# How to Surprise by being a Linux Performance “know-it-all”

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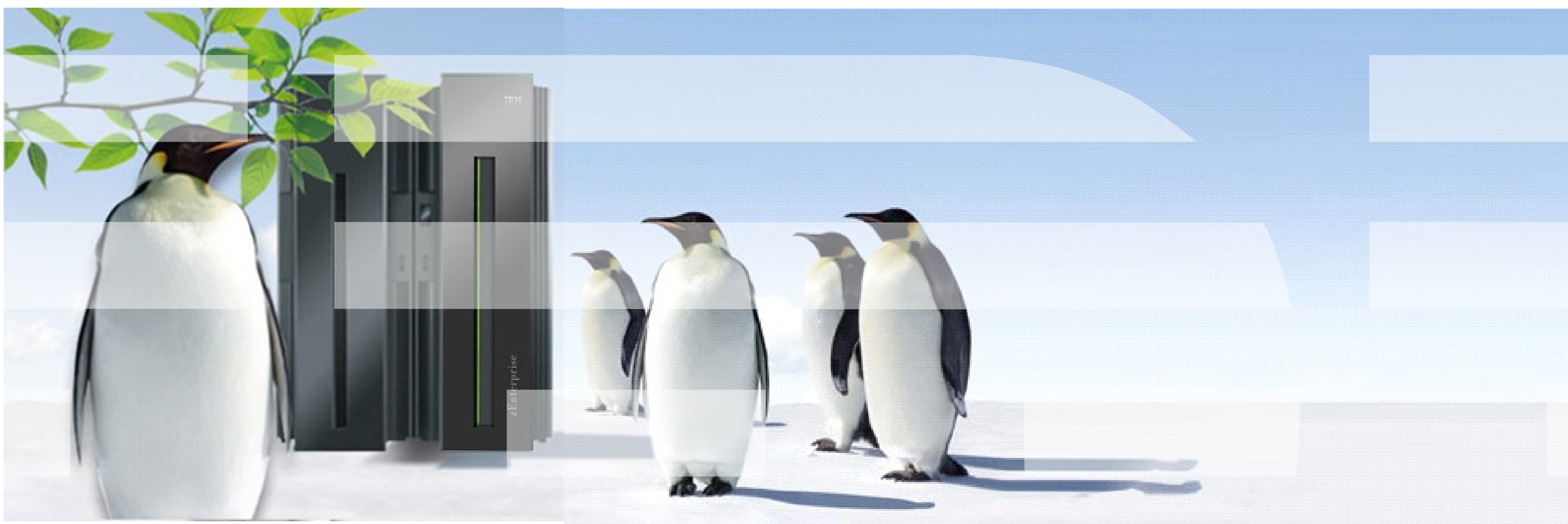

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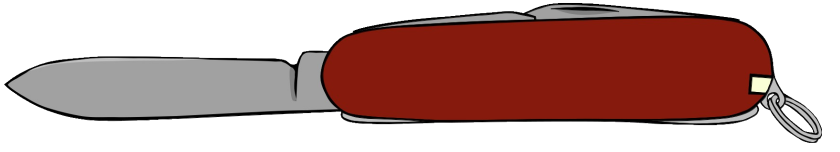
# Agenda (what it used to be)

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



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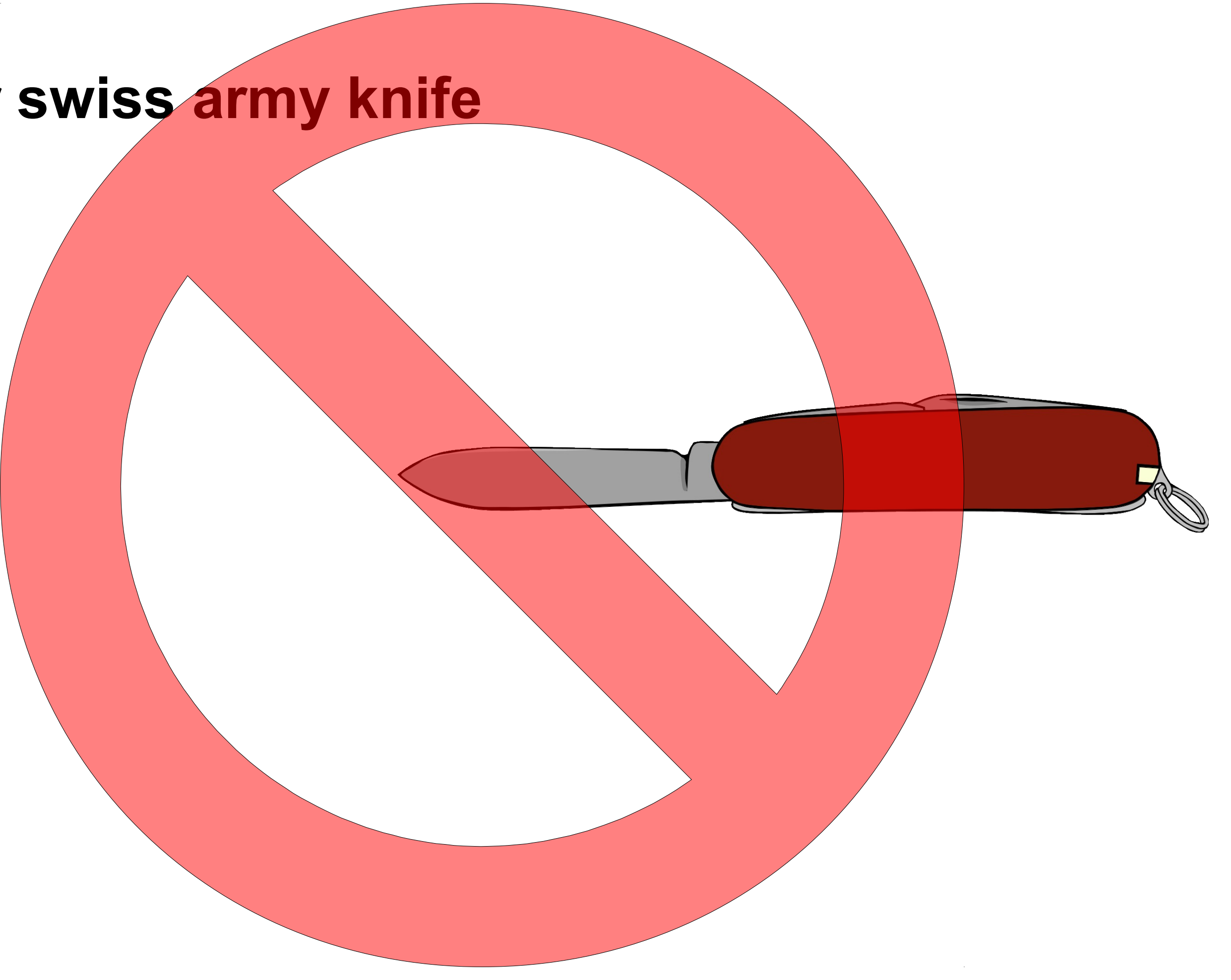

# Ready for take-off

# Agenda

- **Tools are your swiss army knife**
  - htop
  - dstat
  - pidstat
  - irqstats
  - strace/ltrace
  - blktrace
  - hyptop
  - profiling
  - valgrind
  - iptraf
  - tracepoints

# General thoughts on performance tools

- **Things that are always to consider**
  - Monitoring can impact the system
  - Most data gathering averages over a certain period of time
    → this flattens peaks
  - Start with defining the problem
    - which parameter(s) from the application/system indicates the problem
    - which range is considered as bad, what is considered as good
  - monitor the good case and save the results
    - comparisons when a problem occurs can save days and weeks
- **Staged approach saves a lot of work**
  - Try to use general tools to isolate the area of the issue
  - Create theories and try to quickly verify/falsify them
  - Use advanced tools to debug the identified area

# Orientation - where to go

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

# DSTAT

- Characteristics: Live easy to use full system information
- Objective: Flexible set of statistics
- Usage:

```
dstat -tv -aio -disk-util -n -net-packets -i -ipc -D total,
      [diskname] -top-io […] [interval]
dstat -tinv
```

- Shows
  - Throughput and utilization
  - Summarized and per Device queue information
  - Much more, it more or less combines several classic tools like iostat and vmstat
- Hints
  - Powerful plugin concept
    - "`--top-io`" for example identifies the application causing the most I/Os
  - Colorization allows fast identification of deviations

# DSTAT – the limit is your screen width

# HTOP

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

```
htop
```

- Shows
  - Running processes
  - CPU and memory utilization
  - Accumulated times
  - I/O rates
  - System utilization visualization
- Hints
  - Htop can display more uncommon fields (in menu)
  - Able to send signals out of its UI for administration purposes
  - Processes can be sorted/filtered for a more condensed view

# HTOP

Configurable utilization visualization

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

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

Common process info

Accumulated Usage and IO rates

Hierarchy

# PIDSTAT

- Characteristics: Easy to use extended per process statistics
- Objective: Identify processes with peak activity
- Usage:

```
pidstat [-w | -r | -d]
```

- Shows
  - `-w` context switching activity and if it was voluntary
  - `-r` memory statistics, especially minor/major faults per process
  - `-d` disk throughput per process
- Hints
  - Also useful if run as background log due to its low overhead
    - Good extension to sadc in systems running different applications/services
  - `-p <pid>` can be useful to track activity of a specific process

# PIDSTAT examples

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

Voluntarily / Involuntary

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

Faults per process

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

How much KB disk I/O per process

# IRQ Statistics

- Characteristics: Low overhead IRQ information
- Objective: Condensed overview of IRQ activity
- Usage:

```
cat / proc/interrupts
```

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

# IRQ Statistics

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

```
            CPU0       CPU1       CPU2       CPU3
EXT:       21179      24235      22217      22959
I/O:     1542959     340076     356381     325691
CLK:       15995      16718      15806      16531   [EXT] Clock Comparator
EXC:         255        325        332        227   [EXT] External Call
EMS:        4923       7129       6068       6201   [EXT] Emergency Signal
TMR:           0          0          0          0   [EXT] CPU Timer
TAL:           0          0          0          0   [EXT] Timing Alert
PFL:           0          0          0          0   [EXT] Pseudo Page Fault
DSD:           0          0          0          0   [EXT] DASD Diag
VRT:           0          0          0          0   [EXT] Virtio
SCP:           6         63         11          0   [EXT] Service Call
IUC:           0          0          0          0   [EXT] IUCV
CPM:           0          0          0          0   [EXT] CPU Measurement
CIO:         163        310        269        213   [I/O] Common I/O Layer Interrupt
QAI:     1541773     338857     354728     324110   [I/O] QDIO Adapter Interrupt
DAS:        1023        909       1384       1368   [I/O] DASD
[…] 3215, 3270, Tape, Unit Record Devices, LCS, CLAW, CTC, AP Bus, Machine Check
```

# STRACE

- Characteristics: High overhead, high detail tool
- Objective: Get insights about the ongoing system calls of a program
- Usage:

```
strace -p [pid of target program]
```

- Shows
  - Identify kernel entries called more often or taking too long
    - Can be useful if you search for increased system time
  - Time in call (`-T`)
  - Relative time-stamp (`-r`)
- Hints
  - The option "`-c`" allows medium overhead by just tracking counters and durations

# STRACE - example

a lot or slow calls?

shares to rate importance

name (see man pages)

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

# LTRACE

- Characteristics: High overhead, high detail tool
- Objective: Get insights about the ongoing library calls of a program
- Usage:

```
ltrace -p [pid of target program]
```

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

a lot or slow calls?

shares to rate importance

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 time-stamp
  - Useful to "read" what exactly goes on when

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

# BLKTRACE

- Characteristics: High detail info of the block device layer actions
- Objective: Understand whats going with your I/O in the kernel and devices
- Usage:

```
blktrace -d [device(s)]
blkparse -st [commontracefilepart]
```

- Shows
  - Events like merging, request creation, I/O submission, I/O completion, ...
  - Timestamps and disk offsets for each event
  - Associated task and executing CPU
  - Application and CPU summaries
- Hints
  - Filter masks allow lower overhead if only specific events are of interest
  - Has an integrated client/server mode to stream data away
    - Avoids extra disk I/O on a system with disk I/O issues

# BLKTRACE – when is it useful

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

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

# BLKTRACE - events

Common

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

Plugging & Merges:

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

Special

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

# BLKTRACE - events

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Plugging & Merges:

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|---|---|---|
| P -- | plug | When i/o is queued to a previously empty block device queue, Linux will plug the queue in anticipation of future I/Os being added before this data is r [illegible] |
| U -- | unplug | Some request data alread [illegible] driver. This may happen automatically if a timeout period has passed [illegible] en added to the queue.Recent kernels associate the queue with t [illegible] ch. |
| T -- | unplug | due to timer If nobody requ [illegible] ue, Linux will automatically unplug it after a defined period has passed. |
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**Good as documentation, but hard to understand/remember**

Special

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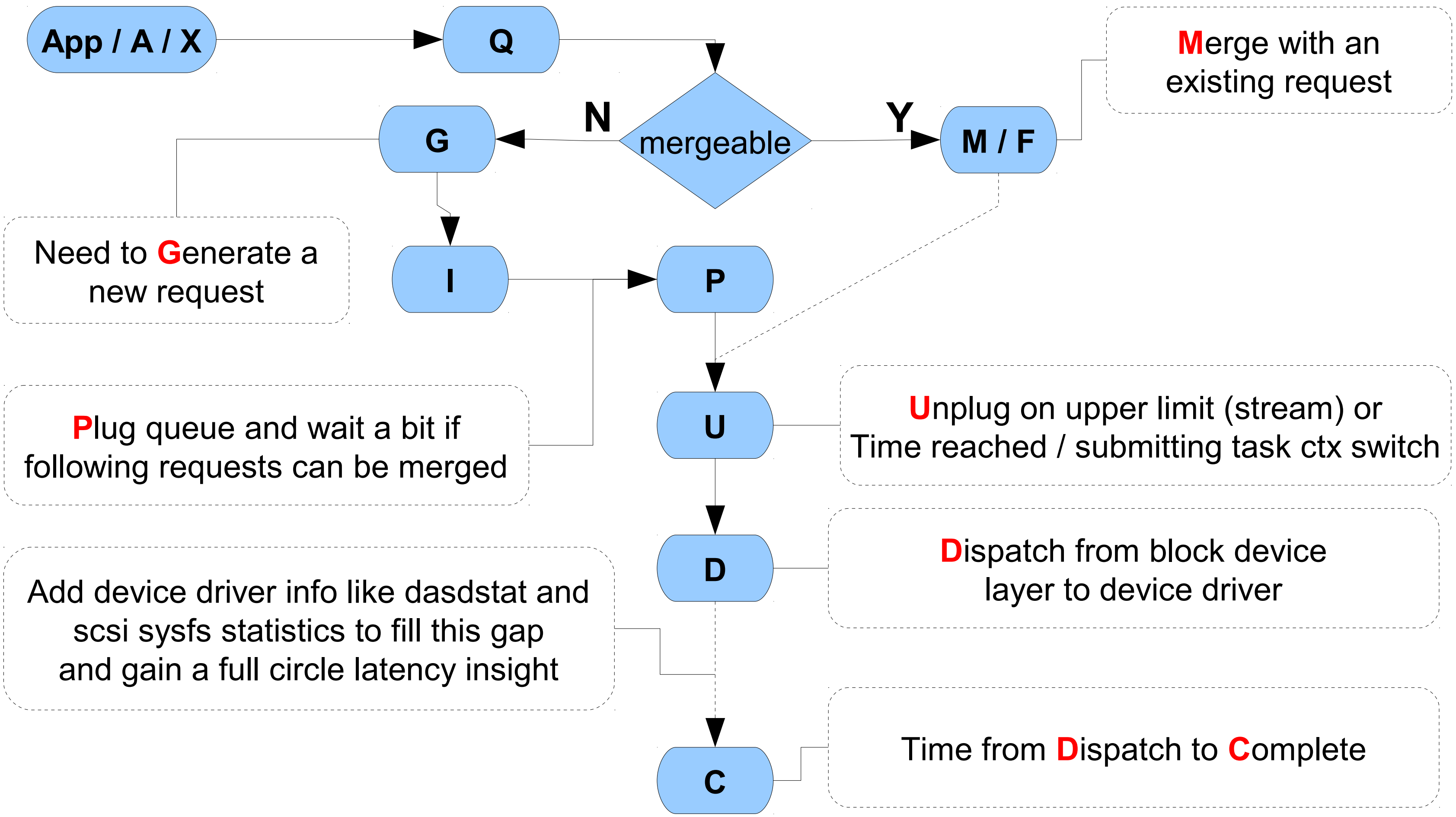
# Block device layer – events (simplified)



# BLKTRACE - example

- 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

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

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

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

# HYPTOP

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

```
hyptop
```

- Shows
  - CPU load & Management overhead
  - Memory usage
  - Can show image overview or single image details
- Hints
  - Good “first view” tool for linux admins that want to look “out of their linux”
  - Requirements:
    - For z/VM the Guest needs Class B
    - For LPAR “Global performance data control” check-box in HMC

# HYPTOP

Why are exactly 4 CPUs used in all 6 CPU guests

Weights are equal

All these do not fully utilize their 2 CPUs

service guest weights

No peaks in service guests

LPAR images would see other LPARs

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 |

# Profiling

- Characteristics: Easy to use profiling and kernel tracing
- Objective: Get detailed information where & why CPU is consumed
- Usage:

```
perf top
```

- Shows
  - Sampling for CPU hotspots
    - Annotated source code along hotspot
  - CPU event counters
  - Further integrated non-sampling tools
- Hints
  - Without HW support only userspace can be reasonably profiled
  - “successor” of oprofile that is available with HW support (SLES11-SP2)
  - Perf HW support code upstream, wait for next distribution releases

# Profiling

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

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

# Profiling

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

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

# Profiling

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

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

# Valgrind

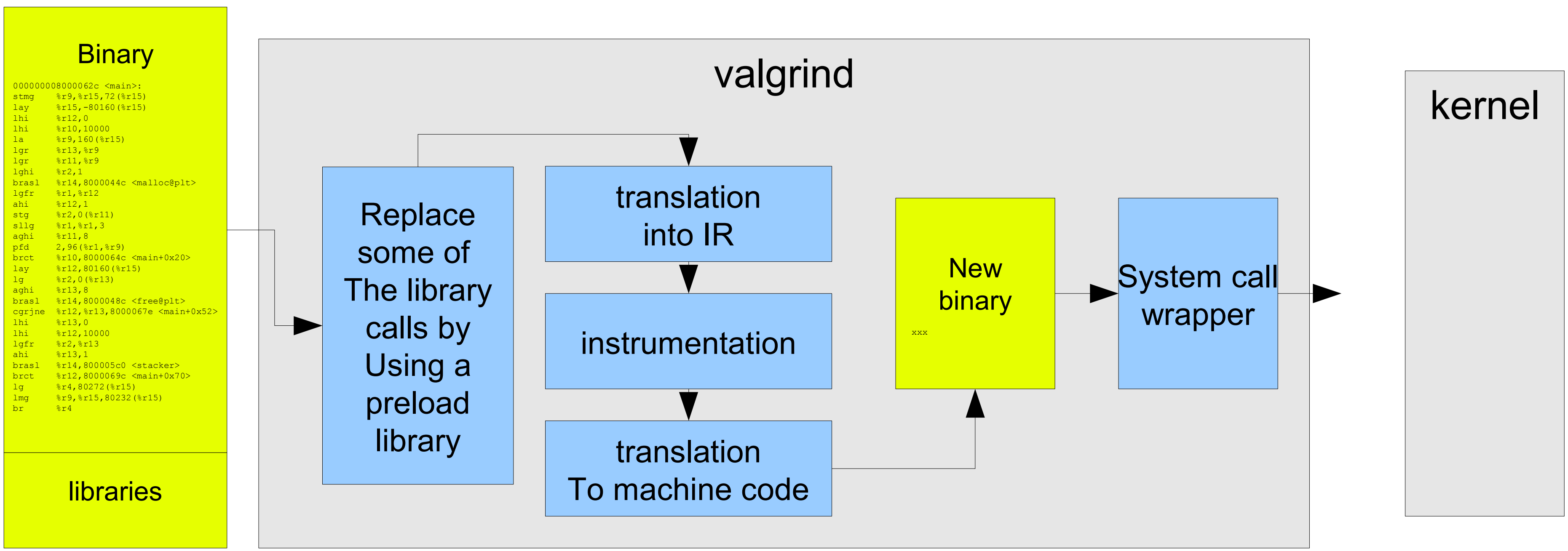
- Characteristics: In depth memory analysis
- Objective: Find out where memory is leaked, sub-optimally cached, ...
- Usage:

```
valgrind [program]
```

- Shows
  - Memory leaks
  - Cache profiling
  - Heap profiling
- Hints
  - Runs on binaries, therefore easy to use
  - Debug Info not required but makes output more useful

# Valgrind Overview

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



# Valgrind – sample output of “memcheck”

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

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

# Valgrind - Tools

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

# IPTRAF

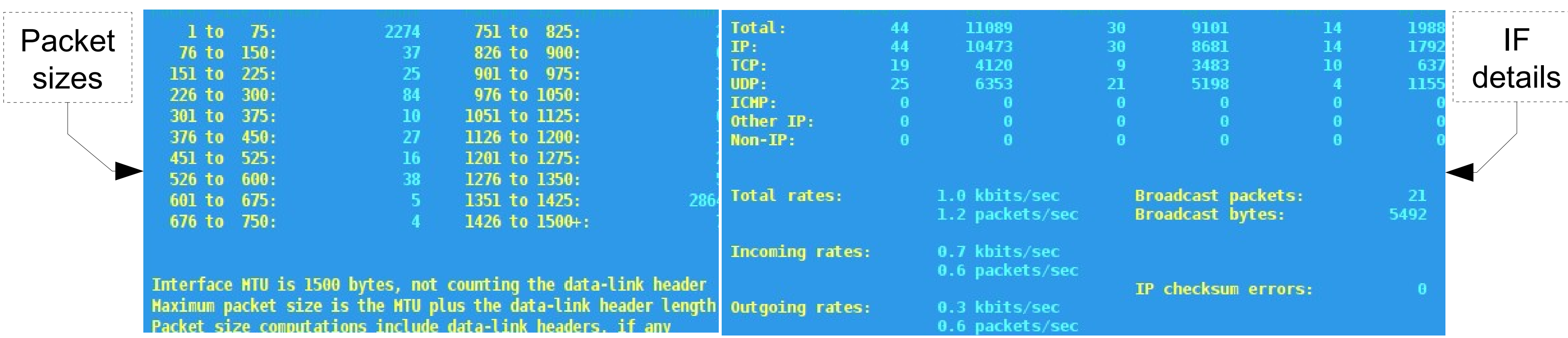
- Characteristics: Live information on network devices / connections
- Objective: Filter and format network statistics
- Usage:

```
iptraf
```

- Shows
  - Details per Connection / Interface
  - Statistical breakdown of ports / packet sizes
  - LAN station monitor
- Hints
  - Can be used for background logging as well
    - Use SIGUSR1 and logrotate to handle the growing amount of data
  - Knowledge of packet sizes important for the right tuning

# IPTRAF

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



# Tracepoints (Events)

- Characteristics: Complex interface, but a vast source of information
- Objective: In kernel latency and activity insights
- Usage: Access debugfs mount point /tracing
- Shows
  - Time-stamp 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 post processing
  - There are much more things you can handle with tracepoints check out Kernel Documentation/trace/tracepoint-analysis.txt (via perf stat) and 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, User-space, Kernel or all of them
  - Workload was a simple 1 connection 1 byte←→1 byte load
  - Call "`perf list`" for a list of currently supported tracepoints
  - We used the following tracepoints

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

# Tracepoints – example II/III

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

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

- Output

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

# Tracepoints – example III/III

- Example postprocessed

| | SUM | COUNT | AVERAGE | MIN | MAX | STD-DEV |
|---|---|---|---|---|---|---|
| P2Q: | 8478724 | 1572635 | 5.39 | 4 | 2140 | 7.41 |
| Q2S: | 12188675 | 1572638 | 7.65 | 3 | 71 | 4.89 |
| S2R: | 38562294 | 1572636 | 24.42 | 1 | 2158 | 9.08 |
| R2P: | 4197486 | 1572633 | 2.57 | 1 | 43 | 2.39 |
| SUM: | 63427179 | 1572635 | 40.03 | | | |

| | SUM | COUNT | AVERAGE | MIN | MAX | STD-DEV |
|---|---|---|---|---|---|---|
| P2Q: | 7191885 | 1300897 | 5.53 | 4 | 171 | 1.31 |
| Q2S: | 10622270 | 1300897 | 8.17 | 3 | 71 | 5.99 |
| S2R: | 32078550 | 1300898 | 24.66 | 2 | 286 | 5.88 |
| R2P: | 3707814 | 1300897 | 2.85 | 1 | 265 | 2.59 |
| SUM: | 53600519 | 1300897 | 41.20 | | | |

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

# Orientation – where to go

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

# Questions ?

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

IBM

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# Please Evaluate!