Runtime and Postmortem Analyze of the Linux Network Stack

Tracing and Probing Techniques from IRQ Context to User Space

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Agenda

- Goals:
  1. Provide information how to analyze the network stack
  2. What tools are available to spot corner cases
- Agenda
  - Tool Overview
  - Tools in Detail
  - Mostly Kernel Space, but some User Space tools are considered
  - „War Stories“

Tools Overview

trace-cmd perf netstat

tcp_probe.ko tc

lttng ethtool

ss

trace-cmd ftrace

oprofile kprobe

systemtap perfmon2

/proc/net/snmp

- What tools are available, when to use, how to use
- But: all of these tools requires a fairly good understanding of the network stack. This talk is about to bring some light into the interaction and provide starting points.

Tools Overview II

- Starting with basic tools
- Going deeper, get into the details by using more specialized tools

Netstat

- `netstat -s`

```
IP:
    3229907 total packets received
        [...]
        108 dropped because of missing route
Icmp:
    ICMP input histogram:
         destination unreachable: 57
Tcp:
    117181 active connections openings
        105765 passive connection openings
        559 connection resets received
        2775 segments retransmited
        2133 resets sent
TcpExt:
    70382 delayed acks sent
        Quick ack mode was activated 772 times
        25235253 bytes directly received in process context from prequeue
        1641950 packet headers predicted
        450 packets collapsed in receive queue due to low socket buffer
        277 connections reset due to unexpected data
        [...]
```

Ethtool

- `ethtool -S eth0`

```
NIC statistics:
     rx_packets: 1172472
     tx_packets: 784183
     rx_bytes: 1561122238
     tx_bytes: 72181402
     rx_broadcast: 2826
     rx_errors: 0
     tx_errors: 0
     tx_dropped: 0
     collisions: 0
     rx_crc_errors: 0
     rx_no_buffer_count: 0
     tx_fifo_errors: 0
     tx_tcp_seg_good: 47
     tx_tcp_seg_failed: 0
     alloc_rx_buff_failed: 0
     rx_dma_failed: 0
     tx_dma_failed: 0
     [...]
```

Ethtool

- Ethtool is an excelent tool to discover CPU, BIOS, RAM and Network Card issues!
- `rx_no_buffer_count` → if CPU cannot keep new buffers to the hardware fast enough (e.g. increasing interrupt rate, increase RX descriptor ring, eliminate locking issues, ...)
- `rx_missed_errors` → Not enough bus bandwidth, host is too busy

Ethtool

- `ethtool -g eth5`

```
Ring parameters for eth5:
Pre-set maximums:
RX:           4096
TX:           4096
Current hardware settings:
RX:                   256
TX:            256
```

- 256 good compromiss:
  - 256 descriptors: 4096 byte, one page (256 * 16)
  - 512 descriptors: 8192 byte, two pages
  - Allow to buffer more incoming packets, increase system memory usage[1], degrade cache line efficiency – especially with routing, cacheline efficienzy is crucial
  - See `drivers/net/e1000/e1000_main.c:e1000_clean_rx_irq()`
-

[1] beside 16 byte descriptor, a recive buffer is also allocated 2048, 4096, 8192 or 16384 bytes; depending on the MTU

Strace and Ltrace

- `strace -tt -T -e trace=network -p $(pidof mutt)`
  - `-T` time spent in system call
  - `-tt` time of day, include microseconds
  - `trace=network` trace all network related system calls
  - Dont forgot `read()`/`write()`/`splice()` in the case it is used to tx/rx data via socket(s)

AF Packet and PCAP

- Understand the internals requires a understanding of the algorithm - why versus how
- Why is partly described in RFCs, IEEE publications and other standard documents
- Why can also be observed by looking from a higher level: monitoring traffic
  - Raw sockets and PCAP provide a wide set of tools
  - TCP Slow Start, window limited sender, neighbor discovery, ...
- Tools
  - tcpdump
  - wireshark
  - tcptrace
  - ...

ss

- To dump socket statistics – `ss(8)`
- Show all established connection for ssh
  - `ss -o state established '( dport = :ssh or sport = :ssh )'`
- `ss -i -s`
- `INET_DIAG_INFO`

Kprobe

- Debugging mechanism for for monitoring events
- Since 2005; developed by IBM
- KProbes as was underlying mechanism, DProbes planned as Tool (scripting capabilities, et cetera)
- KProbes
  - Handler installed at a particular instruction (pre and post)
- JProbes
  - Get access to a kernel function arguments
- Systemtap use it
- Documentation: http://lwn.net/Articles/132196/

Kprobe Registration

- implemented by exception handling mechanisms (intr)
- KProbes Interface

```
struct kprobe {
    struct hlist_node hlist;                /* Internal */
    kprobe_opcode_t addr;                   /* Address of probe */
    kprobe_pre_handler_t pre_handler;       /* Address of pre-handler */
    kprobe_post_handler_t post_handler;     /* Address of post-handler */
    kprobe_fault_handler_t fault_handler; /* Address of fault handler */
    kprobe_break_handler_t break_handler; /* Internal */
    kprobe_opcode_t opcode;                 /* Internal */
    kprobe_opcode_t insn[MAX_INSN_SIZE];  /* Internal */
}
int register_kprobe(struct kprobe *p);
```

Kprobe Overhead

- kprobe Overhead (for `x86_64`)
  - kprobe: 0.5us
  - jprobe 0.8us
  - return probe: 0.8 us
  - kprobe + return probe 0.85us
  - kprobe + return probe 0.85us
- Documentation:
  - http://www.mjmwired.net/kernel/Documentation/kprobes.txt, http://www-106.ibm.com/developerworks/library/l-kprobes.html?ca=dgr-lnxw42Kprobe, http://www.redhat.com/magazine/005mar05/features/kprobes/, http://www-users.cs.umn.edu/ boutcher/kprobes/ http://www.linuxsymposium.org/2006/linuxsymposium_procv2.pdf

Systemtap

- Example: what process allocate pages and report every 5 seconds

```
global page_allocs

probe kernel.trace("mm_page_alloc") {
      page_allocs[execname()]++
}

function print_count() {
      printf ("%-25s %-s\n", "#Pages Allocated", "Process Name")
      foreach (proc in page_allocs-)
              printf("%-25d %s\n", page_allocs[proc], proc)
      printf ("\n")
      delete page_allocs
}

probe timer.s(5) {
        print_count()
}
```

- Systemtap understands tracepoints too
- Access via kernel.trace() function

Systemtap II

- Advantages:
  - Scripting support
  - Multiple instances
  - Type enforcement

Ftrace

- Infrastructure since 2.6.27
- Ftrace can easily trace function calls or use static tracepoints placed in the kernel source
- No dynamic tracepoint on the fly support
- Function tracer implementation via `mcount` (`-pg`, see next foil)
- Interface:

```
mount -t debugfs nodev /sys/kernel/debug
sysctl kernel.ftrace_enabled=1
echo function > current_tracer
echo 1 > tracing_on
usleep 1
echo 0 > tracing_on
cat trace
```

- *Documentation/trace/ftrace.txt*

Function Tracer

- Ingo Molnar and William Lee Irwin created a tracer to find latency problems in the RT branch
- One feature of the latency tracer was the function tracer.
- Used to show what function where called when interrupts
- How can it be that if not enabled nearly no overhead can be measured? How is function tracing implemented?
  - If `CONFIG_DYNAMIC_TRACE` is set the gcc compiles with `-pg`[?, ?]
  - In in turn `mcount()` is placed at every function (this is why inlined function cannot be traced)
  - Gprof is the most prominent user of mcount() (`_mcount()` BTW is provided by GLIBC - not GCC)
  - After compilation objedump will search for mcount() callees in the .text segment (recordmcount.pl)

- This script generates a new segment (`__mcount_loc`) that hold all references to mcount callees
- At boot time the ftrace code iterate over this list and update replace all mcount() calls by nops. Additionally all locations are saved in a list (`available_filter_list`)
- When traceing is enabled these nops are patched back to call the ftrace infrastructure (`mcount()` is a stub)

Background – Trace Points

```
void kfree_skb(struct sk_buff *skb)
{
        if (unlikely(!skb))
                return;
        if (likely(atomic_read(&skb->users) == 1))
                smp_rmb();
        else if (likely(!atomic_dec_and_test(&skb->users)))
                return;
        trace_kfree_skb(skb, __builtin_return_address(0));
        __kfree_skb(skb);
}
```

Trace Points

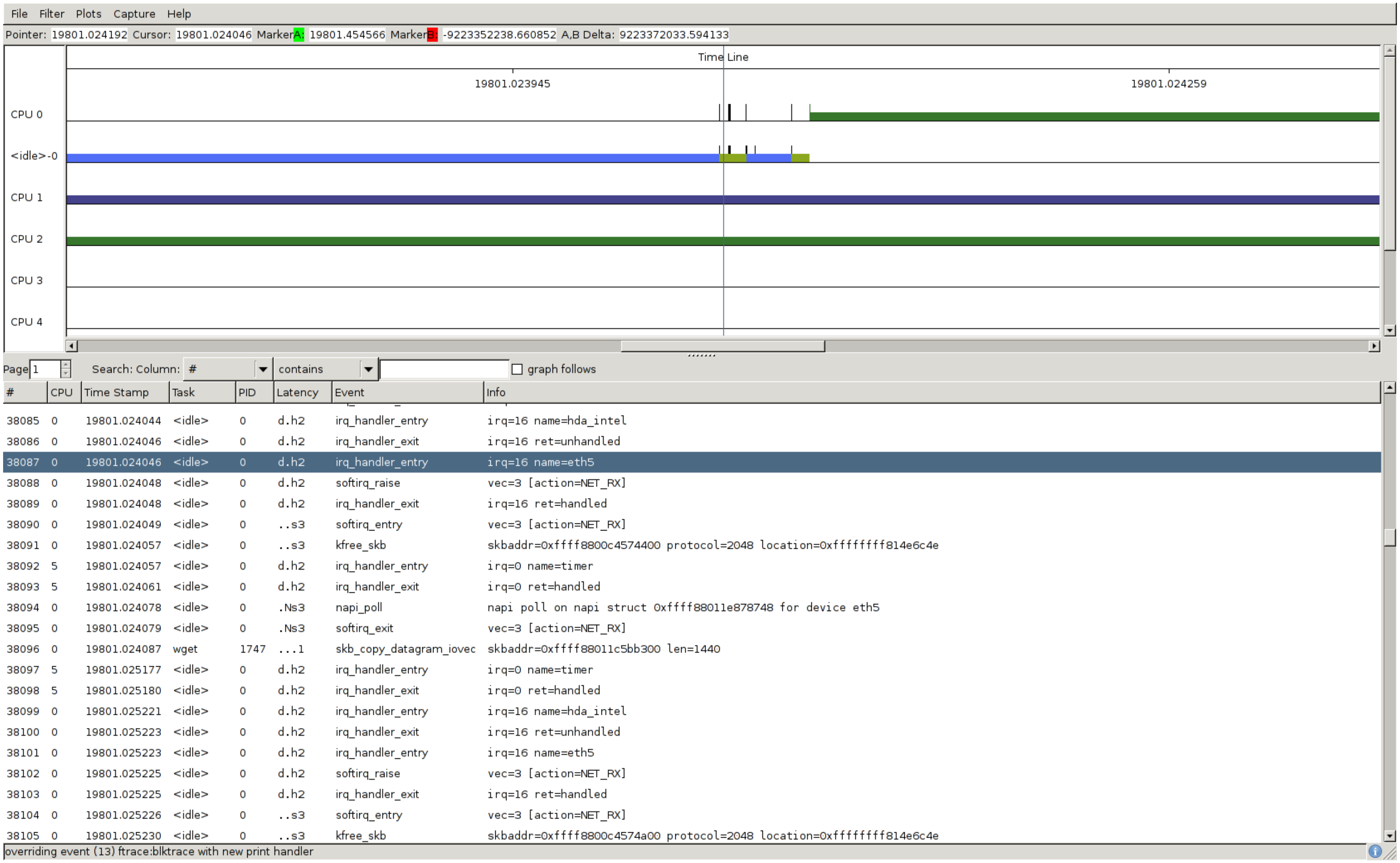
- `cat /sys/kernel/debug/tracing/available_events | wc -l` → 778
- (or `trace-cmd list` or `perf list | grep Tracepoint`

trace-cmd

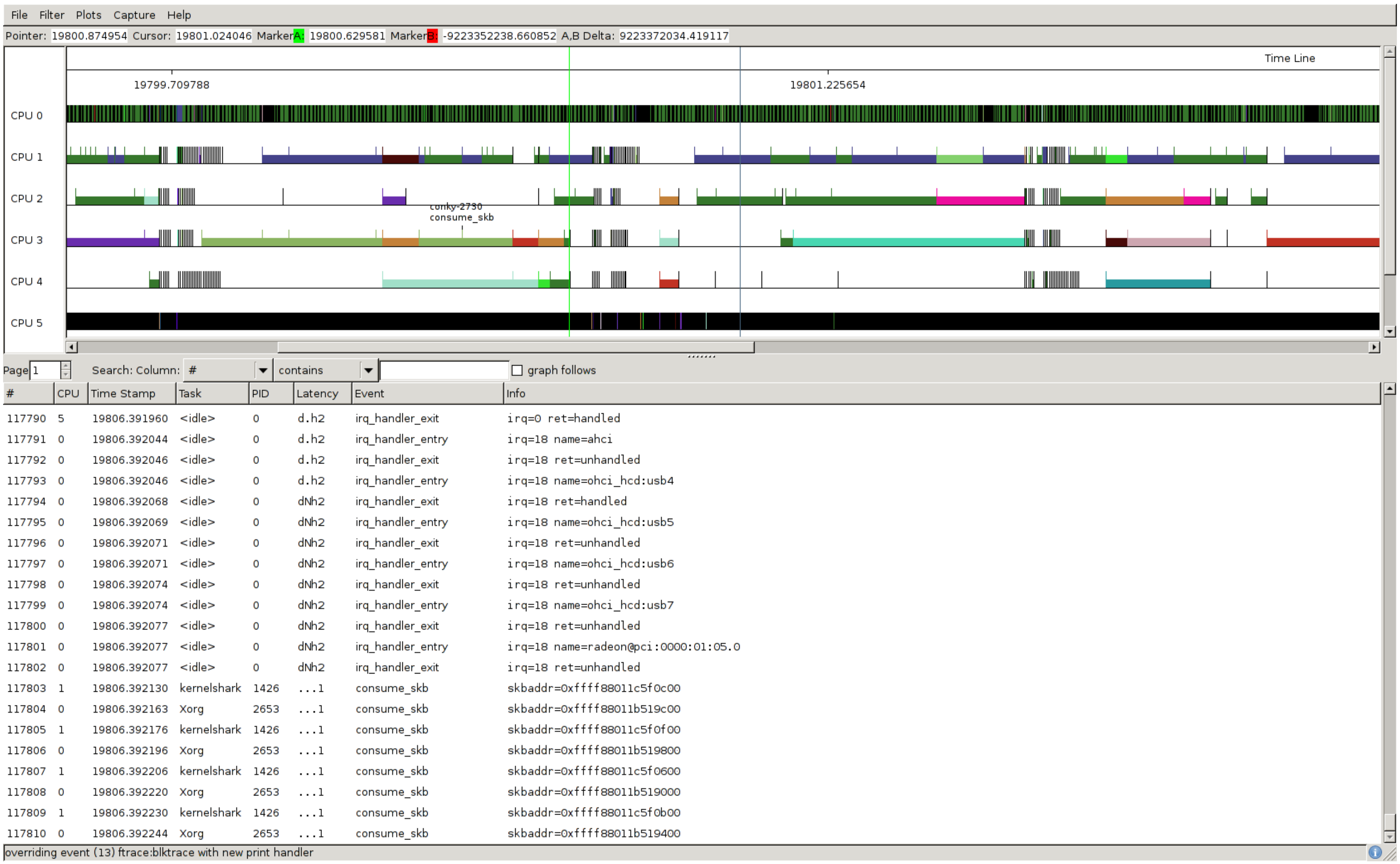
- Originally a user was constrained to echo and cat to set up a `ftrace`
- Tool from Steven Rostedt to hide the detail
- Trace points must be a priory available in the kernel
  - Scheduling
  - Interrupts
  - Free skb's
- Set up a tracer:
  - `trace-cmd record -e <subsystem:event-name>`
  - `trace-cmd record -p function -e sched_switch ls > /dev/null`
  - what interrupts have the highest latency
    - `trace-cmd record -p function_graph -e irq_handler_entry -l do_IRQ sleep 10; trace-cmd report`
  - kmalloc calls that were greater than 1000 bytes

- `trace-cmd report -F 'kmalloc: bytes_req > 1000'`
- Function Graph
  - `trace-cmd record -p function_graph ls /bin`
- Finding high latency interrupts (one of Stevens examples)
  - `trace-cmd record -p function_graph -l do_IRQ -e irq_handler_entry`
  - `trace-cmd report | cut -c32-43 --complement`
- `git://git.kernel.org/pub/scm/linux/kernel/git/rostedt/trace-cmd.git`

Kernelshark II



Kernelshark II



#	CPU	Time Stamp	Task	PID	Latency	Event	Info
117790	5	19806.391960	<idle>	0	d.h2	irq_handler_exit	irq=0 ret=handled
117791	0	19806.392044	<idle>	0	d.h2	irq_handler_entry	irq=18 name=ahci
117792	0	19806.392046	<idle>	0	d.h2	irq_handler_exit	irq=18 ret=unhandled
117793	0	19806.392046	<idle>	0	d.h2	irq_handler_entry	irq=18 name=ohci_hcd:usb4
117794	0	19806.392068	<idle>	0	dNh2	irq_handler_exit	irq=18 ret=handled
117795	0	19806.392069	<idle>	0	dNh2	irq_handler_entry	irq=18 name=ohci_hcd:usb5
117796	0	19806.392071	<idle>	0	dNh2	irq_handler_exit	irq=18 ret=unhandled
117797	0	19806.392071	<idle>	0	dNh2	irq_handler_entry	irq=18 name=ohci_hcd:usb6
117798	0	19806.392074	<idle>	0	dNh2	irq_handler_exit	irq=18 ret=unhandled
117799	0	19806.392074	<idle>	0	dNh2	irq_handler_entry	irq=18 name=ohci_hcd:usb7
117800	0	19806.392077	<idle>	0	dNh2	irq_handler_exit	irq=18 ret=unhandled
117801	0	19806.392077	<idle>	0	dNh2	irq_handler_entry	irq=18 name=radeon@pci:0000:01:05.0
117802	0	19806.392077	<idle>	0	dNh2	irq_handler_exit	irq=18 ret=unhandled
117803	1	19806.392130	kernelshark	1426	...1	consume_skb	skbaddr=0xffff88011c5f0c00
117804	0	19806.392163	Xorg	2653	...1	consume_skb	skbaddr=0xffff88011b519c00
117805	1	19806.392176	kernelshark	1426	...1	consume_skb	skbaddr=0xffff88011c5f0f00
117806	0	19806.392196	Xorg	2653	...1	consume_skb	skbaddr=0xffff88011b519800
117807	1	19806.392206	kernelshark	1426	...1	consume_skb	skbaddr=0xffff88011c5f0600
117808	0	19806.392220	Xorg	2653	...1	consume_skb	skbaddr=0xffff88011b519000
117809	1	19806.392230	kernelshark	1426	...1	consume_skb	skbaddr=0xffff88011c5f0b00
117810	0	19806.392244	Xorg	2653	...1	consume_skb	skbaddr=0xffff88011b519400

Perf

- Access to hardware counters (first releases) [2]
- First release: Ingo Molnar and Thomas Gleixner; now Arnaldo, Frederic, ...
  - Special hardware registers
  - Count number of certain hardware events like
    - Cache misses
    - TLB missed
    - CPU cycles
    - Branch misprediction
  - Without slowing down the execution (hardware register, say nearly without)
- Interface to kernel tracepoints (examples)
  - Trace points are interesting locations in subsystems, not a record of all executed

[2] if you build perf by yourself, make sure you build for the actual kernel version: *perf –version* (perf version 2.6.39.rc1.210.g66ee33.dirty) should match *uname -r* (2.6.39-rc1+)

function

- Between these points the must interpolate what happens during that time

- Collect all kind of performance data
- Superseeds oprofile, perfmon2, (partly systemtap)
- Per thread, task, CPU or system wide

Perf

- Commands:

```
annotate        Read perf.data (created by perf record) and display annotated code
bench           General framework for benchmark suites
list            List all symbolic event types
probe           Define new dynamic tracepoints
record          Run a command and record its profile into perf.data
report          Read perf.data (created by perf record) and display the profile
sched           Tool to trace/measure scheduler properties (latencies)
script          Read perf.data (created by perf record) and display trace output
stat            Run a command and gather performance counter statistics
timechart       Tool to visualize total system behavior during a workload
top             System profiling tool.
[...]
```

Perf stat

- `perf stat ls -R > /dev/null`:

```
Performance counter stats for 'ls -R':

       371,191921 task-clock-msecs         #      0,995 CPUs
               14 context-switches         #      0,000 M/sec
                2 CPU-migrations           #      0,000 M/sec
              479 page-faults              #      0,001 M/sec
    1.208.000.453 cycles                   #   3254,382 M/sec  (scaled from 65,65%)
    1.643.737.756 instructions             #      1,361 IPC    (scaled from 65,67%)
      308.823.362 branches                 #    831,978 M/sec  (scaled from 67,44%)
        8.156.463 branch-misses            #      2,641 %      (scaled from 67,77%)
      472.335.871 cache-references         #   1272,484 M/sec  (scaled from 67,65%)
        4.174.862 cache-misses             #     11,247 M/sec  (scaled from 66,57%)

       0,373027705  seconds time elapsed
```

Perf

- Perf list:

```
  cpu-cycles OR cycles                          [Hardware event]
  instructions                                  [Hardware event]
  cache-references                              [Hardware event]
  cache-misses                                  [Hardware event]
  branch-instructions OR branches               [Hardware event]
  branch-misses                                 [Hardware event]
[...]
  skb:kfree_skb                                 [Tracepoint event]
  skb:consume_skb                               [Tracepoint event]
  skb:skb_copy_datagram_iovec                   [Tracepoint event]
  net:net_dev_xmit                              [Tracepoint event]
  net:net_dev_queue                             [Tracepoint event]
  net:netif_receive_skb                         [Tracepoint event]
  net:netif_rx                                  [Tracepoint event]
  napi:napi_poll                                [Tracepoint event]
```

Perf

- `sudo perf record -g ./client -r 0 -s 1073741824 -i 0 -d 0 -n 1 -e localhost`
- `perf report`

Perf Scripts

- Perl or Python
- Generate template, the rest (processing) is up to the user
- `perf script record netdev-times`
- `perf script report netdev-times dev=eth5`

```
21150.714226sec cpu=0
  irq_entry(+0.000msec irq=16:eth5)
         |
  softirq_entry(+0.004msec)
         |
         |---netif_receive_skb(+0.008msec skb=ffff8800cda03400 len=1492)
         |            |
         |      skb_copy_datagram_iovec(+0.034msec 8948:wget)
         |
  napi_poll_exit(+0.026msec eth5)
```

Kprobe based Event Tracer

- Masami Hiramatsu (26 files changed, 3924 insertions(+), 163 deletions(-))
- Based on kprobe (and kretprobe)
- Probe various kernel events through ftrace interface
- Anywhere where kprobes can probe
- Unlike the function tracer, this tracer can probe instructions inside of kernel functions
- Allows you to check which instruction has been executed
- On the fly
- `p[:EVENT] SYMBOL[+offset|-offset]|MEMADDR [FETCHARGS]`
- `r[:EVENT] SYMBOL[+0] [FETCHARGS]`
- LWN Article: http://lwn.net/Articles/343766/

Perf probe

- `perf probe ip_rcv`
- `perf record -e probe:ip_rcv -R -f -g -a`
- `perf report`

```
100.00%       nyxmms2  [kernel.kallsyms]  [k] ip_rcv
              |
              --- ip_rcv
                 |
                 |--100.00%-- netif_receive_skb
                 |          |
                 |          |--100.00%-- napi_gro_complete
                 |          |          napi_gro_flush
                 |          |          napi_complete
                 |          |          e1000_clean
                 |          |          net_rx_action
                 |          |          __do_softirq
                 |          |          call_softirq
                 |          |          _local_bh_enable_ip
                 |          |          local_bh_enable
                 |          |          dev_queue_xmit
                 |          |          ip_finish_output2
                 |          |          ip_finish_output
```

```
                    |          |         ip_output
                    |          |         dst_output
                    |          |         ip_local_out
                    |          |         ip_queue_xmit
                    |          |         tcp_transmit_skb
                    |          |         tcp_write_xmit
[...]
```

Trace Packet Flow through Kernel

- Attention: NAPI and non-NAPI flow, take your path)
- What we (probably) want to know:
  - We want to know when the Userspace blocked in recvfrom()
    - → `recvfrom()`
  - We want to know when a NIC interrupt is triggered
    - → `irq_entry()`
  - called by driver when frame received on interface; enqueues frame on current processor's packet receive queue (non NAPI implementation; NAPI driver call netif_receive_skb)
    - → `netif_rx`
  - We can check when the softirq is raised
    - → `softirq_raise`
  - We can check when the interrupt is exited

- → `irq_exit`
- We want to know when the softirq is executed
  - → `softirq_entry`
- We want to know when a packet is get from device queue
  - softirq context
  - → `dev.c:__netif_receive_skb()`
- We want to know when data is delivery to the user (receive queue)
  - → `skb_copy_datagram_iovec()`
  - `tcp_data_queue()`, `udp_recvmsg`, ... call `skb_copy_datagram_iovec()`
- We want to know napi loop is leaved
  - → `napi_poll_exit()`
- We want to know when softirq context is leaved
  - → `softirq_exit()`
- We want to know when the Userspace Application is scheduled in

- We want to know when the Userspace returned from recvfrom()
  - $\longrightarrow$ `recvfrom()`

KVM, Qemu and GDB

- Allow so single step in a real system
- Advantage: analyze the behavior on the fly where you don't know where to look in advance (e.g. lot of code must be conditionally analysed, without any prior knowledge)
- Use your standard *qemu* setup with two additional *qemu* flags: `-s` and `-S`
- Both flags instrument *qemu* to start a *qemu gdb* server and to break at the beginning
- Setup for the other side:

```
gdb /usr/src/linux/vmlinux
target remote localhost:1234
c
bt
set architecture i386:x86-64:intel
```

- `set architecture i386:x86-64:intel` fix a bug where gdb cannot detect that the target is `x86_64`

Misc

- If all tools fail? `trace_printk()`
- Interface:
  - `trace_printk()`
    - debug fast path sections that printk is too slow
    - printk may overwhelm the system (livelook)
    - Print to ftrace ringbuffer
    - ms versus ■ us
  - `trace_clock_global()` may be your friend

Background – GCC Instruments

- `-finstrument-functions`[?]
  - Insert hooks for function entry and exit

```
0000000000400514 <func>:
400514: 53                    push   %rbx
400515: 31 f6                 xor    %esi,%esi
400517: 89 fb                 mov    %edi,%ebx
400519: bf 14 05 40 00        mov    $0x400514,%edi
40051e: e8 ed fe ff ff        callq  400410 <__cyg_profile_func_enter@plt>
400523: 31 f6                 xor    %esi,%esi
400525: bf 14 05 40 00        mov    $0x400514,%edi
40052a: e8 f1 fe ff ff        callq  400420 <__cyg_profile_func_exit@plt>
40052f: 69 c3 ad de 00 00     imul   $0xdead,%ebx,%eax
400535: 5b                    pop    %rbx
400536: c3                    retq
```

  - Support **`inlined`** function as well
  - GCC version 2.95 or later required
  - See [?] for an user of **`-finstrument-functions`**

Background – GCC Instruments

```
void __attribute__((__no_instrument_function__)) __cyg_profile_func_enter(
                void *this_fn, void *call_site)
{
        int n;

        call_depth++;
        for (n = 0; n < call_depth; n++)
                printf(" ");
        printf("-> %p\n", this_fn);
}
```

- First argument is the address of the start of traced function
- Address to symbol translation can be done via `nm`

```
[...]
00000000004004d0 t __do_global_dtors_aux
0000000000400540 t frame_dummy
0000000000400564 T __cyg_profile_func_enter
000000000040059a T __cyg_profile_func_exit
00000000004005d2 T func
00000000004005f5 T main
[...]
```

Background – GCC Instruments

- `-ftest-coverage`
  - Instrument the generated code to count the execution frequencies of each basic block
- `fprofile-arcs`
  - count the execution frequencies of each branch
- *gcov* can be used to annotate the source code with this information

Background – GCC Instruments

- `-pg`
  - Adding a call to a function named mcount (or `_mcount()`, depends on compiler)
  - `mcount()` function of GLIBC
  - Lightweight - „only“ function call overhead

```
[...]
4005e4: 55                   push   %rbp
4005e5: 48 89 e5             mov    %rsp,%rbp
4005e8: e8 ab fe ff ff       callq  400498 <mcount@plt>
4005ed: 5d                   pop    %rbp
4005ee: 69 c7 ad de 00 00    imul   $0xdead,%edi,%eax
4005f4: c3                   retq
[...]
```

Kernel Oops

```
BUG: unable to handle kernel NULL pointer dereference at 00000050
IP: [<c12280c0>] tc_fill_qdisc+0x68/0x1e5
*pde = 00000000
Oops: 0000 [#1] SMP
last sysfs file:
Modules linked in:

Pid: 600, comm: qdisc Not tainted 2.6.34 #16 /
EIP: 0060:[<c12280c0>] EFLAGS: 00010282 CPU: 0
EIP is at tc_fill_qdisc+0x68/0x1e5
EAX: 00000000 EBX: ffffffff ECX: 00000000 EDX: c7222070
ESI: c14576e0 EDI: c7115200 EBP: c7239ca0 ESP: c7239c3c
DS: 007b ES: 007b FS: 00d8 GS: 0033 SS: 0068
Process qdisc (pid: 600, ti=c7239000 task=c720b700 task.ti=c7239000)
Stack:
00000024 00000014 00000000 c14323a0 c7222060 c7222060 c10a7abd 00001030
<0> 000000d0 c7222060 000000d0 c1228329 000000d0 00000fc4 000000d0 c7115200
<0> 000000d0 00000ec0 c7239cac c12104b1 00000ec0 c1457a98 c7115200 00000258
Call Trace:
[<c10a7abd>] ? __kmalloc_track_caller+0x122/0x131
[<c1228329>] ? qdisc_notify+0x2a/0xc8
[<c12104b1>] ? __alloc_skb+0x4e/0x115
[<c122838a>] ? qdisc_notify+0x8b/0xc8
```

```
[...]
```

- gdb vmlinuz
- `i line *tc_fill_qdisc+0x68`
- `l sch_api.c:1191`
- `x/8i  *tc_fill_qdisc+0x68`

End

- Contact:
  - Hagen Paul Pfeifer <hagen@jauu.net>
  - Key Id: `0x98350C22`
  - Key Fingerprint: `490F 557B 6C48 6D7E 5706 2EA2 4A22 8D45 9835 0C22`

Perf Internals

- via `perf report -D` recorded raw samples can be displayed
- To disable some cores:
  - add `maxcpus=1` to kernel command line

Trace Points I

`CONFIG_FUNCTION_TRACER`
`CONFIG_FUNCTION_GRAPH_TRACER`
`CONFIG_STACK_TRACER`
`CONFIG_DYNAMIC_FTRACE`

Trace Points II

```
#include <linux/ftrace.h>
#define CREATE_TRACE_POINTS
#include <trace/events/sched.h>

[...]
trace_sched_migrate_task(p, new_cpu);

if (task_cpu(p) != new_cpu) {
        p->se.nr_migrations++;
        perf_sw_event(PERF_COUNT_SW_CPU_MIGRATIONS, 1, 1, NULL, 0);
}

__set_task_cpu(p, new_cpu);
[...]
```

Trace Points III

```
TRACE_EVENT(sched_migrate_task,

  TP_PROTO(struct task_struct *p, int dest_cpu),

  TP_ARGS(p, dest_cpu),

  TP_STRUCT__entry(
          __array(        char,   comm,   TASK_COMM_LEN   )
          __field(        pid_t,  pid                     )
          __field(        int,    prio                    )
          __field(        int,    orig_cpu                )
          __field(        int,    dest_cpu                )
  ),

  TP_fast_assign(
          memcpy(__entry->comm, p->comm, TASK_COMM_LEN);
          __entry->pid            = p->pid;
          __entry->prio           = p->prio;
          __entry->orig_cpu       = task_cpu(p);
          __entry->dest_cpu       = dest_cpu;
  ),

  TP_printk("comm=%s pid=%d prio=%d orig_cpu=%d dest_cpu=%d",
```

```
            __entry->comm, __entry->pid, __entry->prio,
            __entry->orig_cpu, __entry->dest_cpu)
);
```

Gigabit and PCI Bus

- PCI-Express just great for 1Gbps
- `lspci -t -v` and `lspci -vvv`

```
02:00.0 Ethernet controller: Intel Corporation 82574L Gigabit Network Connection
  Subsystem: Intel Corporation Gigabit CT Desktop Adapter
  Control: I/O+ Mem+ BusMaster+ SpecCycle- MemWINV- VGASnoop- ParErr- Stepping- SERR+ Fa
  Status: Cap+ 66MHz- UDF- FastB2B- ParErr- DEVSEL=fast >TAbort- <TAbort- <MAbort- >SERR
  Latency: 0, Cache Line Size: 64 bytes
  Interrupt: pin A routed to IRQ 16
  Region 0: Memory at fe6e0000 (32-bit, non-prefetchable) [size=128K]
  Region 1: Memory at fe600000 (32-bit, non-prefetchable) [size=512K]
  Region 2: I/O ports at bc00 [size=32]
  Region 3: Memory at fe6dc000 (32-bit, non-prefetchable) [size=16K]
  Expansion ROM at fe680000 [disabled] [size=256K]
  Capabilities: <access denied>
  Kernel driver in use: e1000e
```

- Default IRQ assignments are read from the Differentiated System Description Table (DSDT) table in the BIOS

Modifying the DSDT

- AML table in BIOS
- Build a custom DSDT:
  - `aptitude install acpidump iasl`
  - `acpidump > acpidump.data`
  - `acpixtract acpidump.data` (will generate DSDT.dat and SSDT.dat)
  - `iasl -d DSDT.dat`
  - `vim DSDT.dsl`
  - `iasl -tc DSDT.dsl`
  - `cp DSDT.hex /usr/src/linux/include/`
  - `CONFIG_STANDALONE=n, CONFIG_ACPI_CUSTOM_DSDT=y, CONFIG_ACPI_CUSTOM_DSDT_FILE="DSDT.hex"`

Packet Drop

- since the kernel has a limit of how many fragments it can buffer before it starts throwing away packet
- `/proc/sys/net/ipv4/ipfrag_high_thresh` `/proc/sys/net/ipv4/ipfrag_low_thresh`
- Once the number of unprocessed, fragmented packets reaches the number specified by `ipfrag_high_thresh` (in bytes), the kernel will simply start throwing away fragmented packets until the number of incomplete packets reaches the number specified by `ipfrag_low_thresh`.
- Another counter to monitor is IP: ReasmFails in the file `/proc/net/snmp`; this is the number of fragment reassembly failures. if it goes up too quickly during heavy file activity, you may have a problem.

Softnet

- /proc/net/softnet_stat

```
total    dropped  squeezed                                                     collisio
00101ba7 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
0005c045 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
0003a7cf 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
000286ae 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
000126a7 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
00010b04 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000 00000000
```