How to surprise by being a Linux-performance "Know-it-all"

Martin Schwidefsky

IBM Lab Böblingen, Germany

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Sessions 17672 & 17673

Trademarks

Agenda

- Your swiss army knife for the complex cases
  - **Pidstat** – per process statistics
  - **Slabtop** – kernel memory pool consumption
  - **Lsof** – check file flags of open files
  - **Blktrace** – low level disk I/O analysis
  - **Hyptop** – cross guest cpu consumption monitor
  - **Iptraf** - network traffic monitor
  - **Dstat** – very configurable live system overview
  - **Irqstats** – check irq amount and cpu distribution
  - **Smem** – per process/per mapping memory overview
  - **Jinsight** – Java method call stack analysis
  - **Htop** – top on steroids
  - **Strace** – system call statistics
  - **Ltrace** – library call statistics
  - **Kernel tracepoints** – get in-depth timing inside the kernel
  - **Vmstat** – virtual memory statistics
  - **Sysstat** – full system overview
  - **Iostat** – I/O related statistics
  - **Dasdstat** – disk statistics
  - **scsi statistics** – disk statistics
  - **Perf** – hw counters, tracepoint based evaluations, profiling to find hotspots
  - **Valgrind** – in depth memory/cache analysis and leak detection
  - **Java Health Center** – high level java overview and monitoring
  - **Java Garbage Collection and Memory visualizer** – in depth gc analysis
  - **Netstat** – network statistics and overview
  - **Socket Statistics** – extended socket statistics
  - **top / ps** – process overview
  - **Icastats / lszcrypt** – check usage of crypto hw support
  - **Lsluns / multipath** – check multipath setup
  - **Lsqeth** – check hw checksumming and buffer count
  - **Ethtool** – check offloading functions
  - **Collectl** – full system monitoring
  - **Ftrace** – kernel function tracing
  - **Lttng** – complex latency tracing infrastructure
  - **Ziomon** – Analyze FCP setup and I/O
  - **Systemtap** – another kernel tracing infrastructure
  - **Wireshark / Tcpdump** – analyze network traffic in depth
  - **Iotop** – order processes by disk I/O
  - **Iftop** - per connection traffic overview

  … ever growing

Agenda – approximately 5 x 60 minutes

Basic
- Utilization
- Scheduling
- Page Cache
- Swapping
- top
- ps
- vmstat

Intermediate
- General thoughts
- Sysstat
- Dasdstat
- Scsi I/O statistics
- iotop
- Lszcrpt
- icastats
- Lsqeth
- Ethtool
- Preparation

Advanced
- Strace
- Ltrace
- Lsof
- Lsluns
- Multipath
- hyptop
- Dstat
- Htop
- Netstat
- Socket Statistics
- Iptraf

Master
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Elite
- Cachestat
- Smem
- Valgrind
- Irqstats
- Wireshark
- Kernel Tracepoints
- Systemtap

Agenda

Today we make up for the so far missing introduction(s)

Basic
- Utilization
- Scheduling
- Page Cache
- Swapping

- top
- ps
- vmstat

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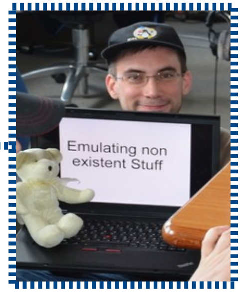
Utilization

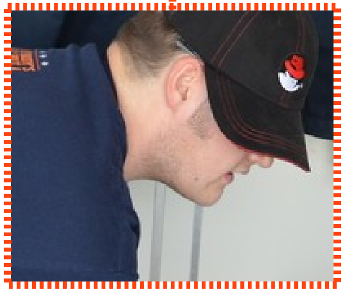
- Utilization means that a cpu core is used
- Categories qualify what the core was used for
  - System, IRQ, SoftIRQ
  - Userspace, Guest
  - Idle, IOWait, Steal
  - Nice
- Accounting unit is Jiffy, reports usually as percentage
  - Percentage is better to express relative ratios
- The majority of those basics is usually known, but it still has a purpose
  - Clarify and synchronize the understanding between everybody
  - Provide metaphors that allow to explain it more easily next time

Utilization - Metaphor

- For all the clarifications on basic terms I will use metaphors
  - Based on well known real world examples
  - At the beginning of a topic the matching metaphor is provided
- Imagine a laptop is a CPU core

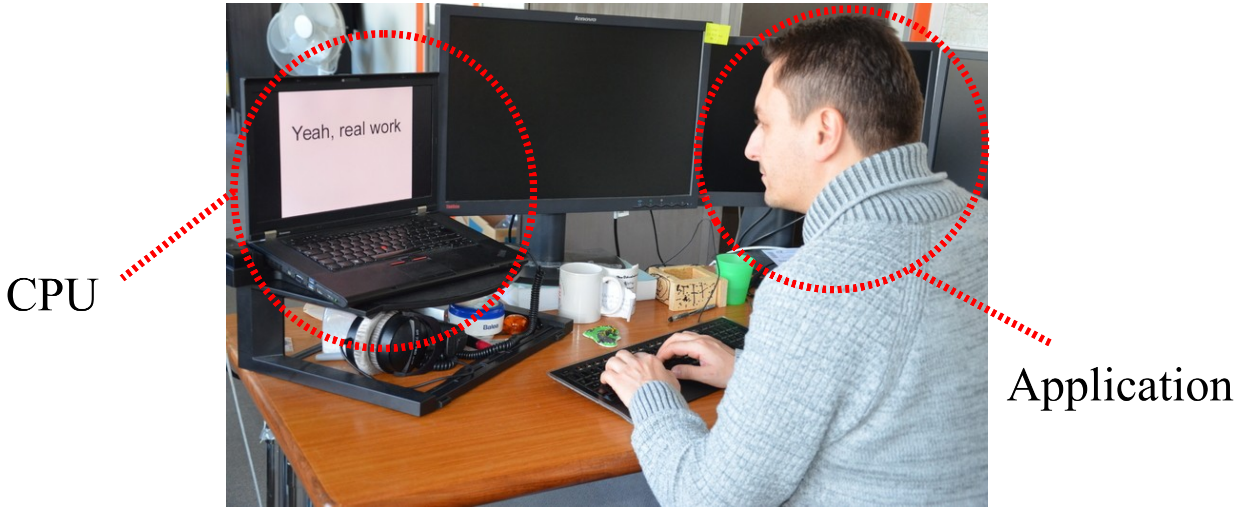
- People using that laptop are different Programs, that could be
  - Application(s)
  - Kernel
  - Hypervisor





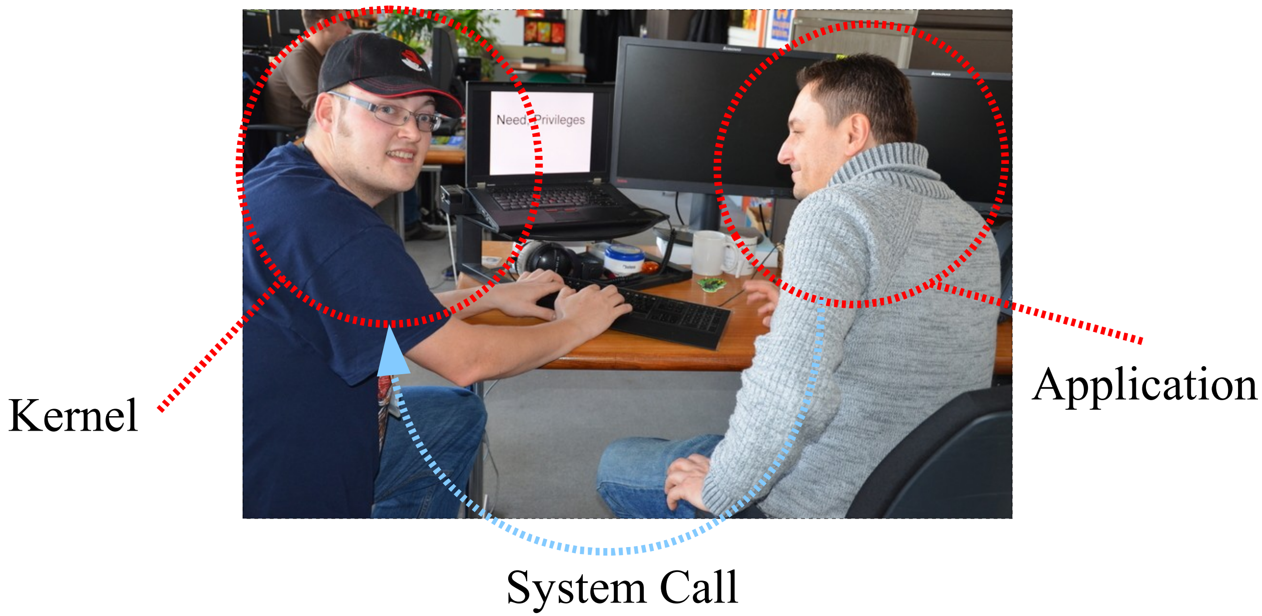
**Roles are defined by clothes and equipment not people (bad actors)*

Utilization - USR



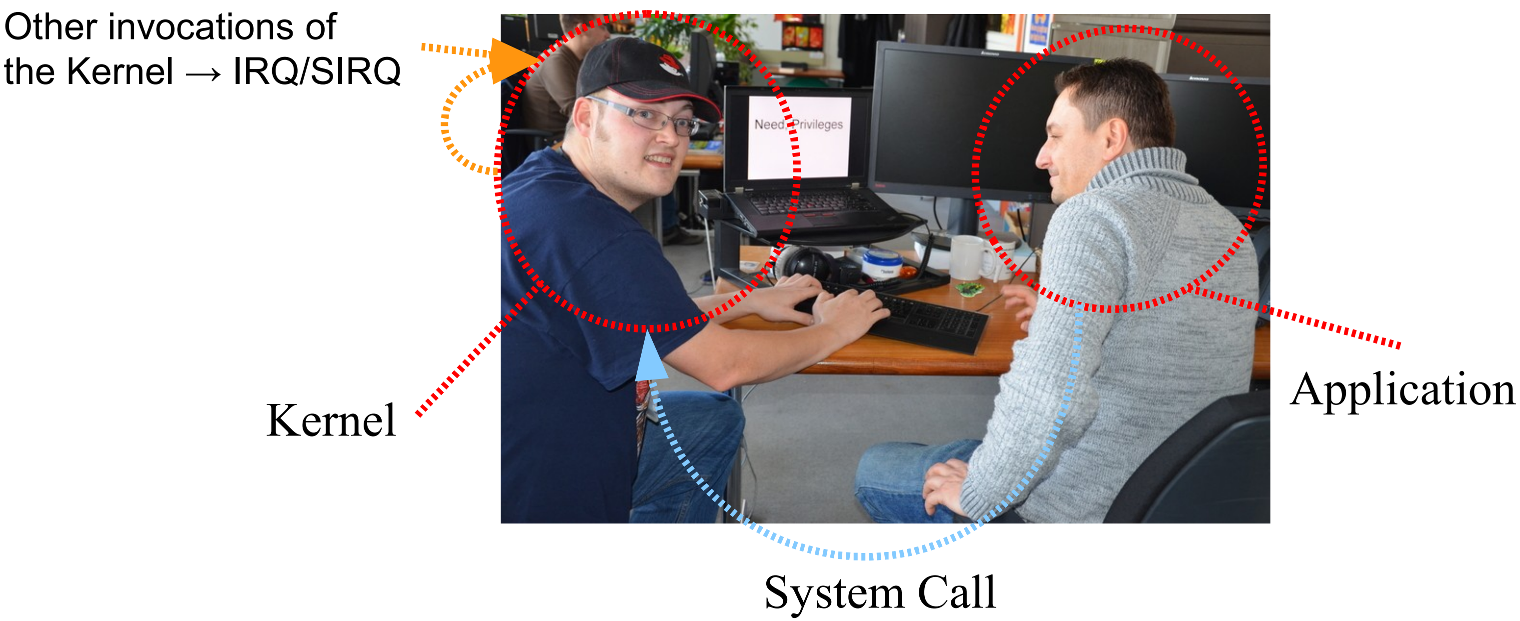
- If a userspace application is running it is accounted as **USR**
  - This is usually what you want
  - Also known as problem state, because there your problems are solved
  - If this “application” is actually a virtualized guest it is accounted to Guest instead

Utilization – SYS, (H)IRQ, SIRQ



- For some tasks you need certain privileges
  - so you call an administrator (System Call to the Kernel)
  - He executes the privileged stuff for you (accounted as **SYS**tem time)

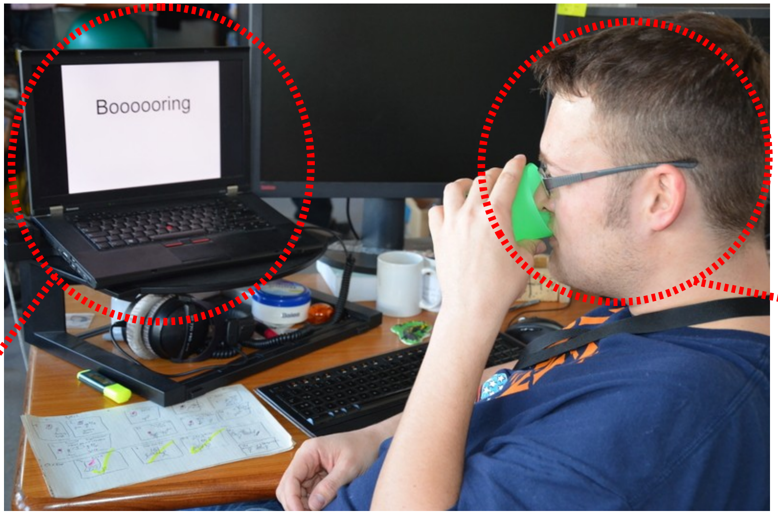
Utilization – SYS, (H)IRQ, SIRQ



- For some tasks you need certain privileges
  - so you call an administrator (System Call to the Kernel)
  - He executes the privileged stuff for you (accounted as **SYS**tem time)
  - There are subcategories
    - **(H)IRQ**: privileged work driven by interrupts instead by the user
    - **SIRQ**: privileged work driven by soft interrupts and tasklets

Utilization - Idle

CPU Idle

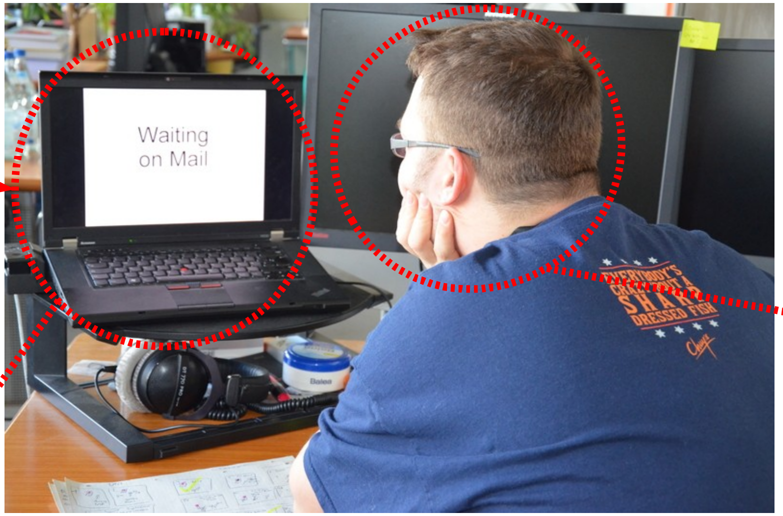


Application not requesting work

- This is the most simple case of “doing nothing”
- The CPU executes nothing because it is not requested to do so
- This is accounted as **idle**

Utilization - IOWait

Waiting for I/O



CPU is Idle
accounted as iowait

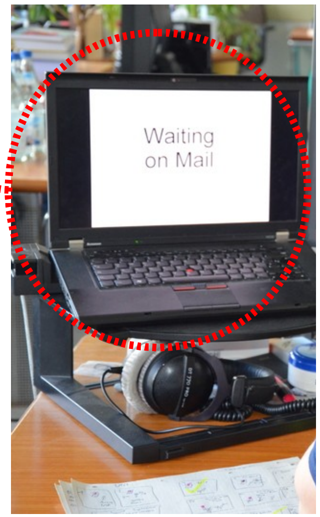
Application
waiting for I/O

- Again "doing nothing", but no more that simple
- The System was requested to do some synchronous I/O
  - Still the CPU executes nothing because it is not requested to do so
  - But it knows it "could" do some work if that I/O would complete
- This is accounted as **iowait**

Utilization – IOWait

Waiting for I/O

CPU is Idle, but accounted as idle



No one waiting for I/O

- If no one is waiting for I/O, (asynchronous)
  - Example 1: real Linux AIO
  - Example 2: writes via page cache
- Not accounted as **iowait**, but **idle**

Utilization - Steal

Application thought it could work (scheduled)

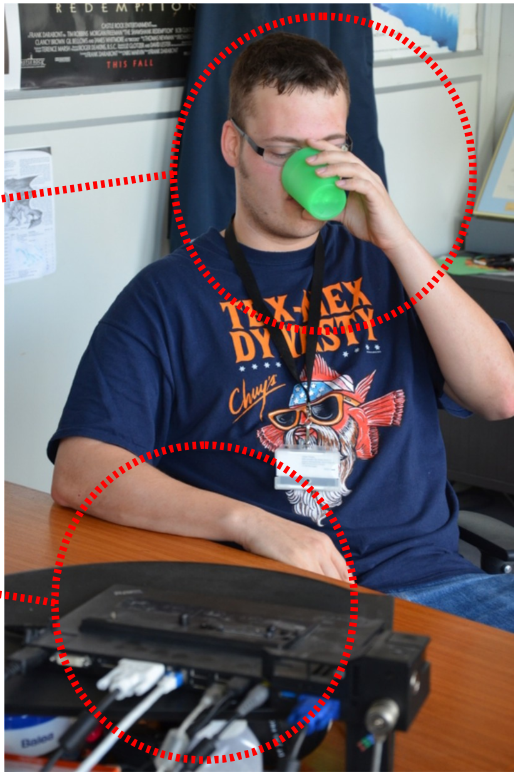
CPU seems to be non existent

- The CPU is doing something, just not for you
- CPU doesn't exist for you, but you'd need a CPU to realize that
  - Accounted as **steal** time
  - Based on Virtual vs Real timers
- Imagine the laptop is used for multiple groups of people and switched between their docking stations
  - A group of people in front of one laptop cause Context switches (later)

Utilization - Steal

If the Application
doesn't work

Nobody cares about
the CPU being
“non existant”



- In case a CPU shouldn't run anyway the stealing isn't even recognized
- Still accounted as **idle** or **iowait**

Utilization - Steal

Thought it would
transmit network packets
It got from the App

Asked the kernel
for I/O handling

CPU is still busy but
for other things
than Linux thought

- A Linux does not know for which purpose the cpu was stolen
- Steal can indicate issues
  - Too high cpu or memory overcommitment
- But steal also isn't always bad
  - It could be work you requested, just like “USR->SYS in Linux alone”

Utilization – Steal Quiz

- I: Driving I/O synchronously e.g. causing a vswitch to work for your submission
  => Steal? **Yes**

- II: Driving sync reads from a file, mdisk does work for you
  => Steal? **No, IOWait**

- III: Driving async writes (AIO) by a DB, causing mdisk work in the HV
  => Steal? **Kind of, depends on if the CPU is idle or not**

- IV: Paging in the HV takes place while you were running a Java based BI load utilizing all cores
  => Steal? **Yes**

- V: Paging in the HV takes place while your system is an idling development testbed
  => Steal? **No, Idle**

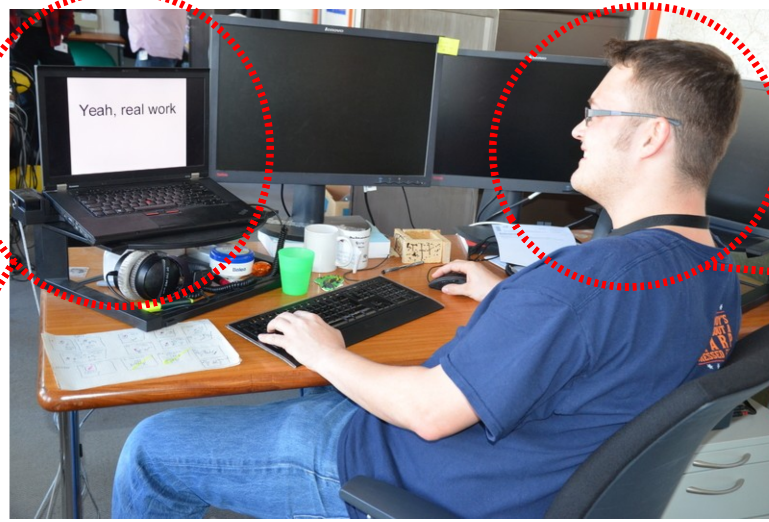
Scheduling on Cores

- Most systems have more programs than CPUs
- So the OS will have to schedule them (time multiplexing)
- Such scheduling is called Context switching

- So in our metaphor we have multiple people of the same privilege level using a laptop …

Scheduling on Cores

CPU busy

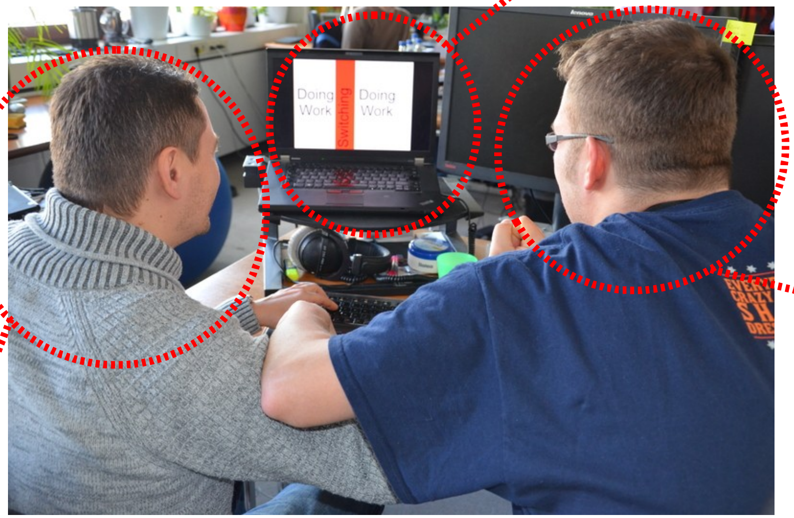


Application working

- Well, that is easy a single program means no context switches

Scheduling on Cores

CPU busy, for work and overhead



Application working

Application working

- With two programs the OS has to switch them every now and then
  - Every program shall get its fair share
  - Switching causes overhead
    - Some CPU time is no more used for the actual work done by the programs (red)

Scheduling on Cores

Applications trying
to working

CPU busy, but primarily for overhead

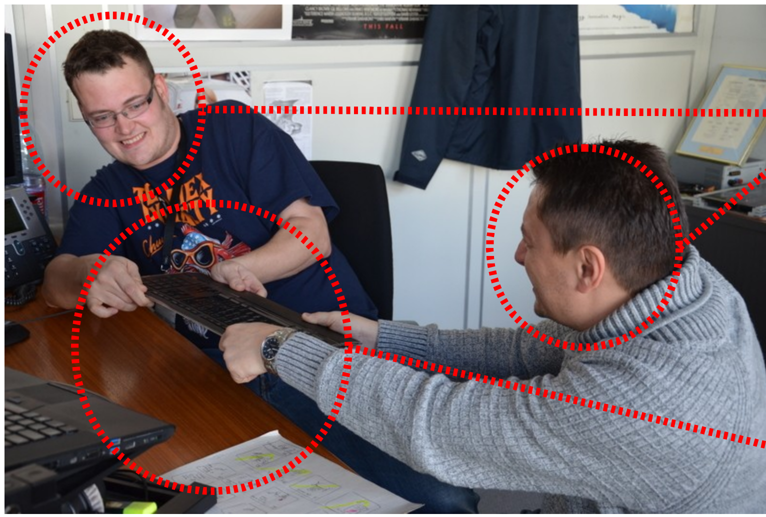
Add steal time if you want real trouble

- With too much runnable programs per CPU the OS gets in trouble
  - Actually with any shared resource being shared a lot
- Eventually there are two bad options to chose from
  - Real throughput converging to zero (latency optimized)
  - Individual applications have to wait longer (throughput optimized)

Scheduling on Cores

- There are ways to switch cooperatively
  - On all blocking system calls like reads, timer sleeps
  - On explicit generic or directed context switch
    - local (yield / yield_to)
    - virtual (diagnose X'44'/ diagnose X'9C')

Scheduling on Cores



greedy Applications

OS has to interrupt and switch
→ non voluntary

- There are ways to switch cooperatively … or not
  - OS can always interrupt and switch
  - Actually it looks more like one works and one has to wait, but we fight ...

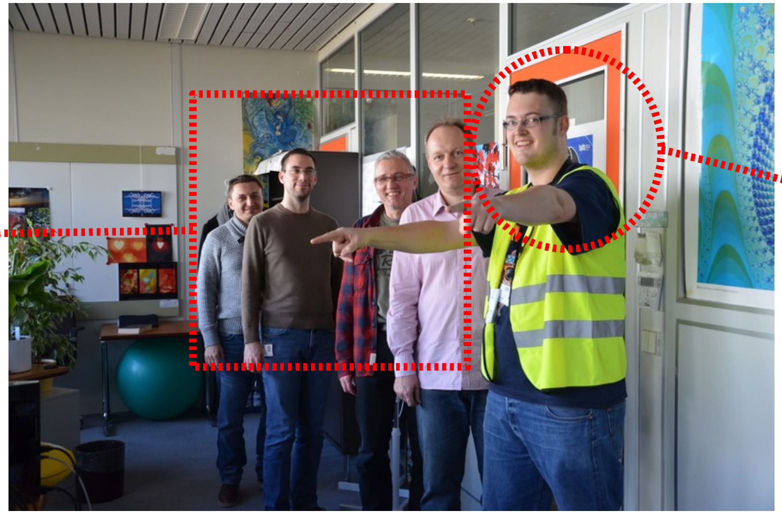
Scheduling between Cores

- Most systems also have more than one CPU
- So the OS will have to schedule/dispatch programs on them
  - most “classic” System z Operating Systems use single queue dispatchers (z/OS, z/VM)
  - Linux has a multi queue scheduler (one queue per CPU)
    - Tasks are migrated to or pulled from cpus

- So in our metaphor we have
  - multiple people and a scheduler
  - in our office being a 4 laptop (CPU core)

Scheduling between Cores

4 Applications
in queue

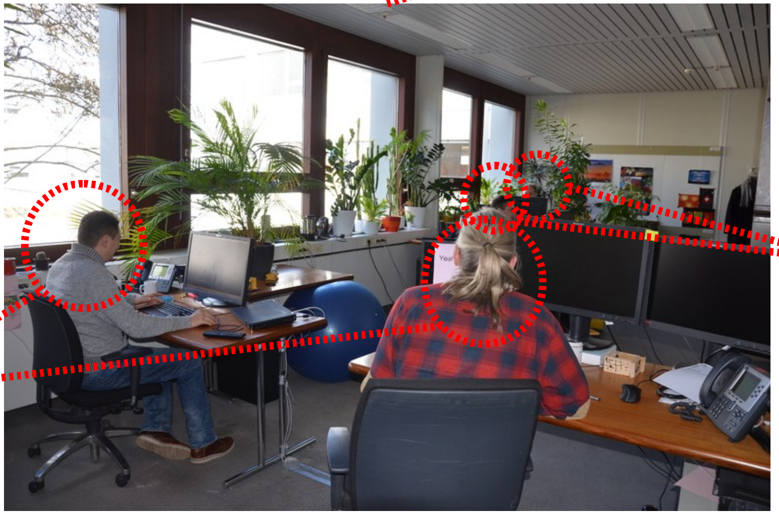


Dispatcher

- Single Queue scheduling
  - One scheduler instance directs programs to the CPU cores
  - Benefit of single control point and easy synchronization

Scheduling between Cores

No need for the scheduler(s) to do anything



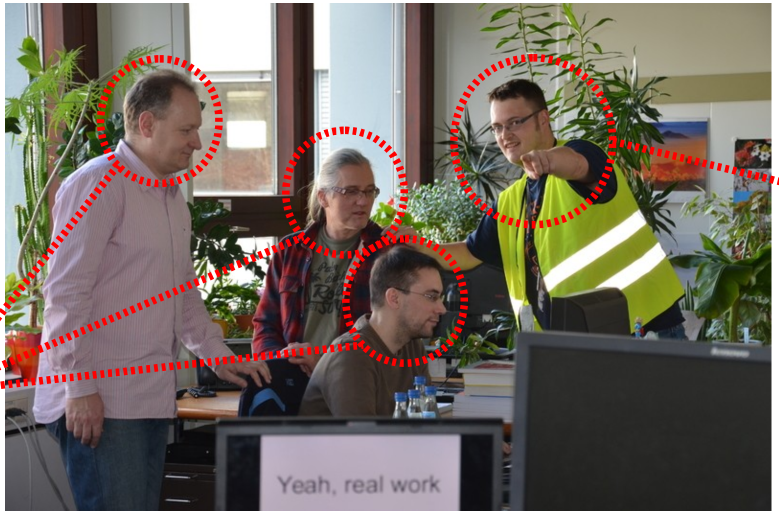
Applications in local runqueue

Applications in local runqueue

- Multi queue scheduler
  - Here with the usual optimum of queues with 1 Program each
  - There are cases where it is better to leave one CPU idle
    - When two task are bound by the speed of their communication
  - You can also see topology here, as some cores are more “remote” than others

Scheduling between Cores

3 Applications
in local runqueue



Scheduler
migrates task

- Multi queue scheduler
  – Here one queue got rather full and a scheduler starts migrating tasks

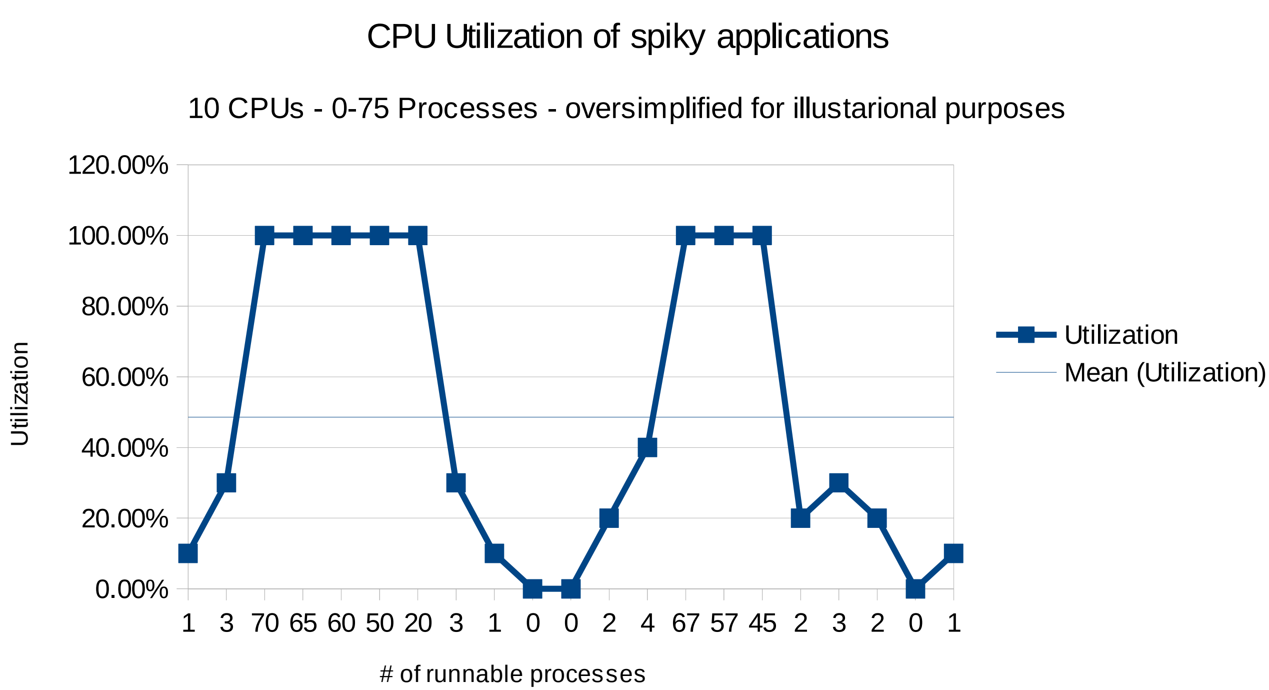
Scheduling / Utilization – Combo Quiz

- Based on a real customer case
  - Database with a lot of stored procedures that does parallelization
  - 0-75 runnable processes varying a lot in a “spiky” fashion
  - They tried various setups, initially 10, later 4 to 20 real CPU cores
  - They didn't achieve their expected target utilization of 85%+ USR

- Question 1: Why was the utilization with 10 CPUs so low at an average of ~45% despite up to 75 runnable processes?

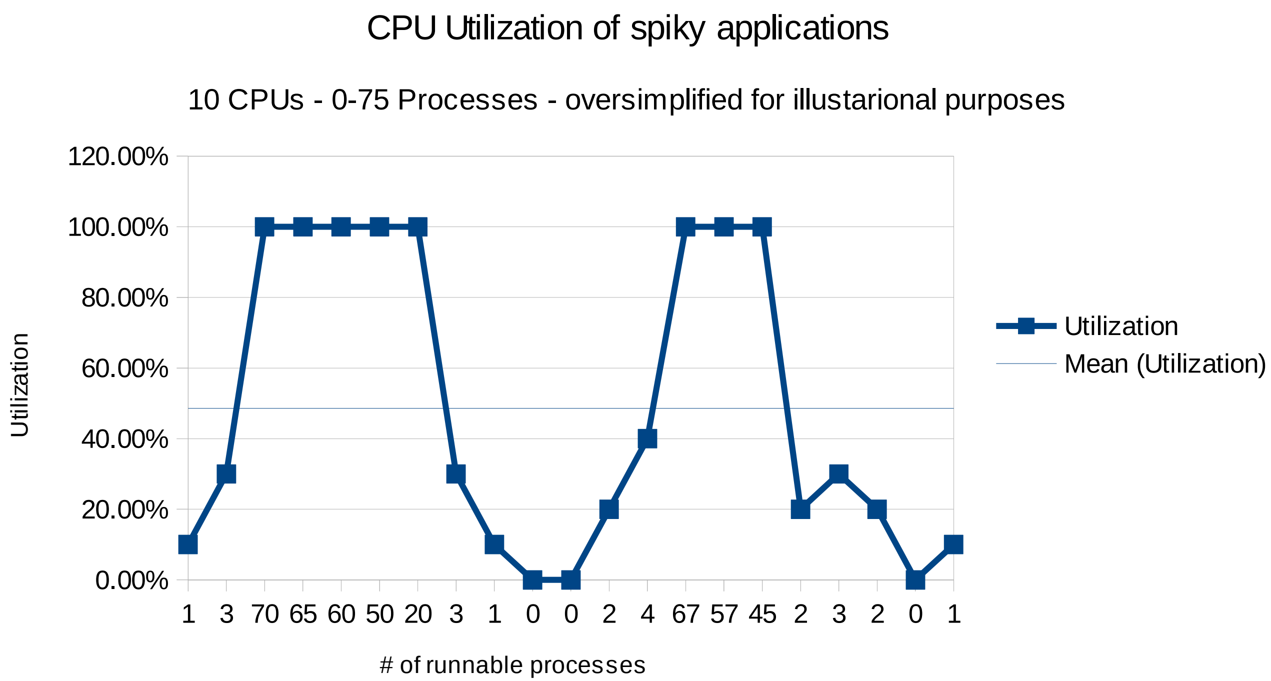
Scheduling / Utilization – Combo Quiz

- Question 1: why was the utilization so low at ~45%?
- Eventually one can never get >100%, but easily less
  - Could the scheduler do anything about it? → No
  - Would it be different with a single queue scheduler? → No



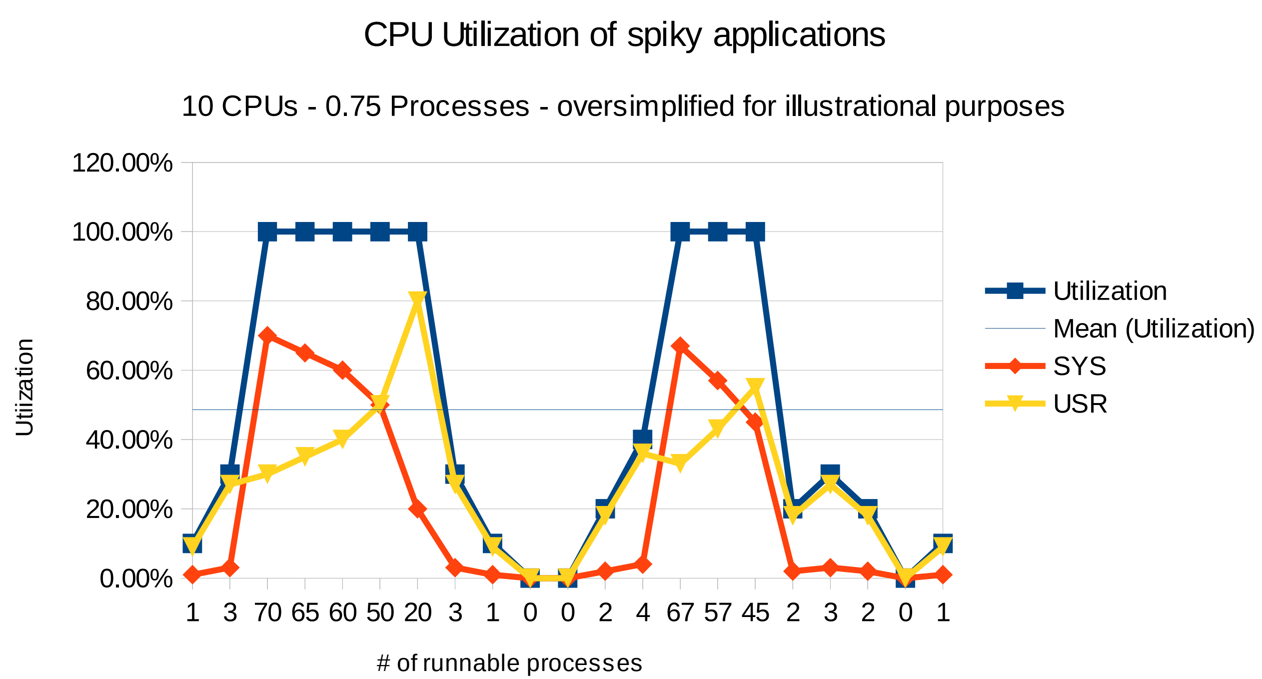
Scheduling / Utilization – Combo Quiz

- Question 2: Why did they achieve the following by changing cpu count?
  - low # of CPUs: fully utilized, but now with a lot of SYS overhead
  - high # of CPUs: even more underutilized but with almost no SYS overhead



Scheduling / Utilization – Combo Quiz

- Question 2: Why did they achieve the following by changing cpu count?
  - low # of CPUs: fully utilized, but now with a lot of SYS overhead
    - Context switch overhead
  - high # of CPUs: even more underutilized but with almost no SYS overhead
    - Even more times of #runnable << #CPUs



Scheduling / Utilization – Combo Quiz

- Based on a real customer case
  - Database with a lot of stored procedures that does parallelization
  - Runnable processes varied a lot in a "spiky" fashion (range 0-75)
  - They tried various setups, initially 10, later 4 to 20 CPU cores
  - They didn't achieve their expected target utilization of 85%+ USR

- Eventually one can never get >100%, but easily less

- Question 3: Real fix approaches?
  - **Application design (recommended)**
  - **Try to let the Hypervisor make underutilized resources otherwise usable (needs lower priority workload)**

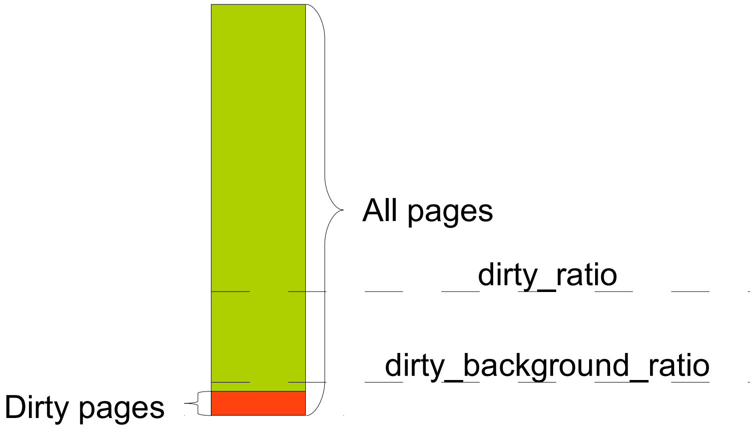
Page Cache

- Keeping disk data available in memory is caching
  - Certain strategies take place
    - What should be cached
    - Read ahead of data that will likely be used
    - Coalesce writes to issue a single disk write for several memory writes
  - Proper management of caches can be complex (read cpu intensive)

- Imagine processes are kids
  - There is obviously some privileged person (kernel) watching
  - If I learned something they surely will make a mess over time (dirty pages)
  - As long as the kids just watch all their toys (read) things stay clean
  - But when they really play with things (write) the room gets messy (dirty)
  - How are things cleaned up?

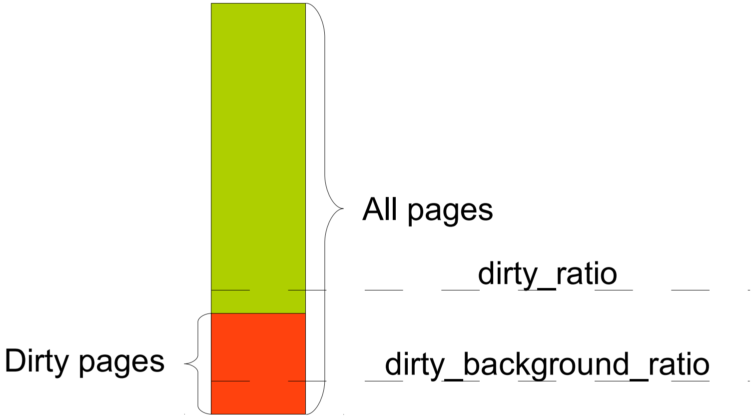
Page Cache – Cleaning I

- If things stay relatively clean nobody cleans anything
  Linux tunable: (`% dirty pages < dirty_background_ratio`)
  - Only long unused items are put back where they belong
    Linux tunable: (`dirty_expire_centisecs`)



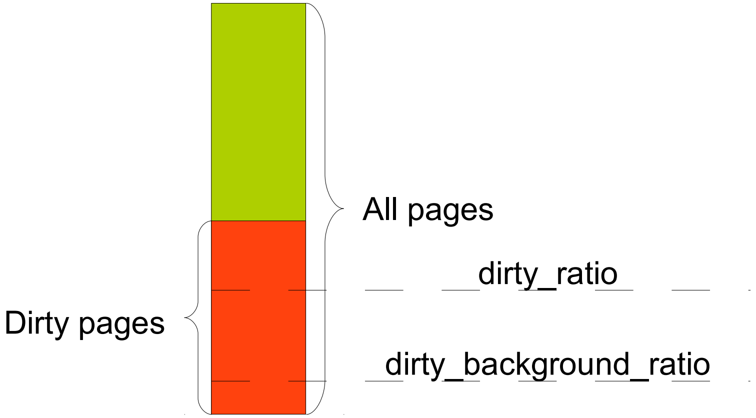
Page Cache – Cleaning II

- As long as the amount of dirtiness is in a sane range it is likely that the parents will clean a bit in background
  Linux tunable: (`dirty pages in % > dirty_background_ratio`)
  - Cleaning of dirty pages consumes CPU, done by the kernel
  - Run by the kswap thread(s) and accounted as **SYS**
  - Kernel tries to be nice and stay in background
    (as you don't bother the kids too much the kernel tries not to take away cpu)



Page Cache – Cleaning III

- If the amount of dirtiness rises too a really high level the parents will force the kids to help cleaning up
  Linux tunable: (`dirty pages in % > dirty_ratio`)
  - Now writing processes have to contribute parts of their time slices to the kernel
  - No more nice, but trying to stall those who make pages dirty



Page Cache – further details

- Another complex topic is the “proper” size of cache
  - Ever realized your flat/house is always too small except for cleaning it
  - If you use the kids room as office from 9am-6pm obviously toys have to be moved aside (cache shrink due to other workload)
  - On the other hand if you organize a party it is likely that they will consume more than just the kids room (cache grow due to more I/O)
- Even cleaning up before going to bed exists in IT
  - for actions like hibernate cache has to be cleaned up before going to sleep

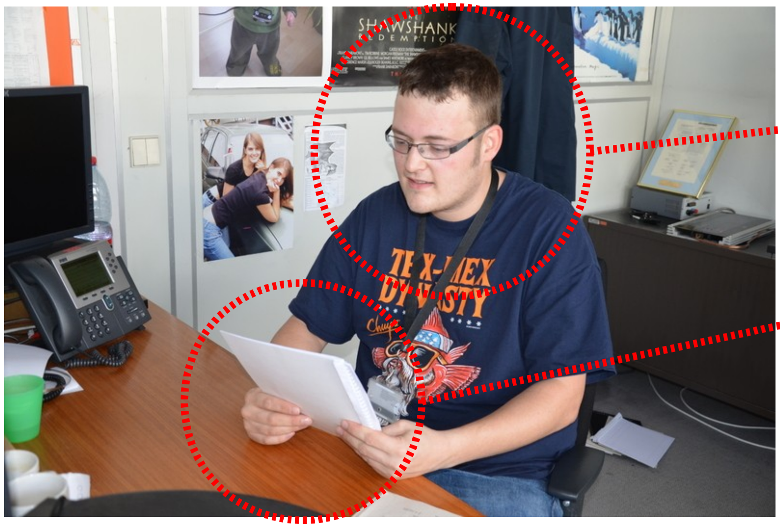
Paging/Swapping

- Spending more memory than available is overcommitment
- In case the accessed memory exceeds the real memory paging has to take place
  - Paging (z/VM) is the same as swapping (Linux)
- As metaphor imagine a notebook page to be your memory ...

Paging/Swapping

- Initially a page is empty, so a process might write onto it

Paging/Swapping



Reading Application

Memory Page

- Later on the process (or someone else) might read from it

Paging/Swapping

Application wants to write

Memory has no free page left

- later the process might have something in mind that he wants to write to the next page
- But all pages the OS could provide are full
  - This now requires swapping (OS level)
  - Or paging (z/VM level)

Paging/Swapping

Literally "back breaking"

Kernel takes over

Swapping can push memory pages to disk (floor) or from disk into memory

- The kernel takes over
  - Swaps out a page (based on least recently used plus some extras)
  - This makes room for a clean new page in real memory
  - Impact high, due to the orders of magnitude between disk and memory
- As you see this burden can literally break the back of your system :-)

Top

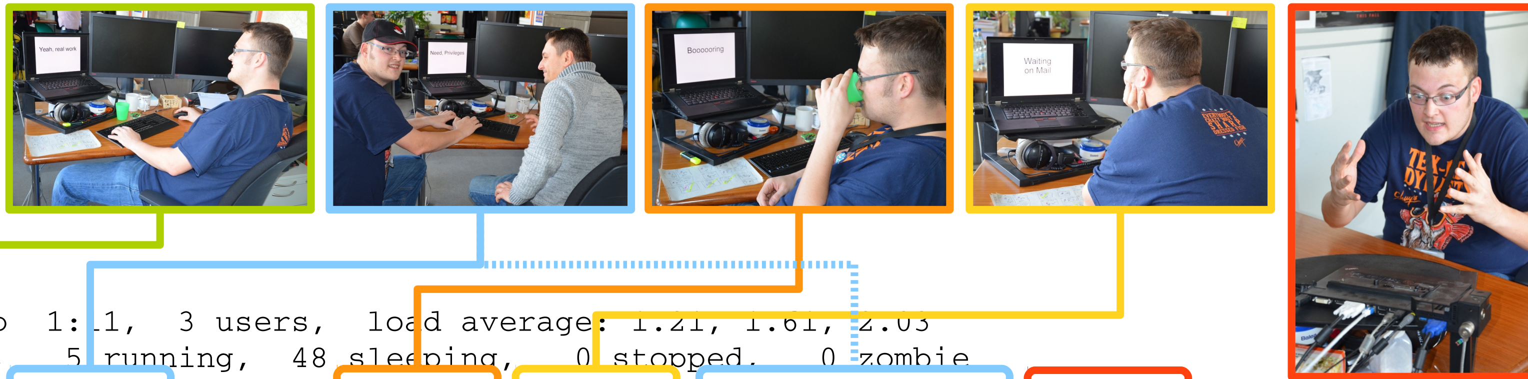
- Characteristics: Easy to use
- Objective: Shows resource usage on process level
- Usage: `top -b -d [interval in sec]  > [outfile]`
- Package: RHEL: procps SLES: procps

- 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.)

- Output

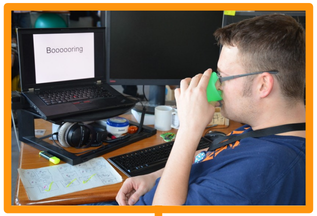


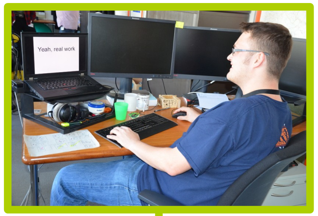
```
top - 11:12:52 up  1:11,  3 users,  load average: 1.21, 1.61, 2.03
Tasks:  53 total,   5 running,  48 sleeping,   0 stopped,   0 zombie
Cpu(s):  3.0%us,  5.9%sy,  0.0%ni, 79.2%id,  9.9%wa,  0.0%hi,  1.0%si,  1.0%st
Mem:   5138052k total,   801100k used,  4336952k free,   447868k buffers
Swap:   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

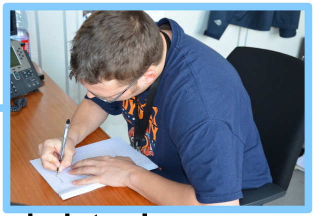




- Shows
  - IDs: Pid, Tid, User, …
  - Status: stat and wchan
  - Details: command, memory consumption and accumulated cpu time

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

…



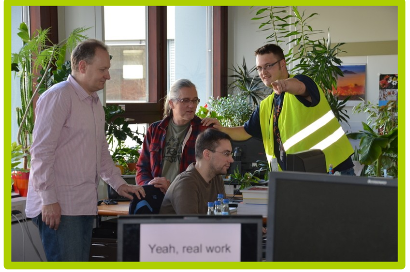
- Hints
  - Do not specify blanks inside the -o format string
  - Status is a one time shot, most interactive or I/O bound processes might sleep

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  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'

Thanks (and complaints) go to

Christian
Ehrhardt

End of Part I

Agenda

Basic
- Utilization
- Scheduling
- Page Cache
- Swapping
- top
- ps
- vmstat

Intermediate
- General thoughts
- Sysstat
- Dasdstat
- Scsi I/O statistics
- iotop
- Lszcrpt
- icastats
- Lsqeth
- Ethtool
- Preparation

Advanced
- Strace
- Ltrace
- Lsof
- Lsluns
- Multipath
- hyptop
- Dstat
- Htop
- Netstat
- Socket Statistics
- Iptraf

Master
- Perf
- slabtop
- Blktrace
- Ziomon
- Tcpdump
- Java Health Center
- Java Garbage Collection and Memory visualizer
- Jinsight

Elite
- Cachestat
- Smem
- Valgrind
- Irqstats
- Wireshark
- Kernel Tracepoints
- Systemtap

Non-legal Disclaimer

- This is an introduction and cheat sheet
  - 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 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
- Work with the tools before an issue occurs
  - Learn what should be normal on your system

Orientation - where to go if something is broken

Tool	Over-View	CPU cons.	lat.	Hot spots	Disk	Mem	Net
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 / ziomon / lsof					x		
Valgrind / smem / slabtop						x	
iptraf	x						x
tracepoints			x	x	x	x	x
iotop					x		
lszcrypt / icastat		x					
lsqeth / ethtool / iftop / iptraf / tcpdump / wireshark							x
lsluns / multipath					x		
Preparation	x	x	x	x	x	x	x

Sysstat - 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

root@h42lp42

File Edit View Terminal Help

```
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

root@h42lp27:~

File Edit View Terminal Tabs Help

```
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)

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

root@h42lp42

File Edit View Terminal Help

```
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

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 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

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

root@h42lp42

File Edit View Terminal Help

```
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

h37lp19 : root

File Edit View Scrollback Bookmarks Settings Help

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
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
10:13:11 AM	16.00	20.00	38.50	0.50	96.00	0.00	0.00	0.00	0.00
10:13:13 AM	0.00	20.00	36.00	0.00	95.50	0.00	0.00	0.00	0.00
10:13:15 AM	2700.00	318.00	698.00	9.00	22343.00	301.00	0.00	287.00	95.35
10:13:17 AM	2.00	20.00	36.00	0.00	60.50	0.00	0.00	0.00	0.00
10:13:19 AM	0.00	20.00	36.00	0.00	61.50	0.00	0.00	0.00	0.00
10:13:21 AM	5558.21	662674.63	2378.11	9.95	147166.17	77842.79	94354.23	146721.39	95.21

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

root@h42lp42

File Edit View Terminal Help

```
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.

Sysstat - 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
```

Recent versions are improved by reporting reads/writes separately which is great as they have vastly different characteristics

Sysstat - 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

Sysstat - mpstat

- Characteristics: Show statistics per processor
- Objective: Identify imbalanced utilization or interrupt peaks
- Usage: `mpstat -A <interval>`
- Package: RHEL: sysstat SLES: sysstat

- Shows
  - `-u` utilization
  - `-I <CPU|SCPU|ALL>` Interrupts

- Hints
  - Can be restricted to selected processor(s) (`-P`)

Sysstat – mpstat example

- As one can see there are plenty of different (s)irq sources these days
  - Ordered horizontally per type and vertically per cpu

- IRQs

```
10:40:12      CPU     EXT/s     I/O/s     AIO/s     CLK/s     EXC/s     EMS/s     TMR/s     TAL/s
PFL/s       DSD/s     VRT/s     SCP/s     IUC/s     CMS/s     CMC/s     CMR/s     CIO/s     QAI/s
DAS/s       C15/s     C70/s     TAP/s     VMR/s     LCS/s     CLW/s     CTC/s     APB/s     ADM/s
CSC/s       PCI/s     MSI/s     VIR/s     VAI/s     NMI/s     RST/s
10:40:17        0      2.40      0.00      0.00      2.00      0.20      0.20      0.00      0.00
  0.00       0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
  0.00       0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
  0.00       0.00      0.00      0.00      0.00      0.00      0.00
10:40:17        1      1.40      0.00      0.00      1.40      0.00      0.00      0.00      0.00
  0.00       0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
  0.00       0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
  0.00
[...]
```

CPU

IRQ type

Rate per second

- SoftIRQs

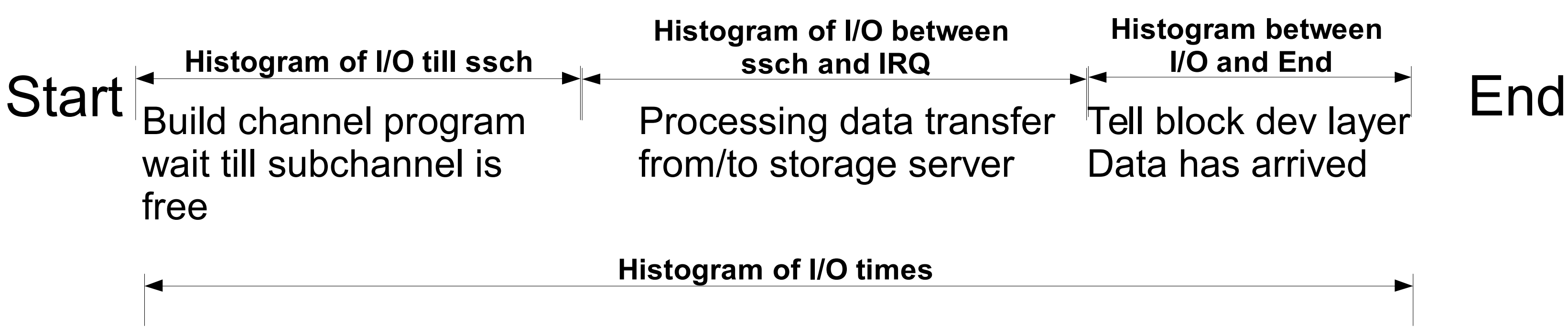
```
10:40:26      CPU      HI/s   TIMER/s  NET_TX/s  NET_RX/s   BLOCK/s BLOCK_IOPOLL/s  TASKLET/s    SCHED/s
HRTIMER/s     RCU/s
10:40:31        0      0.00      0.60      0.00      0.00      0.00      0.00      0.00      1.00
  0.00       0.60
10:40:31        1      0.00      0.00      0.00      0.00      0.00      0.00      0.00      0.00
  0.00       0.00
[...]
```

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

Tool "dasdstat" available to handle that all-in-one

- Shows:
  - various processing times:



DASD statistics – report

- Sample:

8*512b = 4KB <= **request size** < 16*512b =8KB   1ms <= **response time** < 2 ms

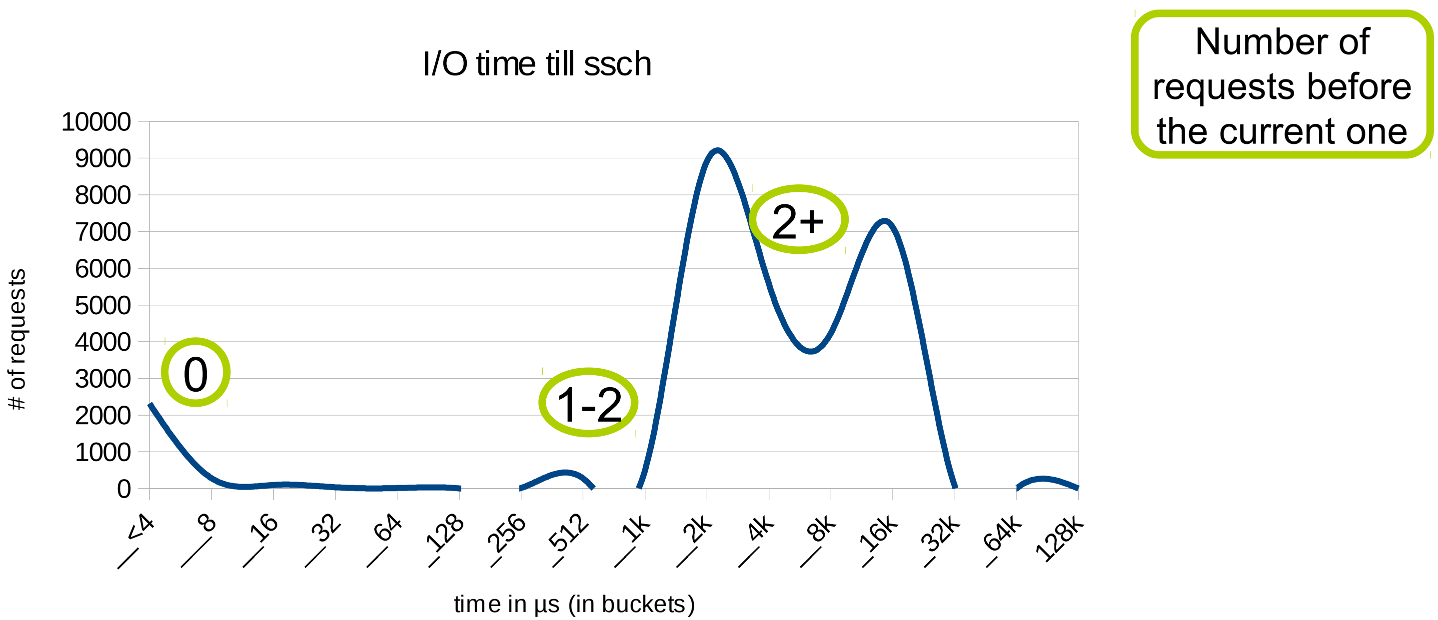
```
29432 dasd I/O requests
with 6227424 sectors(512B each)
   __<4    ___8    __16    __32    __64    _128    _256    _512    __1k    __2k    __4k    __8k    _16k    _32k    _64k    128k
   _256    _512    __1M    __2M    __4M    __8M    _16M    _32M    _64M    128M    256M    512M    __1G    __2G    __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 ← look here for subchannel busy
   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 ← look here for slow SAN
      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 is only confusing

DASD statistics – look for subchannel busy issues

```
  __<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 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
```

- Time consists of
  - “Build subchannel program (usually very fast)
  - wait for a free subchannel (can be long without or too few HPAV)
  - Please be aware that the x axis is scaling by 2^n



FCP statistics

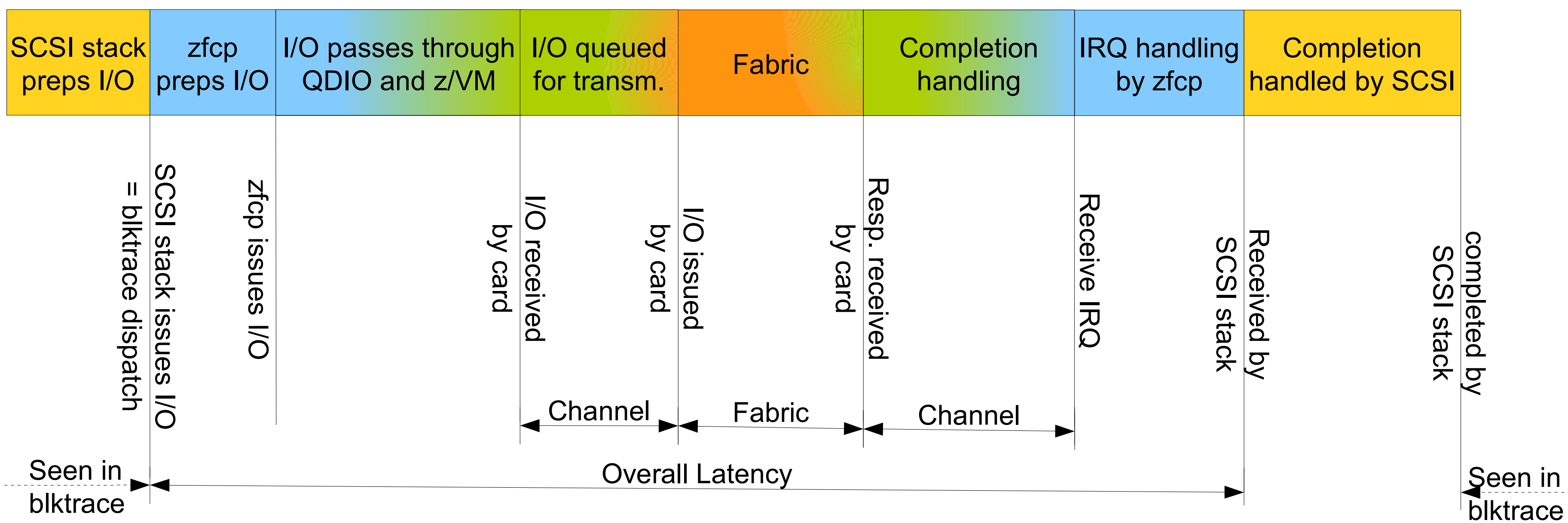
- Characteristics: Detailed latency information for FCP I/O
- Objective: Collect details of I/O operations on FCP devices
- Package: n/a (Kernel interface)

- 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

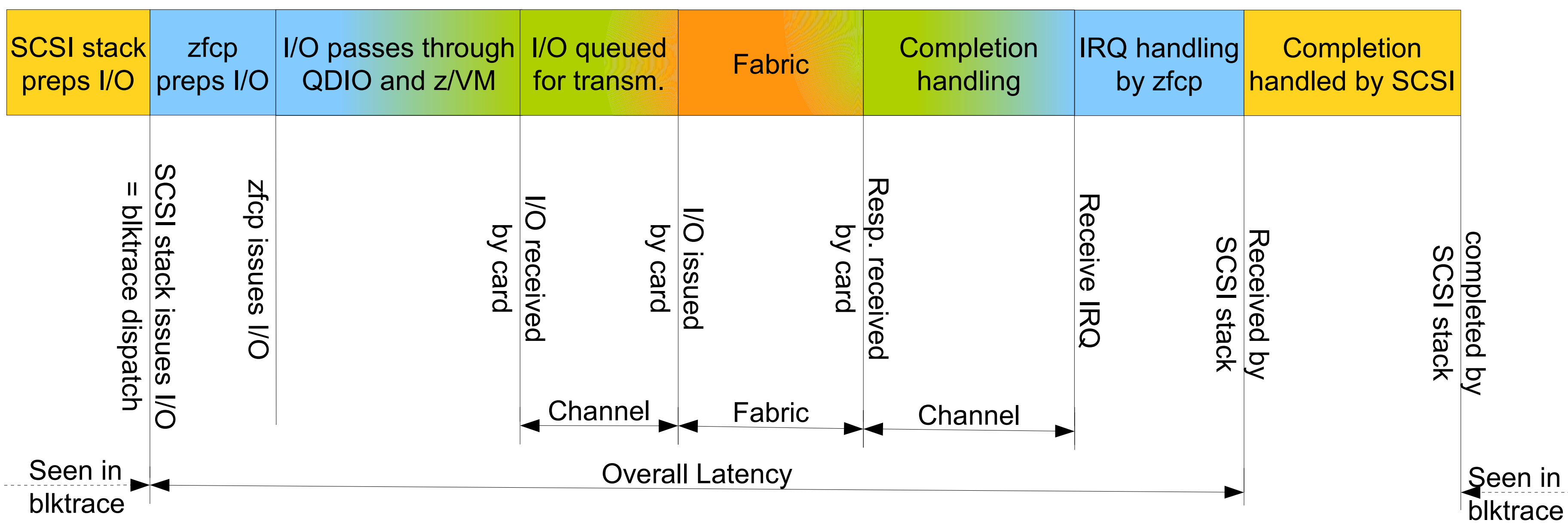
FCP statistics

- Shows:
  - Request sizes in bytes (hexadecimal)
  - Channel latency in ns Time spent on the FCP channel (internal transfer)
  - Fabric latency in ns Time spent in the FCP fabric (outside transfer)
  - (Overall) latencies whole time spent entry/exit of the zFCP layer in ms



FCP statistics

- On popular request – the “where to complain” color coding
  - Linux developers / Distributor in general
  - zfcp/qdio (optional also z/VM) developers
  - FCP card HW/FW stack
  - SAN



FCP statistics example – rather unreadable

```
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

FCP statistics example

- Some statistics are per device
- Some per adapter
  - Adapter statistics can not be reset
- Example beautifying the same data with a little script (not public yet)

per device latency statistics (f - fabric; c - channel)

disk	rd-fmin	rd-fmax	rd-fsum	rd-favg	rd-cmin	rd-cmax	rd-csum	rd-cavg	rd-cnt | wr-* [..wr/cmd]
sda	92	130	1386	126.00	7	10	98	8.91	11
sdb	127	131	2072	129.50	7	10	140	8.75	16
sdc	126	140	2075	129.69	7	14	145	9.06	16
sdd	126	132	1160	128.89	7	8	74	8.22	9
[...]									
sdbd	n/a	n/a	0	0.00	n/a	n/a	0	0.00	0
sdbe	n/a	n/a	0	0.00	n/a	n/a	0	0.00	0

per adapter statistics

adapter (subch/dev)	rd-cnt	rd-mb	rd-avgsz	wr-cnt	wr-mb	wr-avgsz	cmd-cnt	sec-active
0.0.0004/0.0.1700	4899	18	3.76	11572	1249	110.52	240	17324
0.0.000c/0.0.1800	4901	16	3.34	11564	1265	112.02	236	17325
0.0.00d6/0.0.5100	4765	16	3.44	11595	1254	110.75	239	17318
0.0.00e2/0.0.5b00	1888	5	2.71	0	0	0.00	160	17309

iotop

- Characteristics: simple, top like I/O monitor
- Objective: Check which processes are doing I/O
- Usage: `iotop`
- Package: RHEL: iotop SLES: iotop

- Shows
  - Read/Write per thread
  - Can accumulate (-a) for updating summaries instead of live views
    - Useful for Disk I/O tests that don't account on their own
  - Separate accounting for swap

- Hints
  - Can be restricted to certain processes via (`-p`)
  - Has a batch mode like top

Iotop - examples

- Example I: disk I/O can be spread other than expected

System wide totals

```
Total DISK READ:      24.05 M/s | Total DISK WRITE:      31.19 K/s
  TID  PRIO  USER     DISK READ  DISK WRITE  SWAPIN     IO>    COMMAND
 7204 be/4 qemu     378.16 K/s    0.00 B/s  0.00 %  6.16 % qemu-system-s390x -machine accel=kvm -name p1035002 -S -ma
 7231 be/4 qemu     350.87 K/s    0.00 B/s  0.00 %  6.08 % qemu-system-s390x -machine accel=kvm -name p1035002 -S -ma
 7225 be/4 qemu     343.08 K/s   19.49 K/s  0.00 %  6.00 % qemu-system-s390x -machine accel=kvm -name p1035002 -S -ma
 7228 be/4 qemu     346.97 K/s    0.00 B/s  0.00 %  6.00 % qemu-system-s390x -machine accel=kvm -name p1035002 -S -ma
 7174 be/4 qemu     362.57 K/s    0.00 B/s  0.00 %  5.96 % qemu-system-s390x -machine accel=kvm -name p1035002 -S -ma
 7203 be/4 qemu     393.76 K/s    0.00 B/s  0.00 %  5.94 % qemu-system-s390x -machine accel=kvm -name p1035002 -S -ma
```

Read / Write per process

- Example II: even interesting for memory bound (overcommitted) loads

```
08:13:16 Total DISK READ:  971957.16 K/s | Total DISK WRITE:  180500.41 K/s
    TIME  TID  PRIO  USER     DISK READ  DISK WRITE  SWAPIN      IO    COMMAND
08:13:16  8950 be/4 root     7732.35 K/s    0.00 K/s 35.54 %  2.99 %  /mempighd-pf2 -s 2240 -d 1200 -p 32 -w 32 -x
08:13:16  8953 be/4 root     4057.11 K/s    0.00 K/s 23.10 %  2.98 %  /mempighd-pf2 -s 2240 -d 1200 -p 32 -w 32 -x
08:13:16  8947 be/4 root     6496.12 K/s    0.00 K/s 28.59 %  2.86 %  /mempighd-pf2 -s 2240 -d 1200 -p 32 -w 32 -x
08:13:16  8891 be/4 root     6563.95 K/s    0.00 K/s 42.70 %  2.78 %  /mempighd-pf2 -s 2240 -d 1200 -p 32 -w 32 -x
08:13:16  8945 be/4 root     6790.11 K/s    0.00 K/s 30.59 %  2.76 %  /mempighd-pf2 -s 2240 -d 1200 -p 32 -w 32 -x
08:13:16  8958 be/4 root     7033.54 K/s    0.00 K/s 30.03 %  2.74 %  /mempighd-pf2 -s 2240 -d 1200 -p 32 -w 32 -x
08:13:16  8960 be/4 root     5374.43 K/s    0.00 K/s 24.38 %  2.71 %  /mempighd-pf2 -s 2240 -d 1200 -p 32 -w 32 -x
```

% of time while swapping in

% of time waiting for I/O

Lszcrypt / icastats

- Characteristics: overview of s390 crypto HW and libica usage
- Objective: am I really using my crypto hardware
- Usage: "`lszcrypt -VV[V]`" "`cat /proc/icastats`"
- Package: RHEL: s390utils-base SLES: s390-tools

```
lszcrypt -VV
card02: CEX3C       online  hwtype=9  depth=8
request_count=443
card03: CEX3A       offline hwtype=8  depth=8
request_count=0
```

```
Cat/proc/icastats
function | # hardware | # software
----------+------------+-----------
    SHA-1 |          0 |          0
  SHA-224 |          0 |          0
  SHA-256 |          0 |          0
  SHA-384 |          0 |          0
  SHA-512 |          0 |          0
   RANDOM |     187109 |          0
 MOD EXPO |          0 |          0
  RSA CRT |      93554 |          0
  DES ENC |          0 |          0
  DES DEC |          0 |          0
 3DES ENC |          0 |          0
 3DES DEC |          0 |          0
  AES ENC |    2574106 |          0
  AES DEC |    2075854 |          0
 CMAC GEN |          0 |          0
 CMAC VER |          0 |          0
```

- Never assume your HW correctly is used until you confirmed it
  - If not going via libica (e.g. Java pkcs#11 you won't see it in icastat)

lsqeth

- Characteristics: overview of network devices
- Objective: check your network devices basic setup
- Usage: "`lsqeth -p`"
- Package: RHEL: s390-utils-base SLES: s390-tools

```
lsqeth -p
devices                    CHPID interface   cardtype       port chksum prio-q'ing rtr4 rtr6 lay'2 cnt
-------------------------- ----- ----------- -------------- ---- ------ ---------- ---- ---- ----- -----
0.0.e000/0.0.e001/0.0.e002 x84   eth1        OSD_10GIG      0    sw     always_q_2 n/a  n/a  1     64
0.0.e100/0.0.e101/0.0.e102 x85   eth2        OSD_10GIG      0    sw     always_q_2 n/a  n/a  1     64
0.0.f200/0.0.f201/0.0.f202 x6B   eth0        OSD_1000       0    hw     always_q_2 no   no   0     64
```

- Check for layer, offload, and buffer counts
  - More buffers are usually better especially for massive amounts of concurrent connections

Ethtool I

- Characteristics: overview of network device capabilities / offload settings
- Objective: check your network device (offload) settings
- Usage: "`ethtool <dev>`", "`ethtool -k <dev>`"
- Package: RHEL: ethtool SLES: ethtool

```
ethtool eth1
Settings for eth1:
        Supported ports: [ FIBRE ]
        Supported link modes:   10baseT/Half 10baseT/Full
                                100baseT/Half 100baseT/Full
                                1000baseT/Half 1000baseT/Full
                                10000baseT/Full
        Supported pause frame use: No
        Supports auto-negotiation: Yes
        Advertised link modes:  10baseT/Half 10baseT/Full
                                100baseT/Half 100baseT/Full
                                1000baseT/Half 1000baseT/Full
                                10000baseT/Full
        Advertised pause frame use: No
        Advertised auto-negotiation: Yes
        Speed: 10000Mb/s
        Duplex: Full
        Port: FIBRE
        PHYAD: 0
        Transceiver: internal
        Auto-negotiation: on
        Link detected: yes
```

- Check e.g. announced speeds

Ethtool II

- Offload Settings via "`ethtool -k <dev>`"
- Changes via upper case "-K"

```
ethtool -k eth1
Features for eth1:
rx-checksumming: off [fixed]
tx-checksumming: off
        tx-checksum-ipv4: off [fixed]
        tx-checksum-ip-generic: off [fixed]
        tx-checksum-ipv6: off [fixed]
        tx-checksum-fcoe-crc: off [fixed]
        tx-checksum-sctp: off [fixed]
scatter-gather: off
        tx-scatter-gather: off [fixed]
        tx-scatter-gather-fraglist: off [fixed]
tcp-segmentation-offload: off
        tx-tcp-segmentation: off [fixed]
        tx-tcp-ecn-segmentation: off [fixed]
        tx-tcp6-segmentation: off [fixed]
udp-fragmentation-offload: off [fixed]
generic-segmentation-offload: off [requested on]
generic-receive-offload: on
large-receive-offload: off [fixed]
rx-vlan-offload: off [fixed]
tx-vlan-offload: off [fixed]
[...]
```

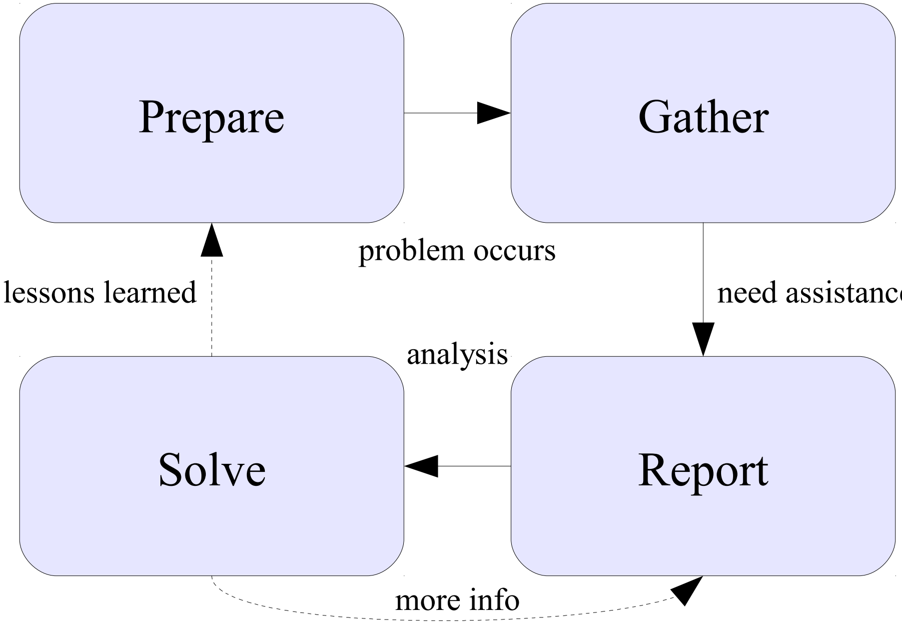
```
[…]
ntuple-filters: off [fixed]
receive-hashing: off [fixed]
highdma: off [fixed]
rx-vlan-filter: on [fixed]
vlan-challenged: off [fixed]
tx-lockless: off [fixed]
netns-local: off [fixed]
tx-gso-robust: off [fixed]
tx-fcoe-segmentation: off [fixed]
tx-gre-segmentation: off [fixed]
tx-udp_tnl-segmentation: off [fixed]
fcoe-mtu: off [fixed]
tx-nocache-copy: off
loopback: off [fixed]
rx-fcs: off [fixed]
rx-all: off [fixed]
tx-vlan-stag-hw-insert: off [fixed]
rx-vlan-stag-hw-parse: off [fixed]
rx-vlan-stag-filter: off [fixed]
```

- In some cases external influences like OSA-layer2 prevent most offloads (the example here)

Don't miss preparation

- Of all tools preparation is clearly
  - The most important
  - The most effective

- Prepare
  - System and Workload descriptions
  - Healthy system data for comparison
- Gather
  - In case of emergency
- Report
  - How to report a Problem Description
- Solve
  - Tools to start an analysis



Don't miss preparation

This is like “Heisenbergs uncertainty principle”
The more time you put into preparation,
the less time you'll need to solve issues
They fundamentally are never both huge,
What do you prefer?

- Of all tools preparation is clearly
  - The most important
  - The most effective

- Prepare
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  - In case of emergency
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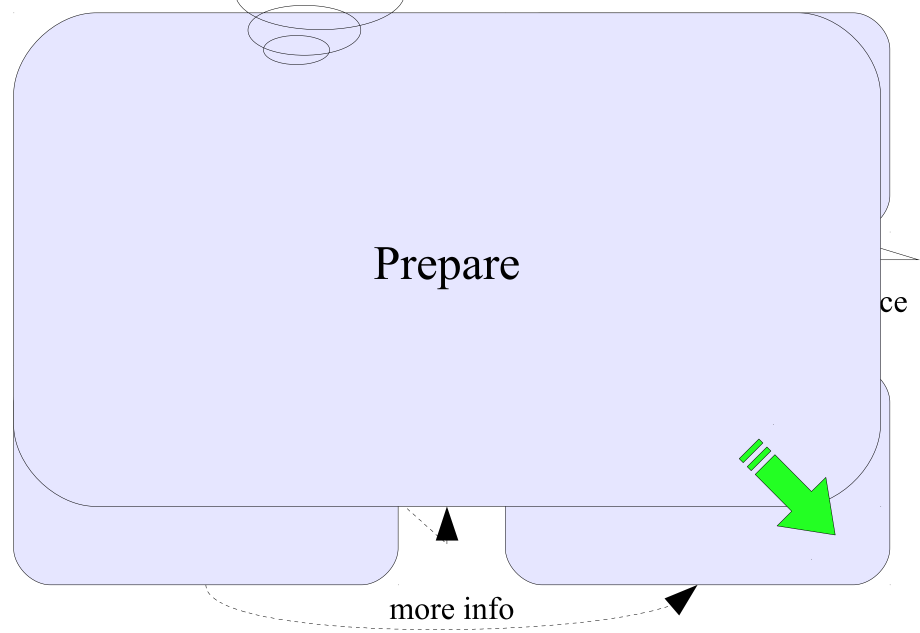

Don't miss preparation

- Of all tools preparation is clearly
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- Prepare
  - System and Workload descriptions
  - Healthy system data for comparison
- Gather
  - In case of emergency
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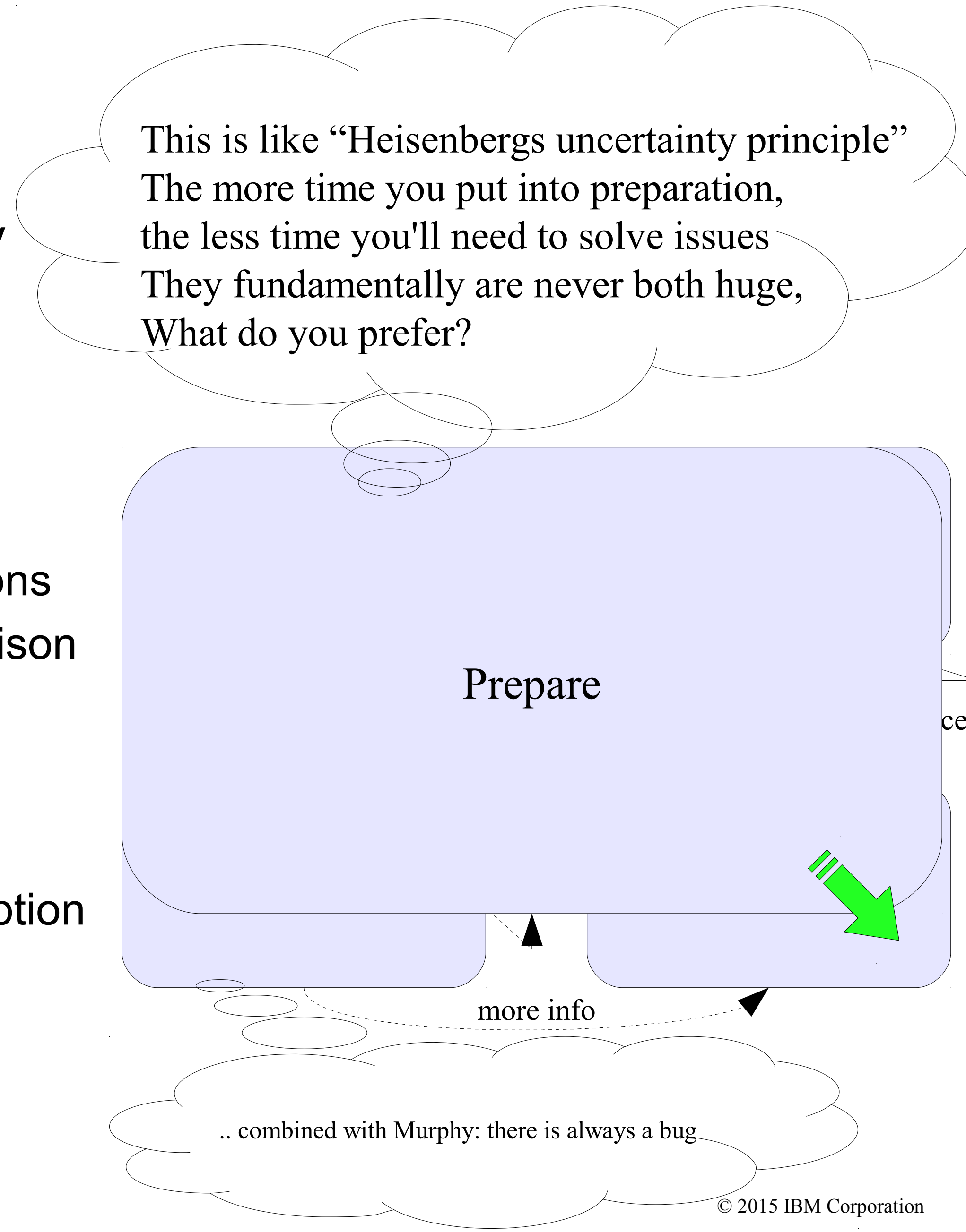

Don't miss preparation

- Of all tools preparation is clearly
  - The most important
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- Prepare
  - System and Workload descriptions
  - Healthy system data for comparison
- Gather
  - In case of emergency
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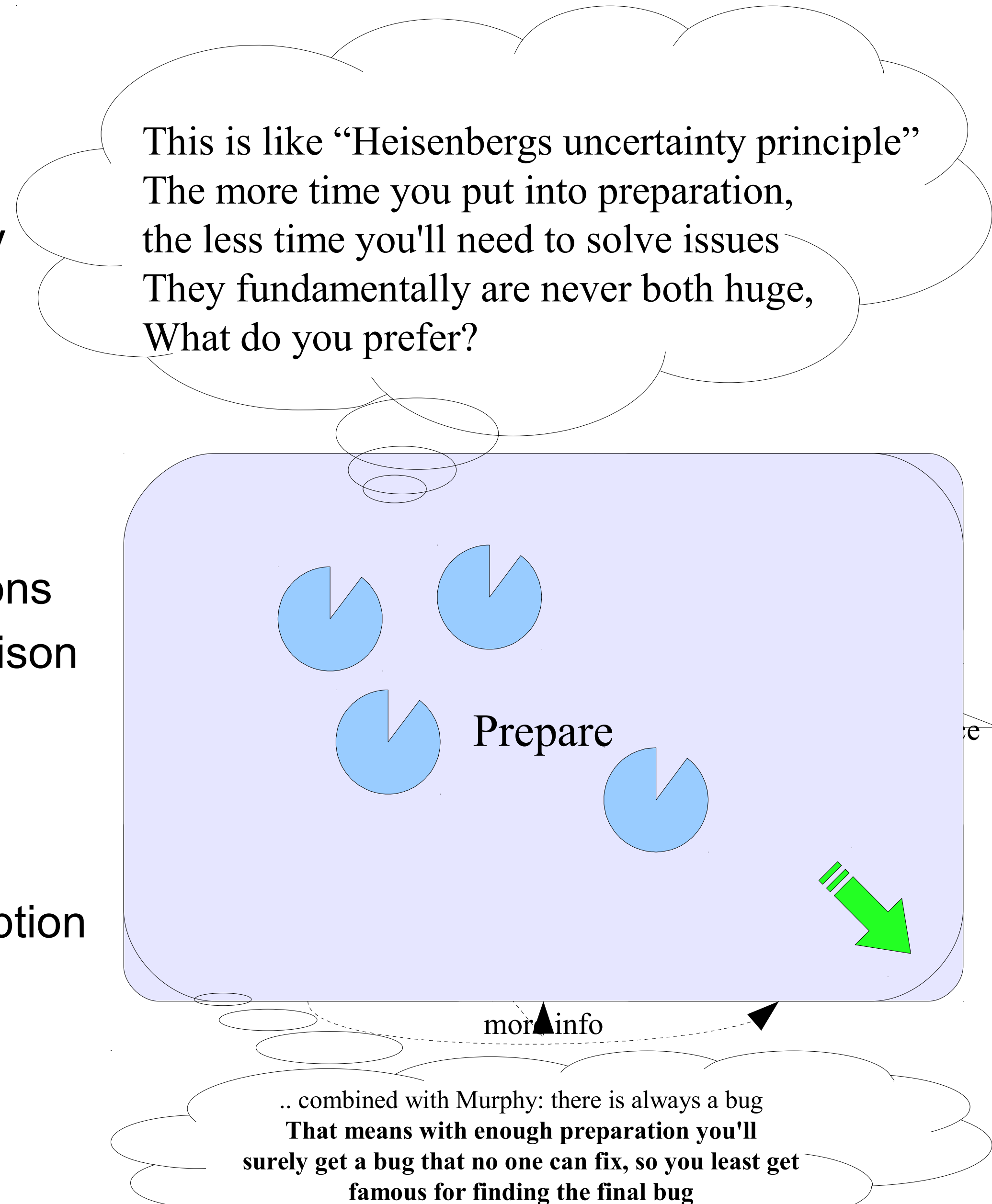
  - Tools to start an analysis



Share: Your chance to win … some love

- Thanks for staying with me, now your final test

- When should you start using all those tools?
- Valid answers:
  - prior to error
  - tomorrow
  - in preparation
  - better soon
  - with any new hire
  - immediately
  - "silence" as you are already busy planning to work with it

Thanks (and complaints) go to

Christian
Ehrhardt

End of Part II

Agenda

Basic

- Utilization
- Scheduling
- Page Cache
- Swapping

- top
- ps
- vmstat

Intermediate

- General thoughts
- Sysstat
- Dasdstat
- Scsi I/O statistics
- iotop
- Lszcrpt
- icastats
- Lsqeth
- Ethtool
- Preparation

Advanced

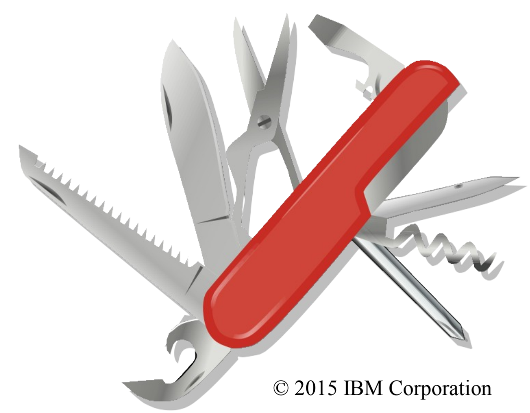
- Strace
- Ltrace
- Lsof
- Lsluns
- Multipath
- hyptop
- Dstat
- Htop
- Netstat
- Socket Statistics
- Iptraf

Master

- Perf
- slabtop
- Blktrace
- Ziomon
- Tcpdump
- Java Health Center
- Java Garbage Collection and Memory visualizer
- Jinsight

Elite

- Cachestat
- Smem
- Valgrind
- Irqstats
- Wireshark
- Kernel Tracepoints
- Systemtap



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\0\17\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"..., 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>
```


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, ...

lsluns

- Characteristics: overview of multipathing
- Objective: check your multipath setup hierarchy
- Usage: "`lsluns -a`"
- Package: RHEL: s390utils-base SLES: s390-tools

```
lsluns -a
adapter = 0.0.1700
        port = 0x500507630900c7c1
                lun = 0x4020402100000000        /dev/sg0        Disk    IBM:2107900
                lun = 0x4020402200000000        /dev/sg1        Disk    IBM:2107900
                lun = 0x4020402300000000        /dev/sg2        Disk    IBM:2107900
                lun = 0x4021402100000000        /dev/sg3        Disk    IBM:2107900
                lun = 0x4021402200000000        /dev/sg4        Disk    IBM:2107900
                lun = 0x4021402300000000        /dev/sg5        Disk    IBM:2107900
adapter = 0.0.1780
        port = 0x500507630903c7c1
                lun = 0x4020402100000000        /dev/sg17       Disk    IBM:2107900
                lun = 0x4020402200000000        /dev/sg23       Disk    IBM:2107900
                lun = 0x4020402300000000        /dev/sg32       Disk    IBM:2107900
                lun = 0x4021402100000000        /dev/sg39       Disk    IBM:2107900
                lun = 0x4021402200000000        /dev/sg43       Disk    IBM:2107900
                lun = 0x4021402300000000        /dev/sg46       Disk    IBM:2107900
[...]
```

- Lsluns provides a hierarchical view which often easily identifies missing paths, adapters or similar imbalances
- Adapter to WWPN associations can have concurring targets
  - Low overhead, max fallback capability, best performance, ...

Multipath -ll

- Characteristics: overview of multipathing
- Objective: check your multipath setup configuration
- Usage: “`mutlipath -ll`”
- Package: RHEL: device-mapper-multipath SLES: mutlipath-tools

```
multipath -ll
swap-3of6 (36005076309ffc7c10000000000002022) dm-2 IBM     ,2107900
size=256G features='0' hwhandler='0' wp=rw
`-+- policy='service-time 0' prio=0 status=active
  |- 0:0:20:1075986464 sdb  8:16   active ready running
  |- 1:0:22:1075986464 sdx  65:112 active ready running
  |- 2:0:21:1075986464 sdh  8:112  active ready running
  |- 3:0:20:1075986464 sdn  8:208  active ready running
  |- 4:0:26:1075986464 sdz  65:144 active ready running
  |- 5:0:19:1075986464 sdy  65:128 active ready running
  |- 7:0:25:1075986464 sdac 65:192 active ready running
  `- 6:0:24:1075986464 sdad 65:208 active ready running
[...]
```

- This also reports multipath.conf inconsitencies
- Check all reported parameters are what you thought them to be
  - For example (in)famous rr_min_io renaming

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 (str)	#cpu (#)	cpu (%)	Cpu+ (hm)	online (dhm)	memuse (GiB)	memmax (GiB)	wcur (#)
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

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 -vtin`
- 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

```
Report nice bugs to bug-coreutils@gnu.org
GNU coreutils home page: <http://www.gnu.org/software/coreutils/>
General help using GNU software: <http://www.gnu.org/gethelp/>
For complete documentation, run: info coreutils 'nice invocation'
[root@r3729001 ~]# nice -n 1 dstat -tv --aio --disk-util -n --net-packets -i --ipc -D total,sda --top-io --noupdate 5
----system---- ---procs--- ------memory-usage----- ---paging-- -dsk/total----dsk/sda-- ---system-- ----total-cpu-usage---- async sda- -
     time     |run blk new| used  buff  cach  free|  in   out | read  writ: read  writ| int   csw |usr sys idl wai hiq siq| #aio|util|
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   3  92   0   0   1|   0 |1.59|
17-07 17:41:24| 13   0   0|1307M 13.5M 10.4G 57.2M|   0     0 |1708k   30k:  45k    0 |   0   16k| 33   9  55   0   0   3|   0 |0.20|
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  15  17   0   0   5|   0 |0.20|
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  17   6   0   0   6|   0 |   0|
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  18   0   0   0   6|   0 |0.40|
17-07 17:41:44| 13   0   0|1318M 13.6M 10.4G 53.1M|   0     0 |1601k   16k:  37k    0 |   0   14k| 75  19   0   0   0   6|   0 |0.40|
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  28   0   0   0   5|   0 |0.20|
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   6  65   0   0   2|   0 |0.20|
```

●●

similar to vmstat

similar to iostat
(also per device)

new in live tool

●●●

```
kets -i --ipc -D total,sda --top-io --noupdate 5
tal----dsk/sda-- ---system-- ----total-cpu-usage---- async sda- -net/total- -pkt/total- inter --sysv-ipc- ----most-expensive----
writ: read  writ| int   csw |usr sys idl wai hiq siq| #aio|util| recv  send|#recv #send|  1  |msg sem shm|     i/o process
  14M: 124k  337k|   0  4968 |  4   3  92   0   0   1|   0 |1.59|   0     0 |   0     0 | 300 |  0  35   1|sshd          15M   25M
  30k:  45k    0 |   0   16k| 33   9  55   0   0   3|   0 |0.20|  21B  426B|0.40  0.40 |  81 |  0  35   1|postgres: p  78k     0
  19k:  60k    0 |   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:  32k    0 |   0   11k| 71  17   6   0   0   6|   0 |   0| 142B  148B|0.60  0.20 |  62 |  0  35   1|postgres: p 141k     0
  23k:  26k    0 |   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
  16k:  37k    0 |   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
  16k:  31k    0 |   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
3277B:  40k    0 |   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 a 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:
```

Hierarchy

Common process info

Accumulated Usage
and IO rates

netstat

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

IPTRAF

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

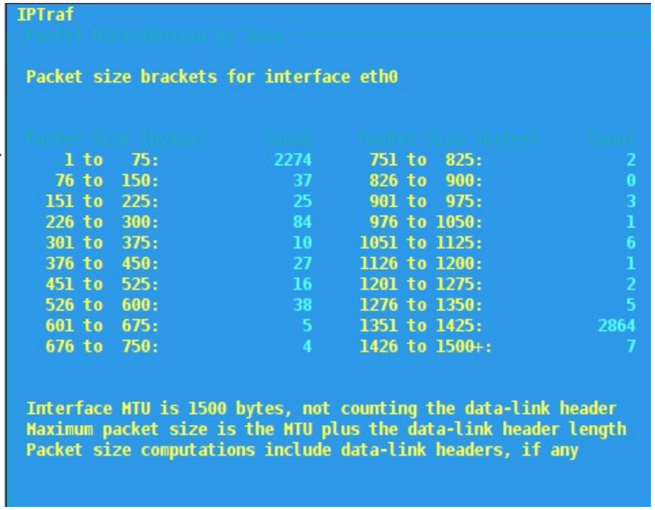
- Shows
  - Details per Connection / Interface
  - Statistical breakdown of ports / packet sizes
  - LAN station monitor

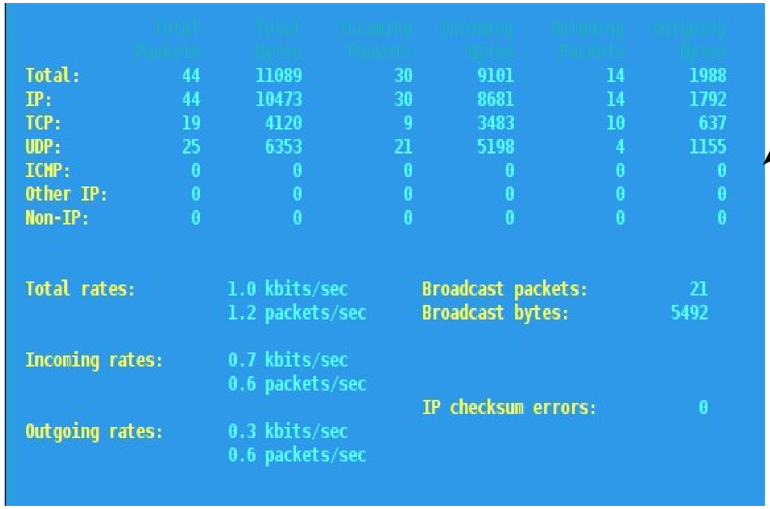
- Hints
  - Can be used for background logging as well
    - Use SIGUSR1 and logrotate to handle the growing amount of data
  - Knowledge of packet sizes important for the right tuning
  - There are various other tools: iftop, bmon, …
    - like with net benchmarks no one seem to fit all

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

End of Part III

Agenda

Basic

- Utilization
- Scheduling
- Page Cache
- Swapping
- top
- ps
- vmstat

Intermediate

- General thoughts
- Sysstat
- Dasdstat
- Scsi I/O statistics
- iotop
- Lszcrpt
- icastats
- Lsqeth
- Ethtool
- Preparation

Advanced

- Strace
- Ltrace
- Lsof
- Lsluns
- Multipath
- hyptop
- Dstat
- Htop
- Netstat
- Socket Statistics
- Iptraf

Master

- Perf
- slabtop
- Blktrace
- Ziomon
- Tcpdump
- Java Health Center
- Java Garbage Collection and Memory visualizer
- Jinsight

Elite

- Cachestat
- Smem
- Valgrind
- Irqstats
- Wireshark
- Kernel Tracepoints
- Systemtap

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 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", …
    - Other than real "sampling" this can help to search for stalls
  - – Counters provide even lower overhead and report HW and Software events

Perf profiling

- Perf example how-to
  - Needs proper HW support to work well for the kernel (not yet in the field)
    - Ignore and kernel profiling data until this is available!
  - 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

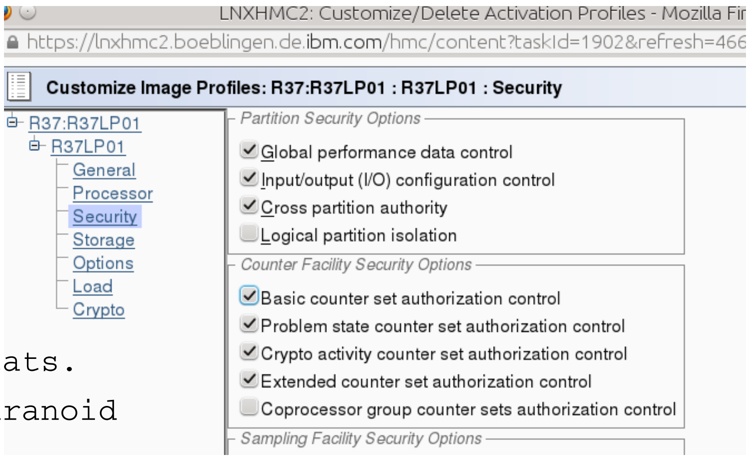
- “Myriad” of further options/modules
  - Live view with `perf top`
  - Perf sched for an integrated analysis of scheduler tracepoints
  - Perf annotate to see samples alongside code
  - Perf stat for a counter based analysis
  - [...]

Perf 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
```


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
    - separate for counter and sampling
    - Basic and/or Diagnostic mode

```
lscpumf -i
CPU-measurement counter facility
[...]
Sampling facility information for cpum_sf
[...]
Authorized sampling modes:
     basic      (sample size:  32 bytes)
     diagnostic (sample size:  85 bytes)
[...]
```

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 PROBLEM_STATE_CPU_CYCLES
       757,589,098 PROBLEM_STATE_INSTRUCTIONS
       705,740,759 L1I_PENALTY_CYCLES
       576,226,424 L1D_PENALTY_CYCLES
            40,675 sched:sched_wakeup
       6.156288957 seconds time elapsed
```

- Events
  - Cycles/Instructions globally
  - Note: counters are now readable, but aliases can still be used
    - e.g. r20 = PROBLEM_STATE_CPU_CYCLES
    - List of all existing events `lscpumf -C`
    - counters available to you `lscpumf -c`
  - Not only HW events, you can use any of the currently 163 tracepoints

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

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

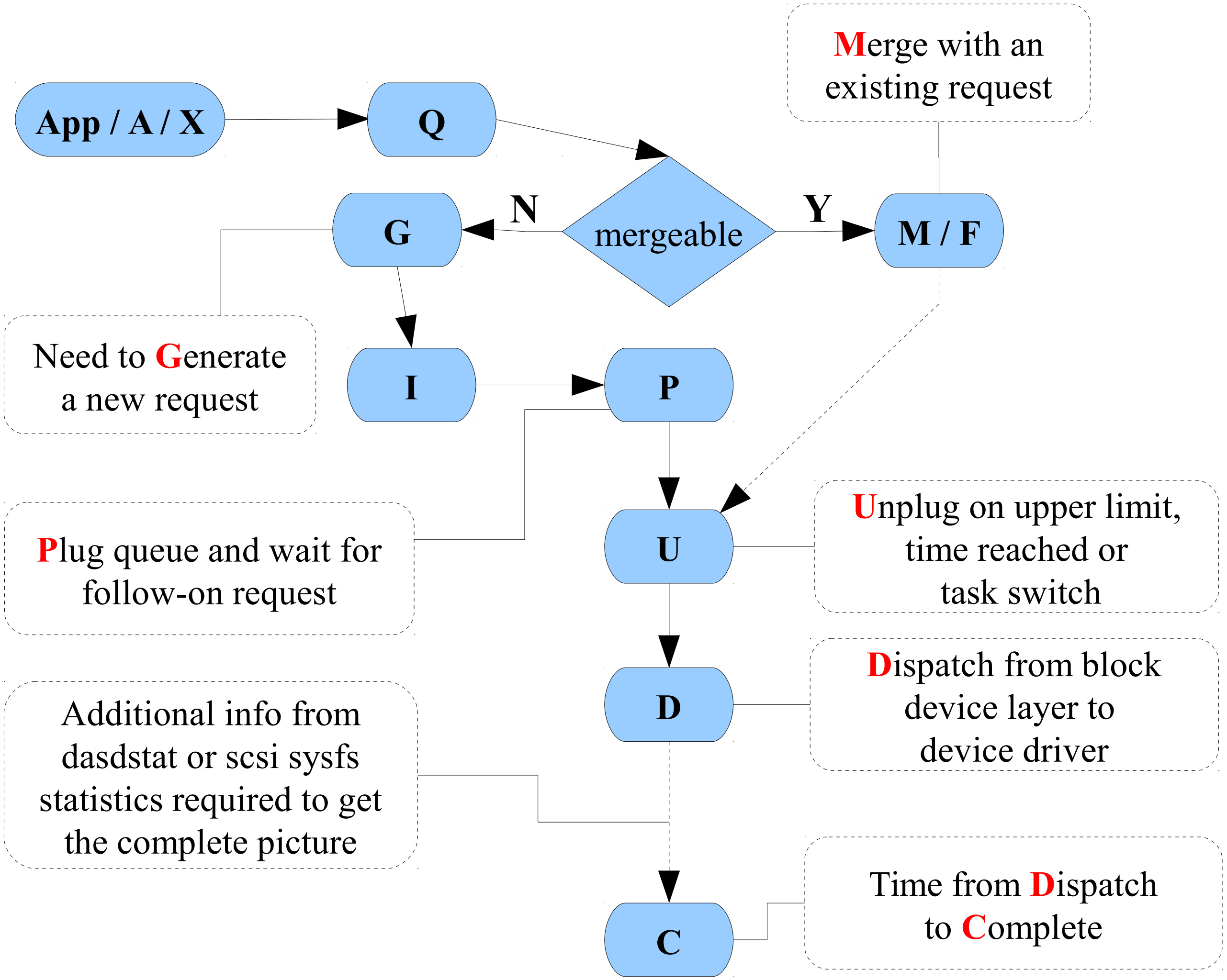
- Hints
  - Filter masks allow lower overhead if only specific events are of interest
  - Has an integrated client/server mode to stream data away
    - Avoids extra disk I/O on a system with disk I/O issues

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

The "blktrace" tool – block device events (simplified)



A - remap
B - bounced
C - complete
D - issued
F - front merge
G - get request
I - inserted
M - back merge
P - plug
Q - queued
T - timer unplug
U - unplug
X - split

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

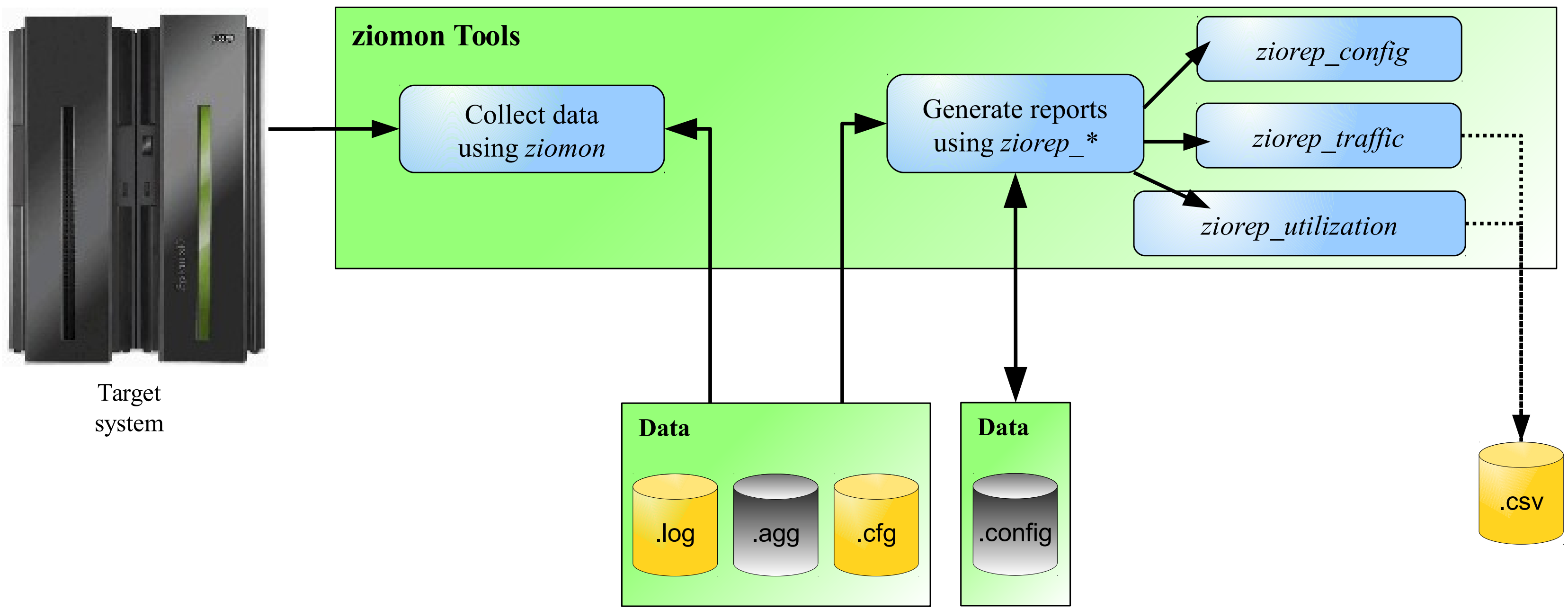
- Example Case
  - Analysis turned out that the I/O was from the swap code
    - Same offsets were written by kswapd
  - A recent code change there disabled the ability to merge I/O
  - The summary below shows the difference after a fix

```
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
```

ziomon

- Characteristics: in depth zfcp based I/O analysis
- Objective: Analyze your FCP based I/O
- Usage: "`ziomon`" → "`ziorep`*"
- Package: RHEL: s390utils(-ziomon) SLES: s390-tools



- Be aware that ziomon can be memory greedy if you have very memory constrained systems
- The has many extra functions please check out the live virtual class of Stephan Raspl
  - PDF: http://www.vm.ibm.com/education/lvc/LVC0425.pdf
  - Replay: http://ibmstg.adobeconnect.com/p7zvdjz0yye/

TCPDump

- Characteristics: dumps network traffic to console/file
- Objective: analyze packets of applications manually
- Usage: "`tcpdump ...`"
- Package: RHEL: tcpdump SLES: tcpdump

```
tcpdump host pserver1
tcpdump: verbose output suppressed, use -v or -vv for full protocol decode
listening on eth0, link-type EN10MB (Ethernet), capture size 65535 bytes
13:30:00.326581 IP pserver1.boeblingen.de.ibm.com.38620 > p101p35.boeblingen.de.ibm.com.ssh: Flags [.], ack 3142, win
102, options [nop,nop,TS val 972996696 ecr 346994], length 0

13:30:00.338239 IP p101p35.boeblingen.de.ibm.com.ssh > pserver1.boeblingen.de.ibm.com.38620: Flags [P.], seq 3142:3222,
ack 2262, win 2790, options [nop,nop,TS val 346996 ecr 972996696], length 80
13:30:00.375491 IP pserver1.boeblingen.de.ibm.com.38620 > p101p35.boeblingen.de.ibm.com.ssh: Flags [.], ack 3222, win
102, options [nop,nop,TS val 972996709 ecr 346996], length 0
[...]
^C
31 packets captured
31 packets received by filter
0 packets dropped by kernel
```

- Not all devices support dumping packets in older distribution releases
  - Also often no promiscuous mode
- Check flags or even content if your expectations are met
- -w flag exports captured unparsed data to a file for later analysis in libpcap format
  - Also supported by wireshark
- Usually you have to know what you want to look for

Java Performance in general

- “Too” many choices
  - There are many Java performance tools out there
- Be aware of common Java myths often clouding perception
- Differences
  - Profiling a JVM might hide the Java methods
  - Memory allocation of the JVM isn't the allocation of the Application

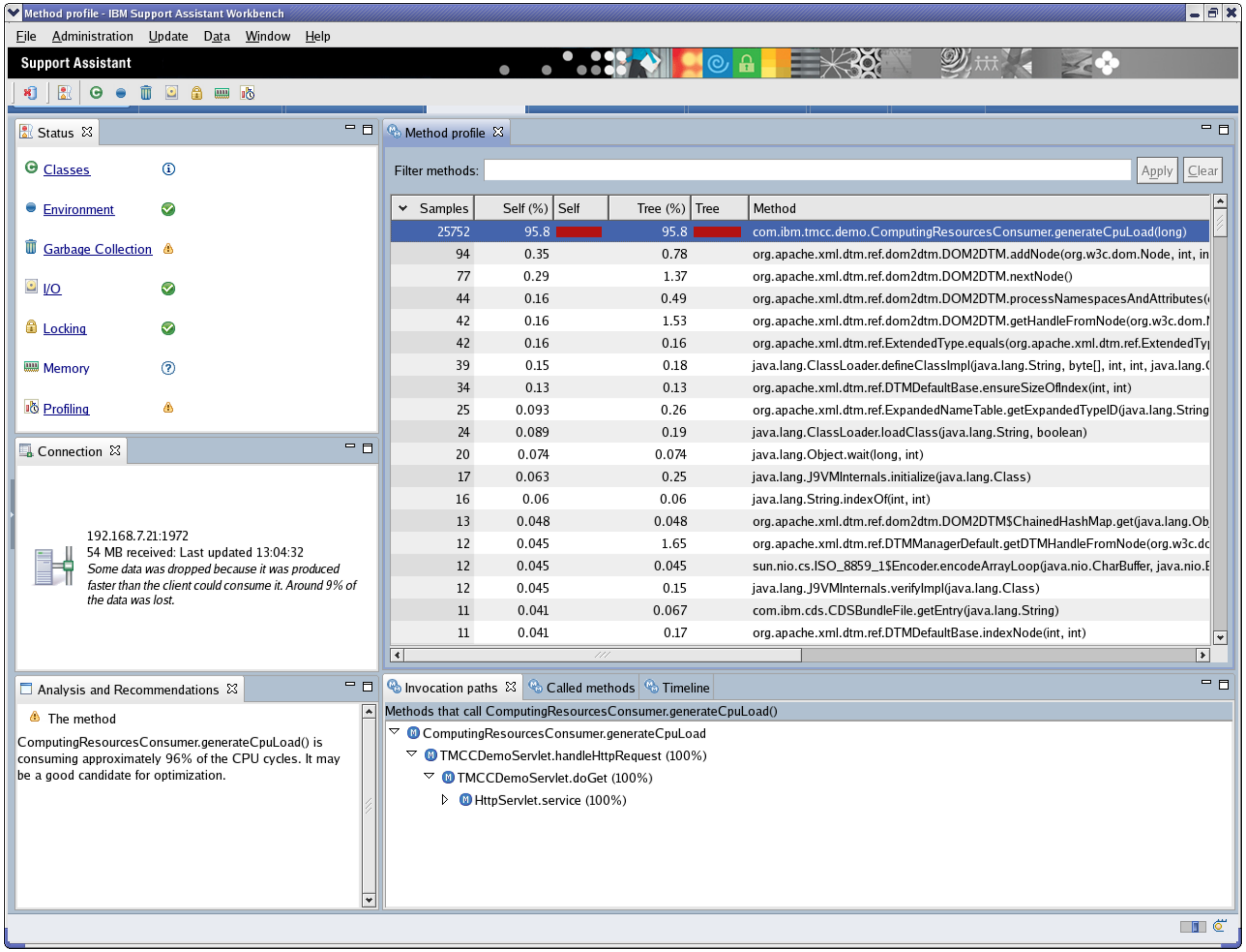
Java - Health Center

- 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

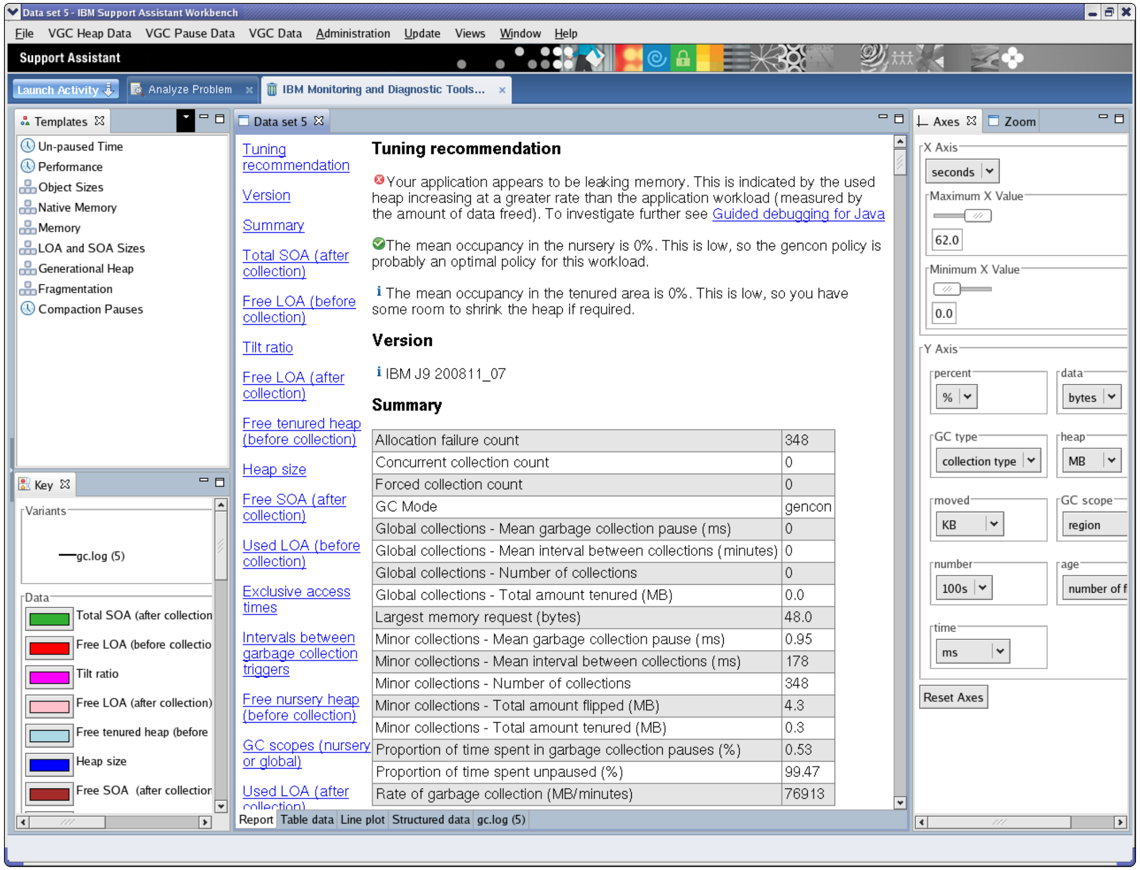
Java - Garbage Collection and Memory Visualizer

- 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

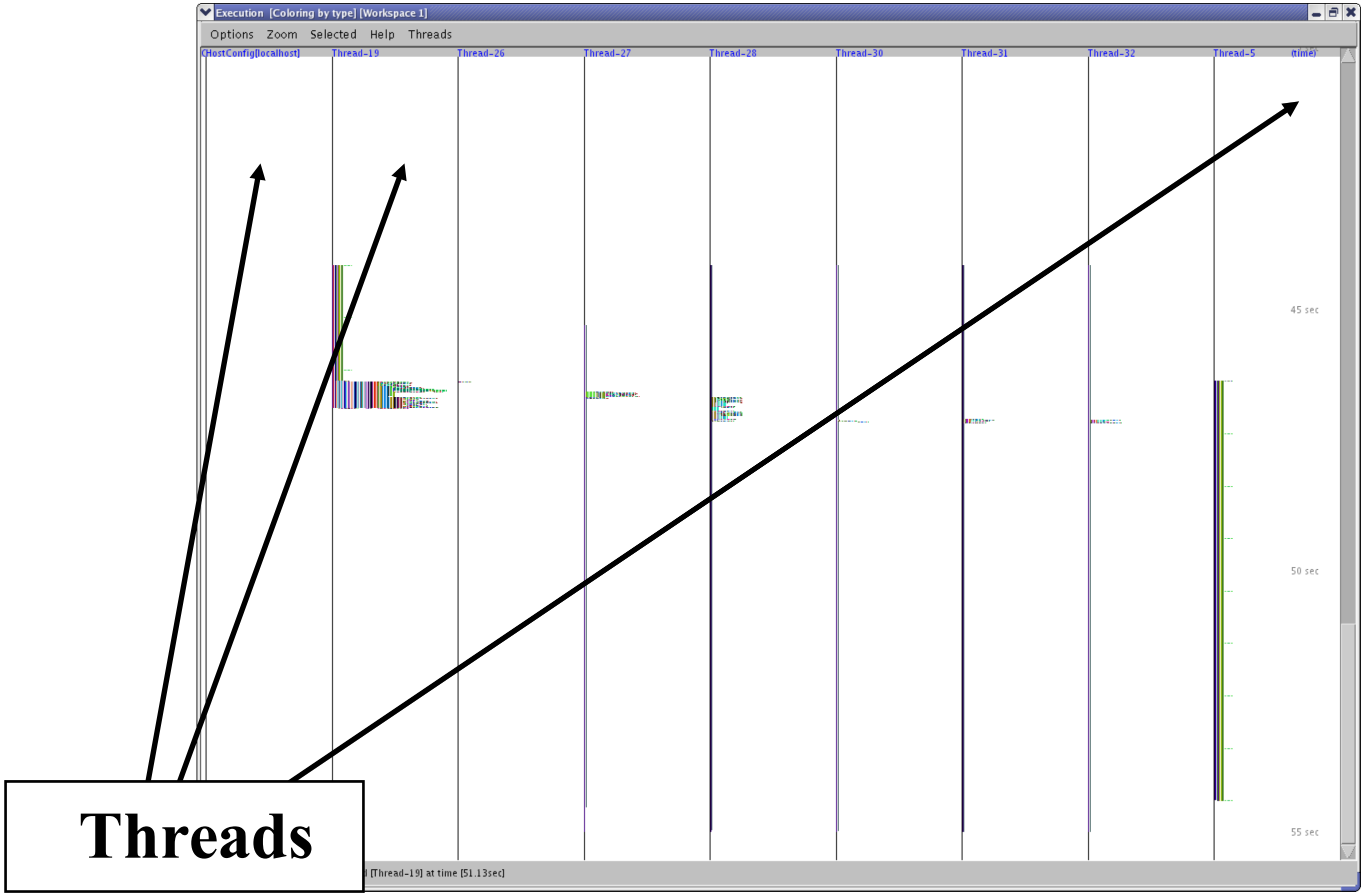
Java - Jinsight

- 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

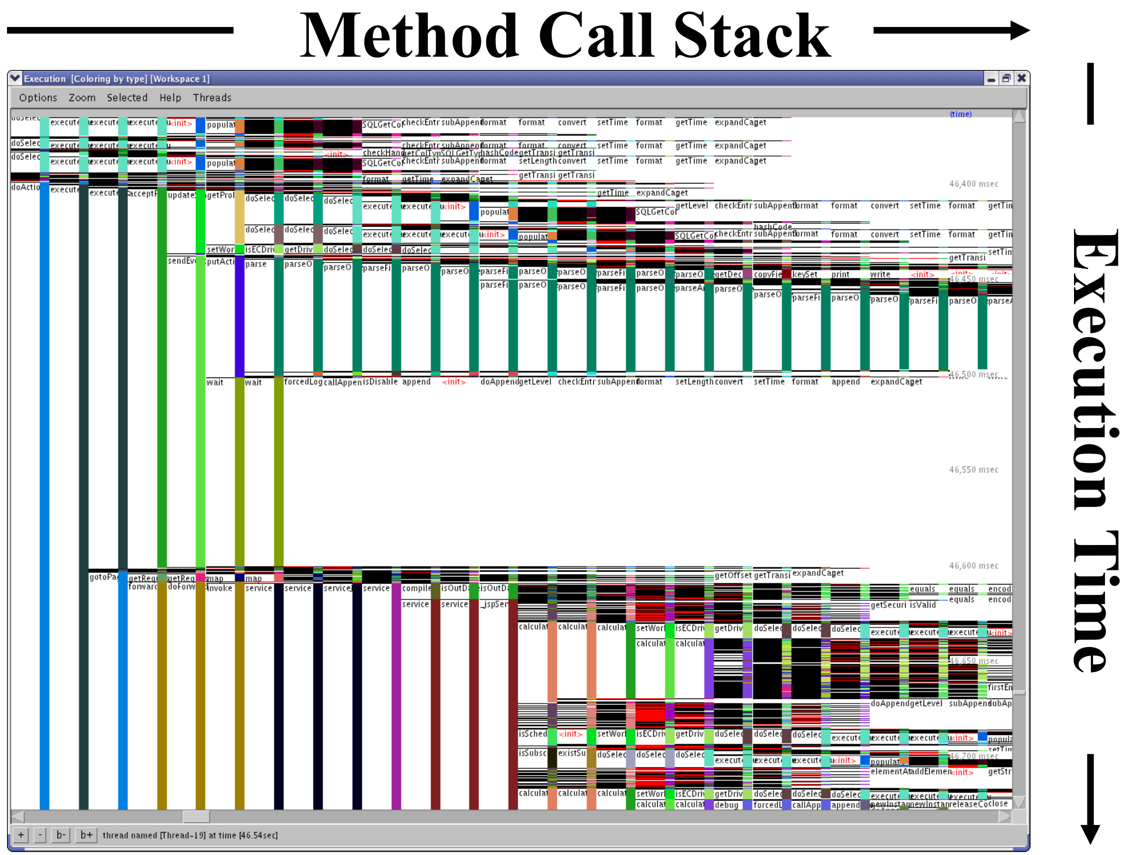
- Hints
  - Significant slowdown, not applicable to production systems
  - No more maintained, but so far still working

Jinsight Execution View



- Threads in columns, select one to zoom in

Jinsight Execution View, *continued*



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

End of Part IV

Agenda

Basic
- Utilization
- Scheduling
- Page Cache
- Swapping

- top
- ps
- vmstat

Intermediate
- General thoughts
- Sysstat
- Dasdstat
- Scsi I/O statistics
- iotop
- Lszcrpt
- icastats
- Lsqeth
- Ethtool
- Preparation

Advanced
- Strace
- Ltrace
- Lsof
- Lsluns
- Multipath
- hyptop
- Dstat
- Htop
- Netstat
- Socket Statistics
- Iptraf

Master
- Perf
- slabtop
- Blktrace
- Ziomon
- Tcpdump
- Java Health Center
- Java Garbage Collection and Memory visualizer
- Jinsight

Elite
- Cachestat
- Smem
- Valgrind
- Irqstats
- Wireshark
- Kernel Tracepoints
- Systemtap

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
  - We are 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|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|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|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|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|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|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|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

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 (kernel interface missing)

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

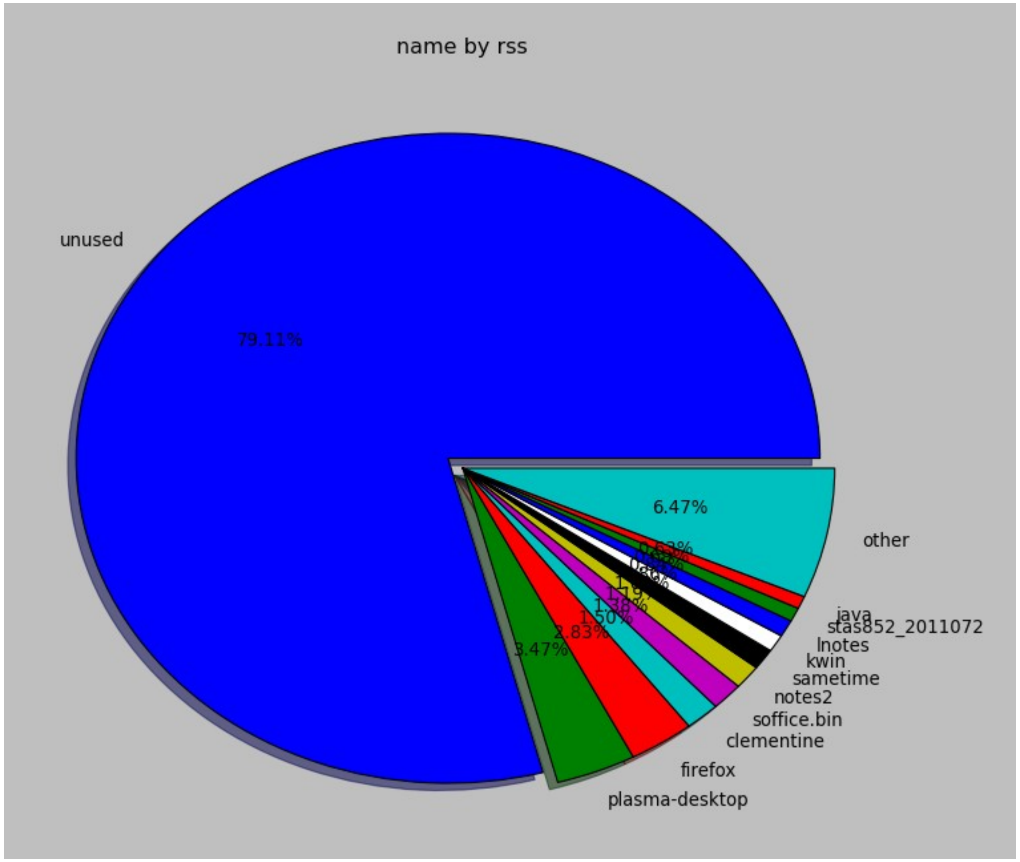
smem – mappings overview

```
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



- Example of a memory distribution Visualization (many options)
- But before thinking of monitoring be aware that the proc/#pid/smaps interface is an expensive one

Valgrind

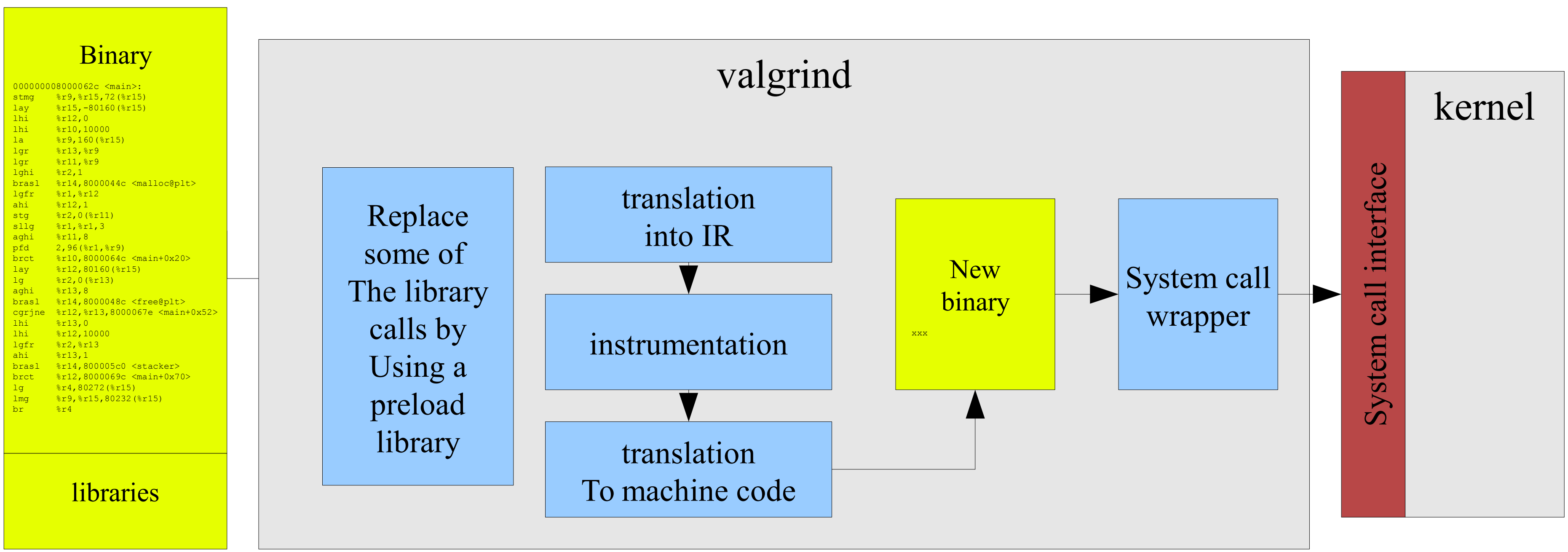
- Characteristics: in-depth memory analysis
- Objective: Find out where memory is leaked, sub-optimally cached, ...
- Usage: `valgrind [program]`
- Package: RHEL: valgrind SLES: valgrind

- 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
[...]
```

- 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)

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, Machine 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

Wireshark

- Characteristics: Analyzes captured network traffic
- Objective: In depth analysis of handshakes, missing replies, protocols, ...
- Usage: Dump in libpcap or pcap-ng format (`tcpdump, dumpcap`)
  then analyze on remote system via "`wireshark`"
- Package: RHEL: wireshark SLES: wireshark

- No "direct" invocation on System z usually
  – e.g. on RH6 there is not even a wireshark binary
- Scrolling huge files on Remote X isn't fun anyway
  – Capturing tools are available

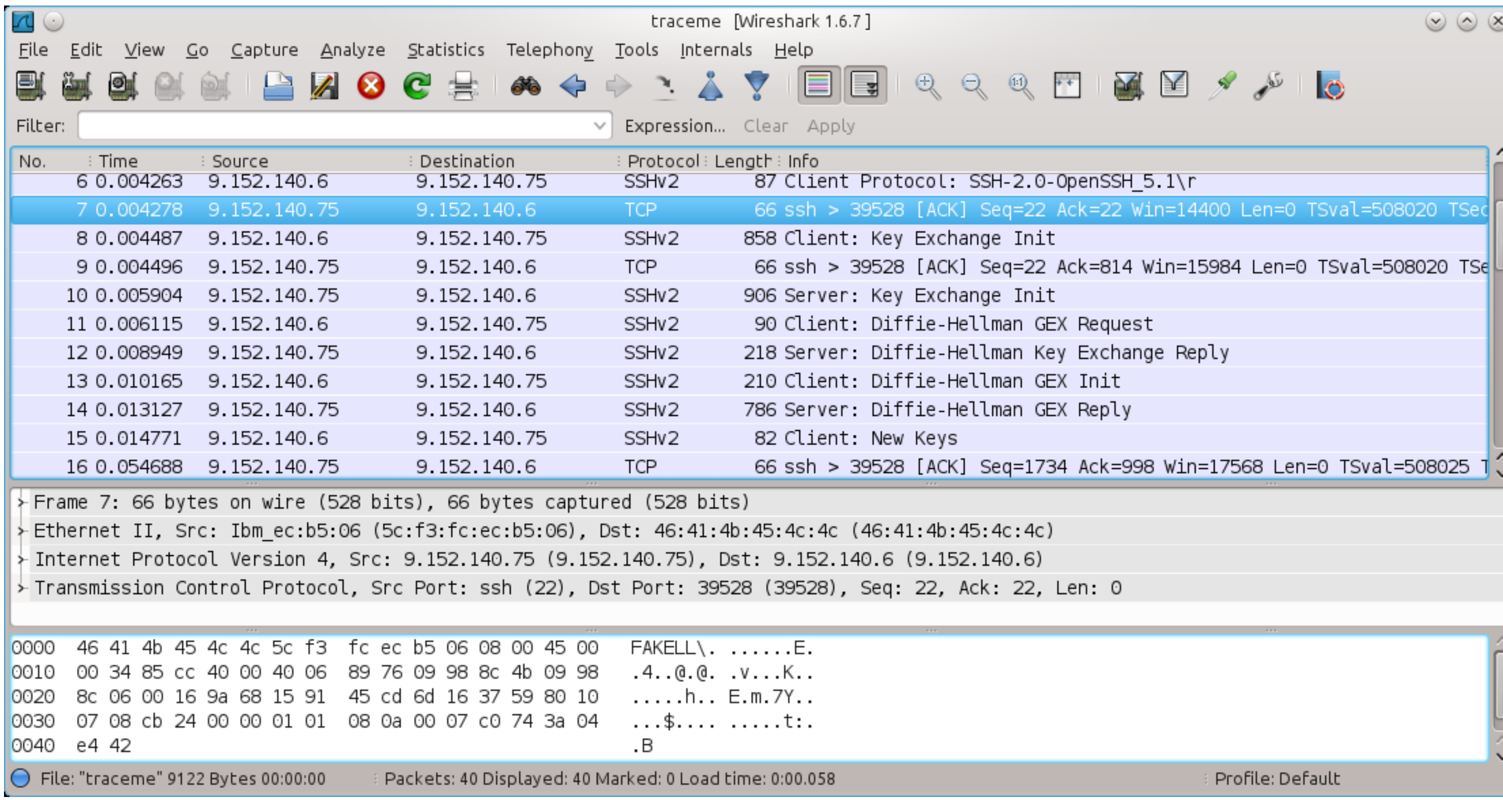
- Custom columns and profiles are important to visualize what you want to look for
- For more details you might start at
  – The share sessions of Mathias Burkhard
    https://share.confex.com/share/121/webprogram/Session13282.html
  – Official documentation http://www.wireshark.org/docs/wsug_html/

Wireshark example

- 1. Dump via "`tcpdump -w`" or wiresharks "`dumpcap`"
- 2. analyze on remote system via "`wireshark`"

```
tcpdump host pserver1 -w traceme
tcpdump: listening on eth0, link-type EN10MB (Ethernet), capture size 65535 bytes
^C40 packets captured
40 packets received by filter
0 packets dropped by kernel
```

```
[scp to my system]
wireshark traceme
```



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 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

Systemtap

- Characteristics: tool to “tap” into the kernel for analysis
- Objective: analyze in kernel values or behavior that otherwise would be inaccessible or require a modification/recompile cycle
- Usage (mini example): “`stap -v -e 'probe vfs.read {printf(“read performed\n”); exit()}'`”
- Package: RHEL: systemtap + systemtap-runtime SLES: systemtap
- Also requires kernel debuginfo and source/devel packages

- Procedural and C-like language based on two main constructs
  - Probes – “catching events”
    - On functions, syscalls or single statements via file:linenumber
  - Functions – “what to do”
    - Supports local and global variables
    - Program flow statements if, loops, …
- Tapsets provide pre written probe libraries

- Fore more check out “Using SystemTap on Linux on System z” from Mike O'Reilly https://share.confex.com/share/118/webprogram/Handout/Session10452/atlanta.pdf

There would be even more tools to cover ...

- Further tools - (no slides yet)
  - **Collectl** – full system monitoring
  - **Ftrace** – kernel function tracing
  - **Lttng** – complex latency tracing infrastructure (packages start to appear in Fedora 19)
  - **Nicstat**, **ktap**, **stap**, ...

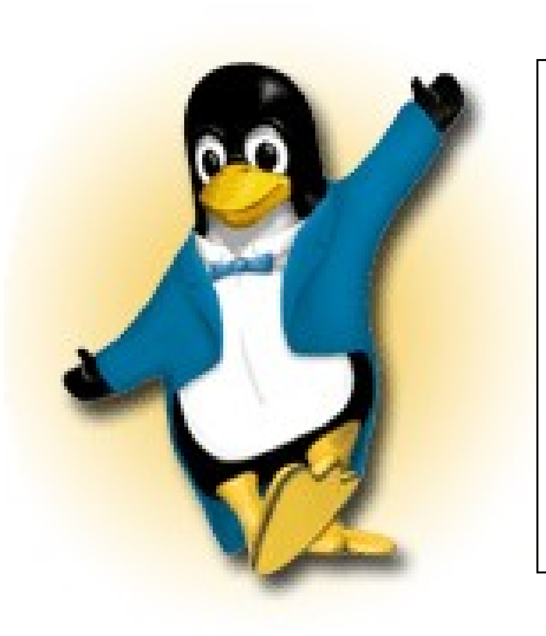
End of Part V

Thanks (and complaints) go to

Christian Ehrhardt

Questions?

- **Further information is 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/



Martin Schwidefsky

Linux on System z Development

Schönaicher Strasse 220
71032 Böblingen, Germany

Phone +49 (0)7031-16-2247
schwidefsky@de.ibm.com