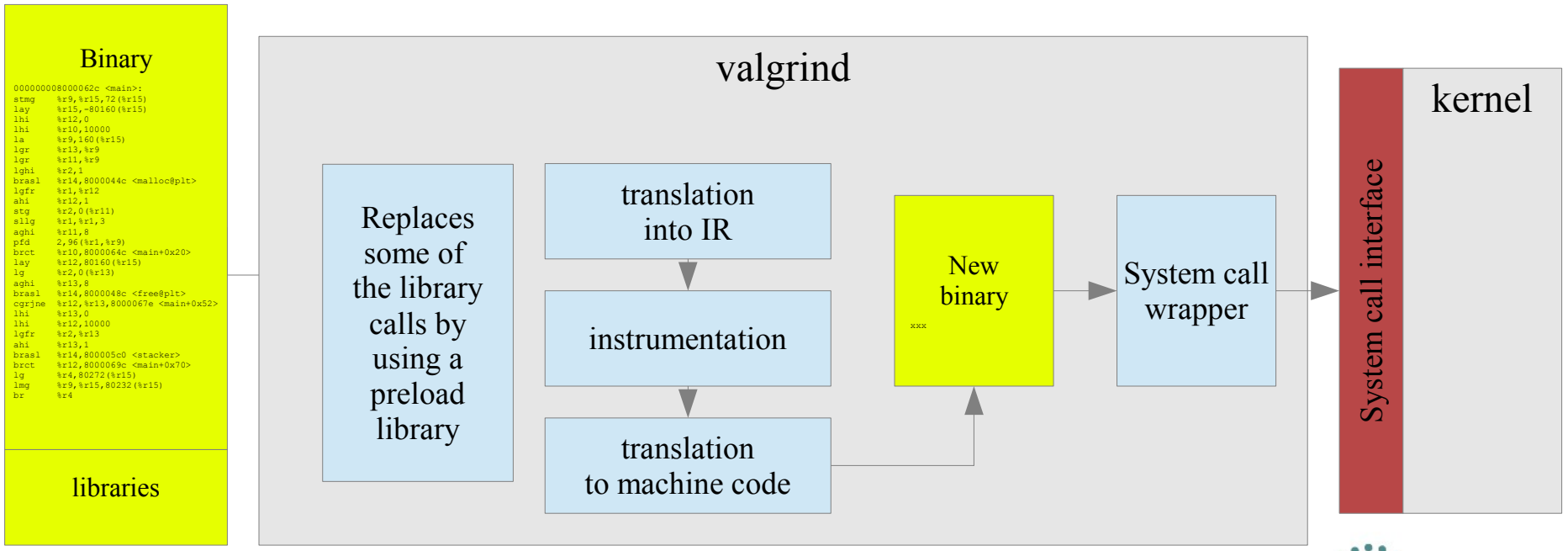
- Characteristics: in-depth memory analysis
- Objective: Find out where memory is leaked, sub-optimally cached, ...
- Usage: `valgrind [program]`
- Package: RHEL: valgrind SLES: valgrind

- 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



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
[...]
```

Valgrind - Tools

- Several tools
  - Memcheck (default): detects memory and data flow problems
  - Cachegrind: cache profiling
  - Massif: heap profiling
  - Helgrind & 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)

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

IRQ Statistics

- Characteristics: Low overhead IRQ information
- Objective: Condensed overview of IRQ activity
- Usage: `cat /proc/interrupts and cat /proc/softirqs`
- Package: n/a (Kernel interface)

- Shows
  - Which interrupts happen on which cpu
  - Where softirqs and tasklets take place

- Hints
  - Recent Versions (SLES11-SP2) much more useful due to better naming
  - 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 focused 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, M-Check
```

IRQ Statistics II

- Also softirqs can be tracked which can be useful to
  - check if tasklets execute as intended
  - See if network, scheduling and I/O behave as expected

```
                    CPU0       CPU1       CPU2       CPU3
          HI:         498       1522       1268       1339
       TIMER:        5640        914        664        643
      NET_TX:          15         16         52         32
      NET_RX:          18         34         87         45
       BLOCK:           0          0          0          0
BLOCK_IOPOLL:           0          0          0          0
     TASKLET:          13         10         44         20
       SCHED:        8055        702        403        445
     HRTIMER:           0          0          0          0
         RCU:        5028       2906       2794       2564
```

Java Performance in general

- Differences
  - Profiling a JVM might hide the Java methods (you see a JVM)
  - Memory allocation of the JVM isn't the allocation of the Application
- Be aware of common Java myths often clouding perception
  - Non Java as well, don't blindly trust 3rd party libraries
- “Too” many choices
  - There are many Java performance tools out there
- Smallest overview possible
  - 1st overview & low overhead – Java Health Center
  - Debug Method interactions – Jinsight
  - Analyze garbage collection – IBM garbage collection and memory visualizer

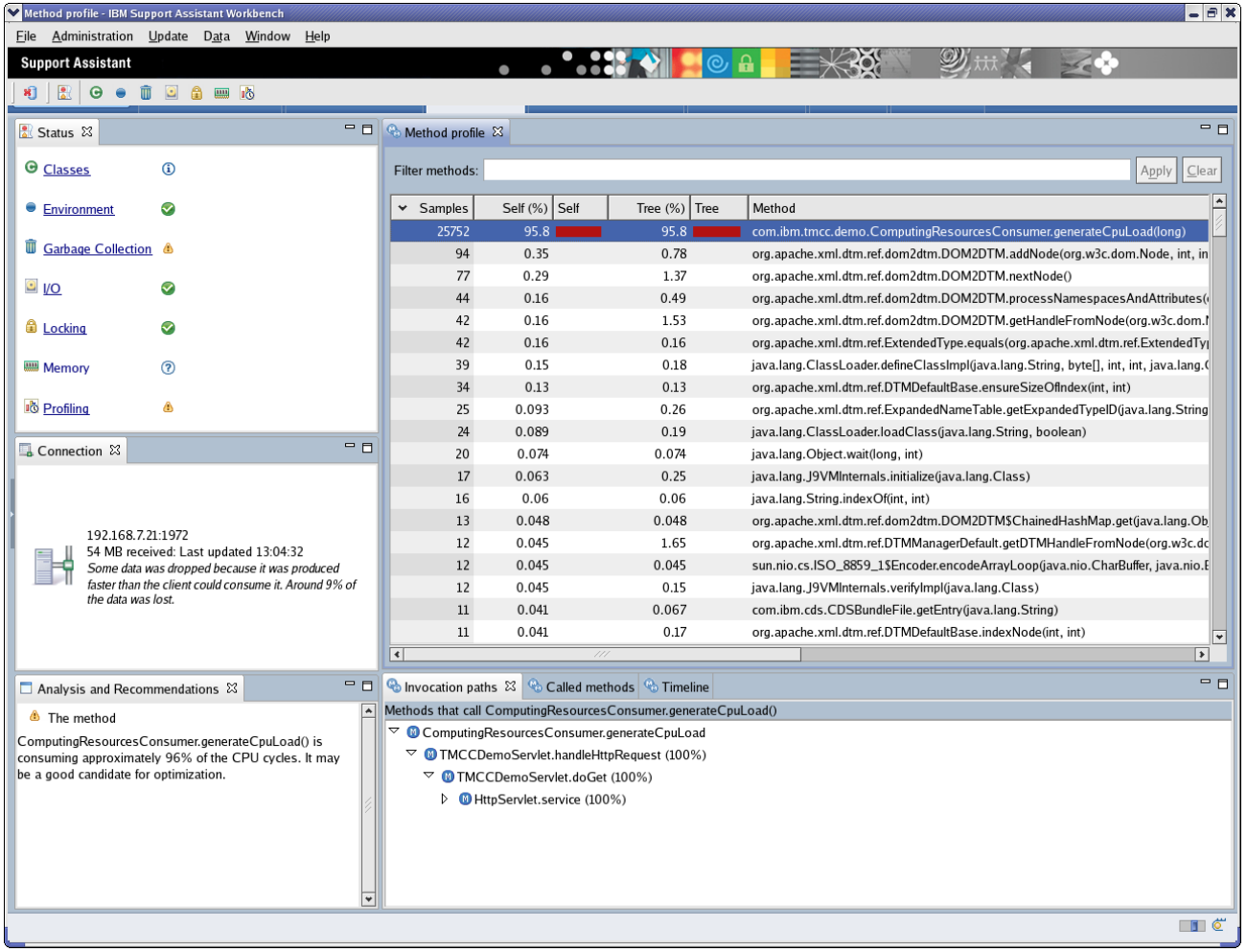
Java - Health Center

- Characteristics: Lightweight Java Virtual Machine Overview
- Objective: Find out where memory is leaked, sub-optimally cached, ...
- Usage: `IBM Support Assistant (Eclipse)`
- Package: RHEL: n/a SLES: n/a WWW: ibm.com/developerworks/java/jdk/tools/healthcenter
  Java Agents integrated V5SR10+, V6SR3+, usually no target install required

- Shows
  - Memory usage, Method Profiling, I/O Statistics, Class loading, Locking

- Hints
  - Low overhead, therefore even suitable for monitoring
  - Agent activation -Xhealthcenter:port=12345
  - Can trigger dumps or verbosegc for in-depth memory analysis

Health Center - example



- Example of Method profiling

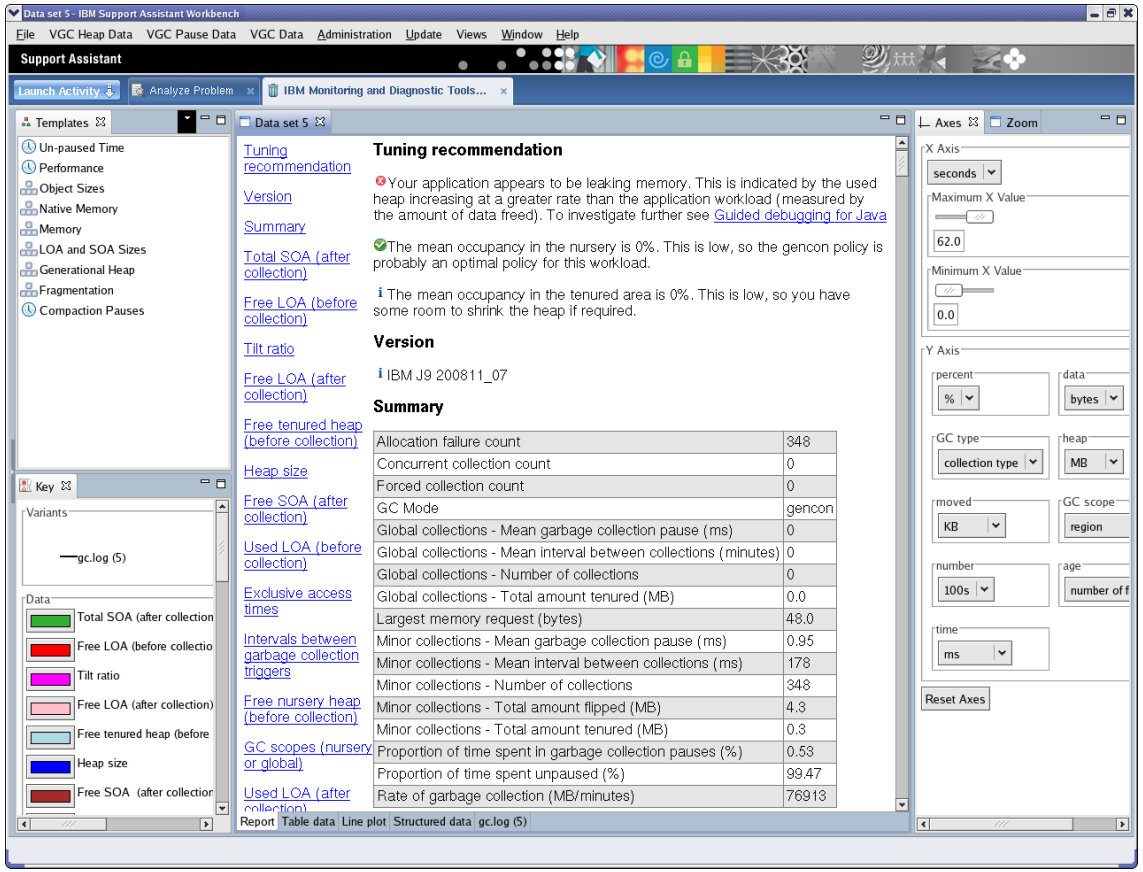
Java - Garbage Collection and Memory Visualizer

- Characteristics: in-depth Garbage Collection analysis
- Objective: Analyze JVM memory management
- Usage: `IBM Support Assistant (Eclipse)`
- Package: RHEL: n/a SLES: n/a WWW: ibm.com/developerworks/java/jdk/tools/gcmv
  reads common verbosegc output, so usually no target install required

- Shows
  - Memory usage
  - Garbage Collection activities
  - Pauses
  - Memory Leaks by stale references

- Hints
  - GCMV can also compare output of two runs
  - Activate verbose logs `-verbose:gc -Xverbosegclog:<log_file>`

Garbage Collection and Memory Visualizer



- Most important values / indicators are:
  - Proportion of time spent in gc pauses (should be less than 5%)
  - For gencon: global collections << minor collections

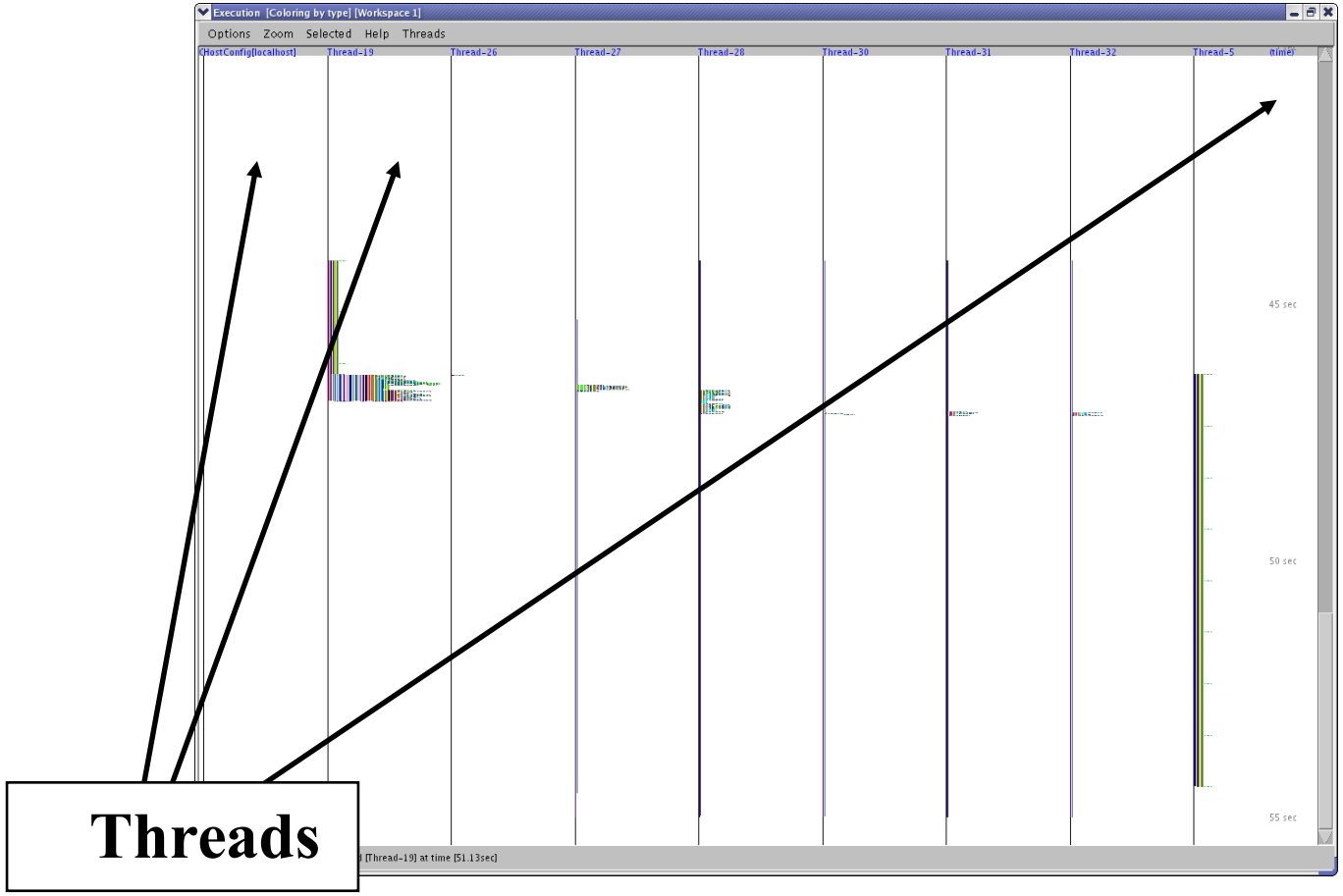
Java - Jinsight

- Characteristics: zoomable call stack
- Objective: Analyze method call frequency and duration
- Usage: `jinsight_trace -tracemethods <yourProgram> <yourProgramArgs>`
- Package: RHEL: n/a SLES: n/a WWW: IBM alphaworks

- Shows
  - Call-Stack and time

- Hints
  - Significant slowdown, not applicable to production systems
  - No more maintained, but so far still working

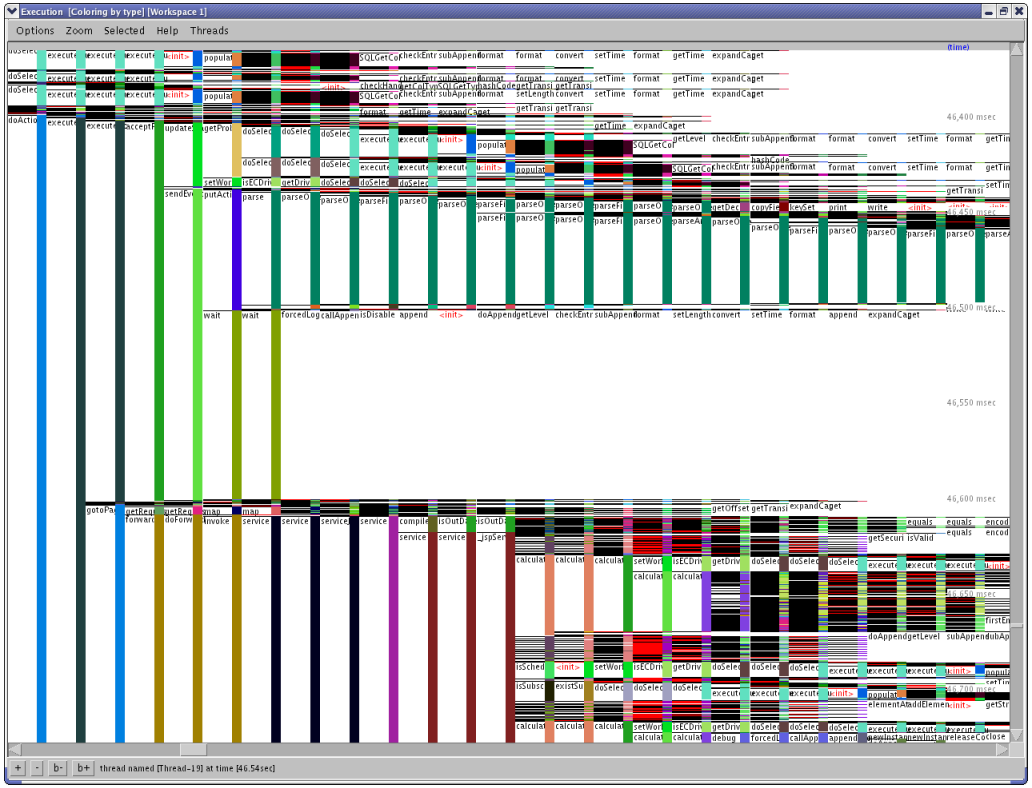
Jinsight Execution View



- Threads in columns, select one to zoom in

Jinsight Execution View, *continued*

Method Call Stack →



Execution Time →

- Many horizontal stages mean deep call-stacks
- Long vertical areas mean long method execution
- Rectangles full of horizontal lines can be an issue

Tracepoints (Events)

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

- 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 no 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 tunes buffer sizes, checks files, ...*

```
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 ~all of the 1.2 ms were lost inside Linux (not in the fabric)
  - Confirmed that it was not at/between specific function tracepoints
    - *Eventually it was an interrupt locality issue causing bad caching*

Cachestat

- Characteristics: Simple per page views of caching
- Objective: Detect what parts of a file are in page cache
- Usage: Write – or search for example code
- Package: n/a (pure code around the mincore system call)

- Shows
  - How much of a file is in cache

- Hints
  - This is now going from unsupported to non existent packages
  - Still the insight can be so useful, it is good to know

Cachestat usage

```
./cachestat -v ../Music/mysong.flac
pages in cache: 445/12626 (3.5%) [filesize=50501.0K, pagesize=4K]

cache map:
     0: |x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|
    32: |x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|
    64: |x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|
[...]
   320: |x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|
   352: |x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|
   384: |x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|
   416: |x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x|x| | | | |
   448: | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
   480: | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
[...]
 12576: | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
 12608: | | | | | | | | | | | | | | | | |x|
```

- Here I show how much of a file is in cache while playing a song
  - You'll see readahead here
  - You'll also see the last block is almost always read in this case

There are always more tools to know ...

- But one you should always have → IBM System z Enterprise

Orientation - where to go

Tool	1st overview	CPU cons.	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 / ss	x						x
htop / dstat / pidstat	x	x	x		x		
irqstats	x	x	x				
strace / ltrace			x				
hyptop		x					
perf		x	x	x	x	x	x
jinsight		x	x				
Health Center	x						
GMVC			x			x	
blktrace					x		
lsof					x		
valgrind						x	
smem						x	
slabtop						x	
iptraf	x						x
tracepoints			x	x	x	x	x

Appendix Preview covering even more tools

- Entry level Tools
  - **Vmstat** – virtual memory statistics
  - **Sysstat** – full system overview
  - **Iostat** – I/O related statistics
  - **Dasdstat** – disk statistics
  - **scsi statistics** – disk statistics
  - **Netstat** – network statistics and overview
  - **Socket Statistics** – extended socket statistics
  - **top / ps** – process overview

- Further complex tools - (no slides yet)
  - **lcastats / lszcrypt** – check usage of crypto hw support
  - **Lsqeth** – check hw checksumming and buffer count
  - **Ethtool** – check offloading functions
  - **Collectl** – full system monitoring
  - **Ftrace** – kernel function tracing
  - **Lttng** – complex latency tracing infrastructure (no s390 support yet)
  - **Systemtap** – another kernel tracing infrastructure
  - **Ziomon** – blktrace plus s390 zfcp driver insights

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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vmstat

- Characteristics: Easy to use, high-level information
- Objective: First and fast impression of the current state
- Usage: vmstat [interval in sec]
- Package: RHEL: sysstat.s390x SLES: sysstat
- Output sample:

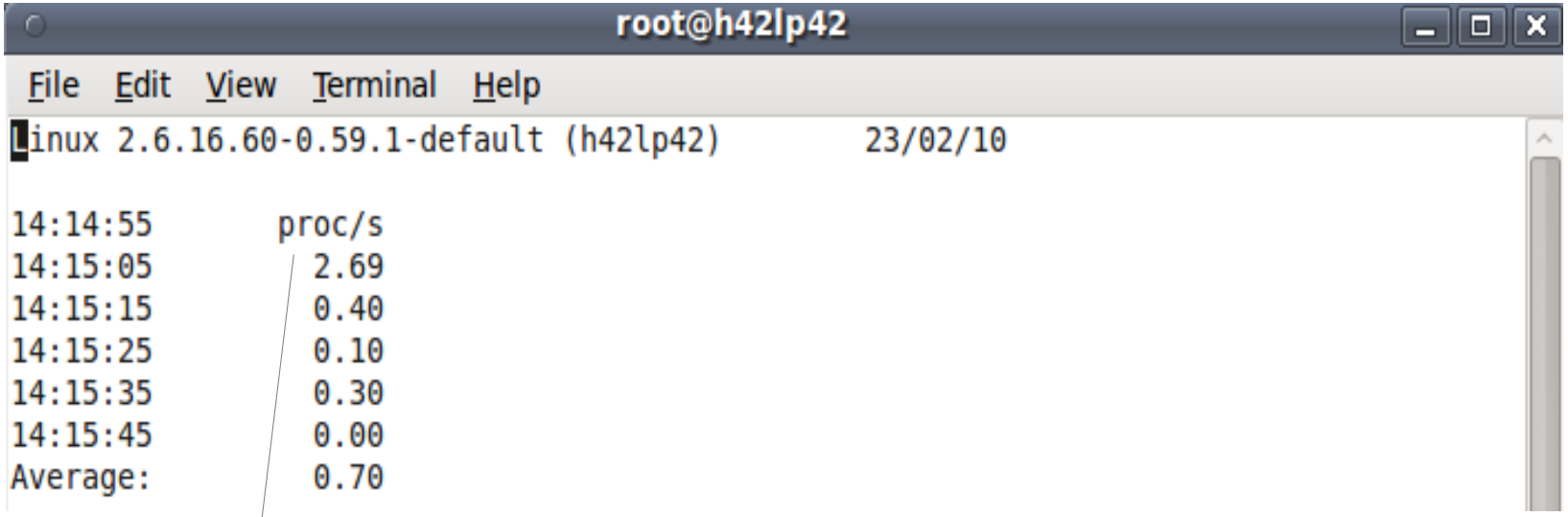
```
vmstat 1
procs -----------memory---------- ---swap-- -----io---- -system-- -----cpu------
 r  b   swpd   free   buff  cache   si   so    bi    bo   in   cs us sy id wa st
 2  2      0 4415152  64068 554100    0    0     4 63144  350   55 29 64  0  3  4
 3  0      0 4417632  64832 551272    0    0     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 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

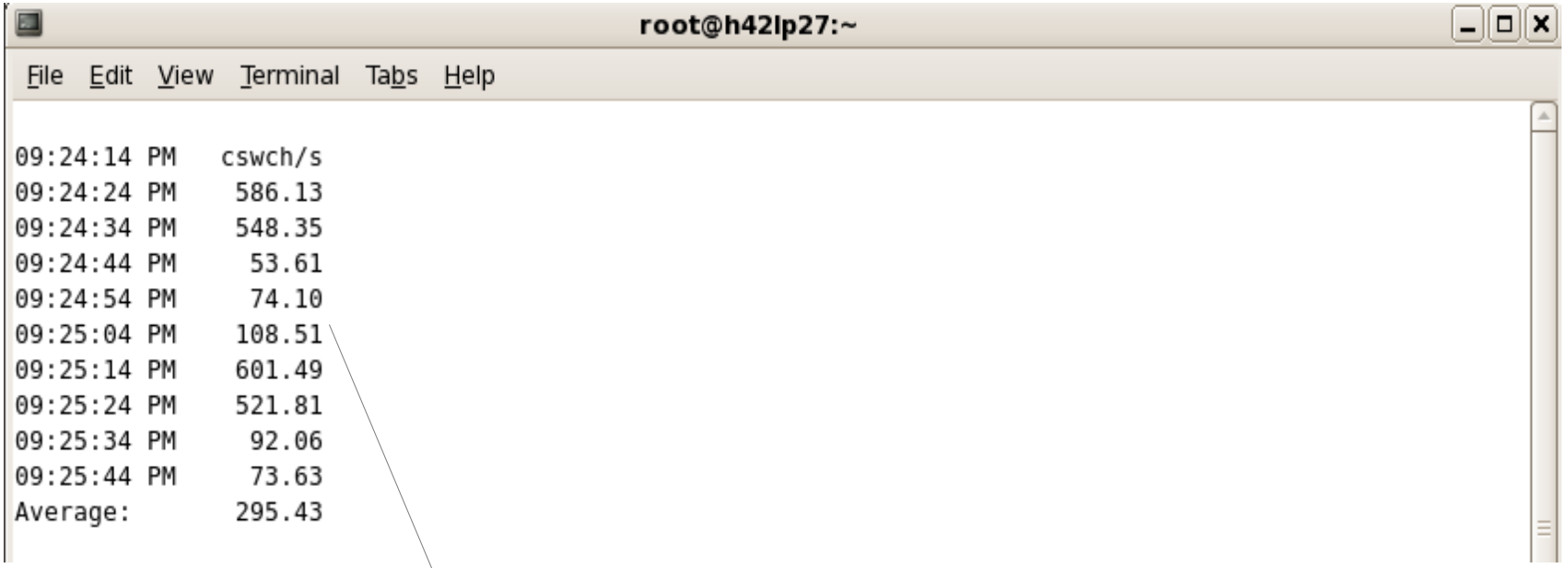
- Characteristics: Very comprehensive, statistics data on device level
- Objective: Suitable for permanent system monitoring and detailed analysis
- Usage (recommended):
  - monitor `/usr/lib64/sa/sadc [-S XALL] [interval in sec] [outfile]`
  - View `sar -A -f [outfile]`
- Package: RHEL: sysstat.s390x SLES: sysstat
- 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
  - sadc parameter “-S XALL” enables the gathering of further optional data
  - 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



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



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)

root@h42lp42

File Edit View Terminal Help

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

root@h42lp42

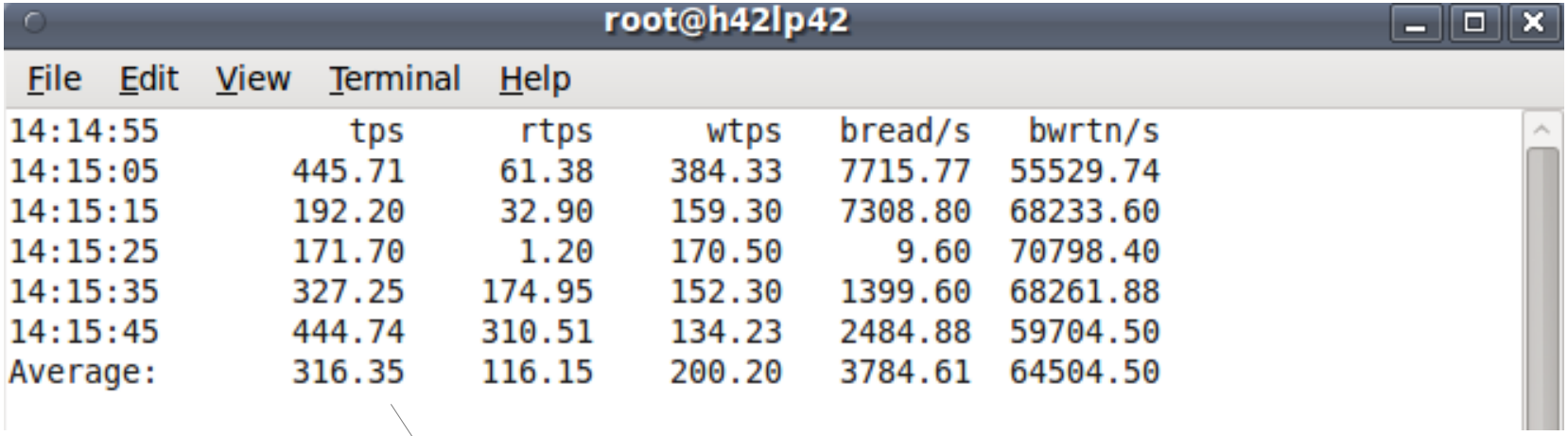
File Edit View Terminal Help

```
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



Overview of
- operations per second
- transferred amount

SAR – Disk I/O II – per device

root@h42lp42

File Edit View Terminal Help

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 with 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

root@h42lp42

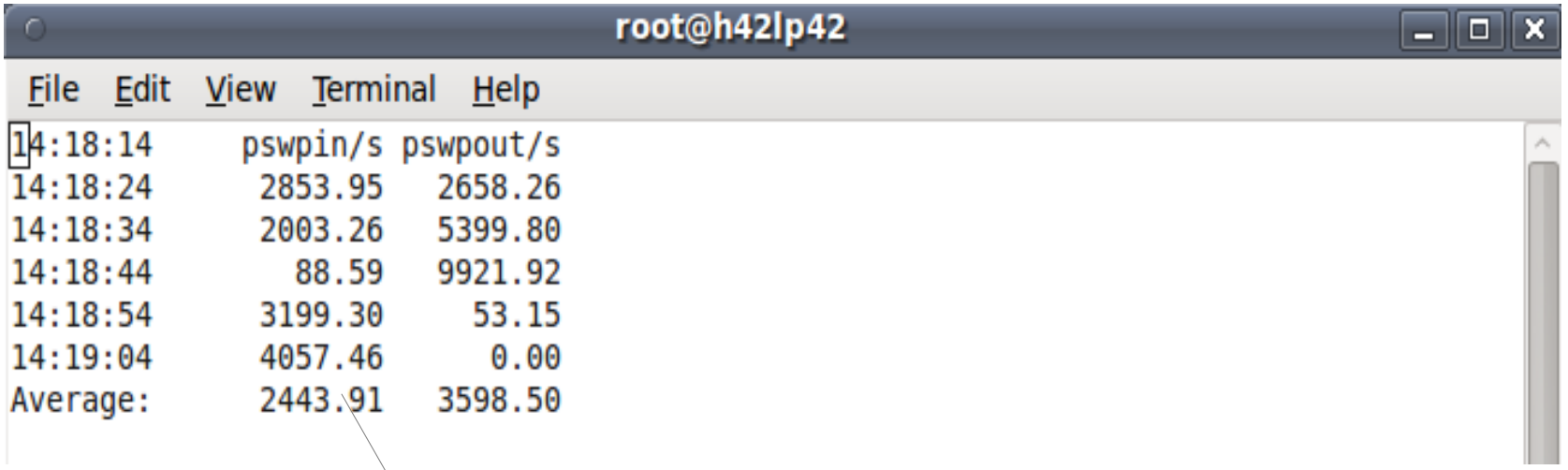
File Edit View Terminal Help

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



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.

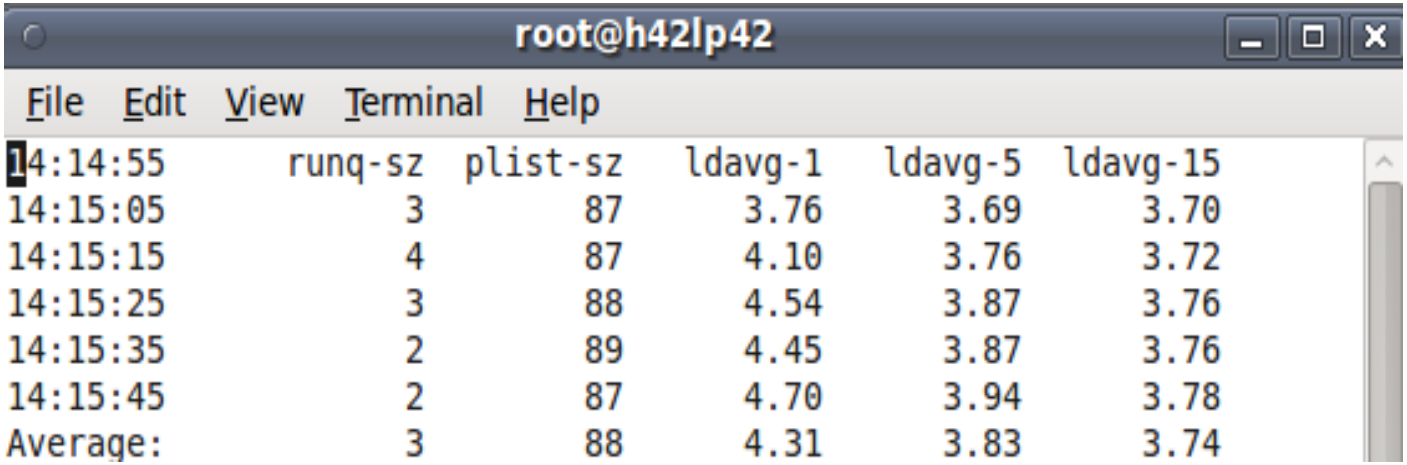
SAR - Memory pressure – faults and reclaim

File Edit View Scrollback Bookmarks Settings Help

	pgpgin/s	pgpgout/s	fault/s	majflt/s	pgfree/s	pgscank/s	pgscand/s	pgsteal/s	%vmeff
10:12:15 AM									
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
10:12:47 AM	1269.39	699144.90	44.39	1.53	173979.08	89181.63	112045.41	173909.69	86.42
10:12:49 AM	1691.54	677327.36	62.19	2.49	171114.93	89499.00	104974.13	171048.26	87.95
10:12:51 AM	1979.70	285857.87	143.15	4.57	69777.16	37740.61	44834.01	69590.86	84.28
10:12:53 AM	458.00	20.00	57.00	1.00	156.50	98.00	0.00	96.00	97.96
10:12:55 AM	433751.72	5944.83	1818.23	24.14	109168.97	3466.01	210573.89	108376.85	50.63
10:12:57 AM	924042.00	336.00	248.50	26.50	231500.50	2384.50	461443.00	231027.50	49.81
10:12:59 AM	906810.00	214.00	225.00	25.00	226950.50	2117.00	447010.00	226605.50	50.45
10:13:01 AM	917504.00	180.00	206.00	38.00	230020.50	2225.00	460268.00	229486.50	49.62
10:13:03 AM	865062.00	348.00	464.00	58.00	216892.50	7677.50	419680.50	215976.00	50.54
10:13:05 AM	12.06	20.10	42.21	0.00	267.84	160.80	16.08	176.88	100.00
10:13:07 AM	770.15	123.38	201.99	9.95	266.17	131.34	0.00	130.85	99.62
10:13:09 AM	484.42	20.10	64.32	2.51	263.82	192.96	0.00	192.96	100.00

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



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]
- Package: RHEL: sysstat.s390x SLES: sysstat

- 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:

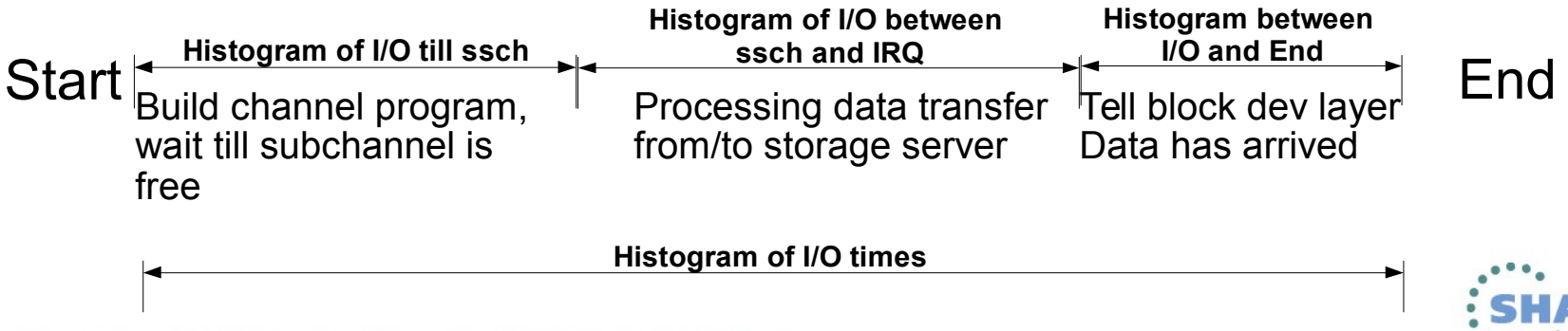
```
Time: 10:56:35 AM
Device:         rrqm/s   wrqm/s     r/s     w/s    rkB/s    wkB/s avgrq-sz avgqu-sz   await  svctm  %util
dasda             0.19     1.45    1.23    0.74    64.43     9.29    74.88     0.01    2.65   0.80   0.16
dasdb             0.02   232.93    0.03    9.83     0.18   975.17 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

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`
- Package: n/a for kernel interface, s390-tools for dasdstat

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

- Shows:
  - various processing times:



DASD statistics - report

- Sample:

8*512b = 4KB <= request size < 1*512b =8KB

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 which usually only confuses

FCP statistics

- Characteristics: Detailed latency information
- Objective: Collects statistics of I/O operations on FCP devices on request base, separate for read/write
- Package: n/a (Kernel interface)
- 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

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
...
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
...
```

request size 4KB, 1163 occurrences

response time <= 1ms

Channel response time <= 32µs
= all below driver

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

netstat

- Characteristics: Easy to use, connection information
- Objective: List connections
- Usage: `netstat -eeapn / netstat -tlpn`
- Package: RHEL: net-tools SLES: net-tools

- 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`
- Package: RHEL: iproute-2 SLES: iproute2
- 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]`
- Package: RHEL: procps SLES: procps

- 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: “`ps axlf`”
- Package: RHEL: procps SLES: procps

```
  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]
 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