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Using the Linux Tracing Infrastructure

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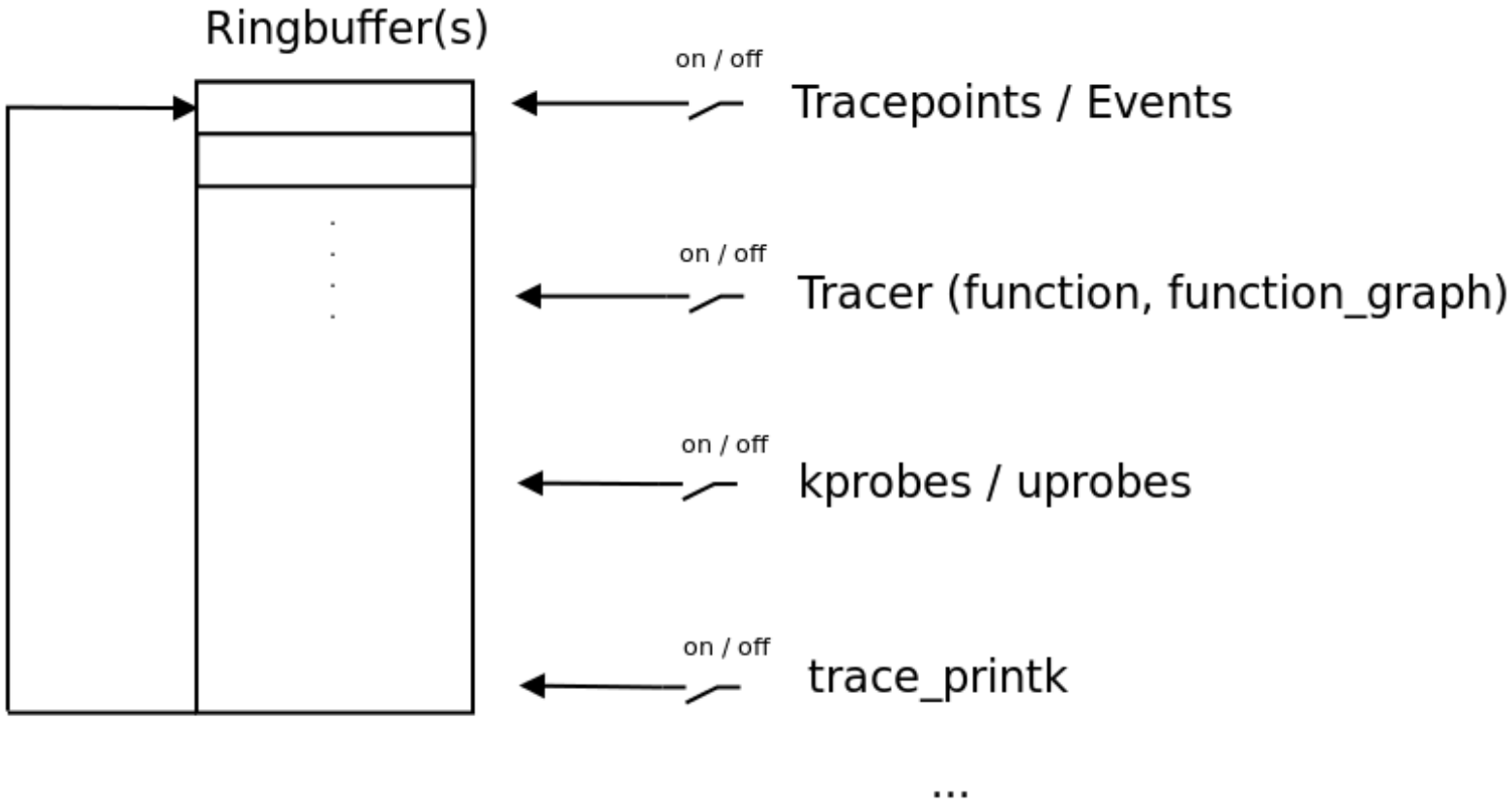
Overview

1. Event tracing
2. Tracers
3. trace_marker
4. trace_printk
5. kprobes
6. uprobes
7. trace-cmd
8. Kernelshark
9. Tracecompass

Kerneltracing: Overview

- DebugFS / TraceFS interface
- Event Tracing
- Custom trace events
- Different tracers: function, function_graph, wakeup, wakeup_rt, ...
- Graphical frontend(s) available

Kerneltracing: Overview



Kernel-Tracing: DebugFS

```
$ mount -t debugfs debugfs /sys/kernel/debug
$ cd /sys/kernel/debug/tracing
$ cat available_tracers
blk function_graph mmiotrace wakeup_rt wakeup
```

Event tracing

- Pre-defined Events in the kernel
- Event groups
- Each event comes with several options
- Filtering based on event options

Event tracing

```
$ cd /sys/kernel/debug/tracing
$ ls -1 events/sched/
enable
filter
sched_kthread_stop
sched_kthread_stop_ret
sched_migrate_task
sched_pi_setprio
[...]
```

Event tracing: Enable events

```
$ cd /sys/kernel/debug/tracing
# Enable ALL events of the group ''sched''
$ echo 1 > events/sched/enable
```

Record a trace

After enabling the events you want to see, do:

```
$ cd /sys/kernel/debug/tracing
# Start recording to the ringbuffer
$ echo 1 > tracing_on
# Stop recording to the ringbuffer
$ echo 0 > tracing_on
```

Analyze a trace

You can even do this while recording!

```
$ cd /sys/kernel/debug/tracing
# Just print the current content of the ring buffer
$ cat trace
# or: do a consuming read on the ring buffer
$ cat trace_pipe
```

Trace event format and filters

Each trace event has a specific format and parameters. You can put a filter on those parameters for recording a trace:

```
$ cat events/sched/sched_switch/format
[...]
field:__u8 prev_comm[15];
field:pid_t prev_pid;
field:int prev_prio;
field:long prev_state;
[...]
$ echo 'next_comm == bash' \
    > events/sched/sched_switch/filter
$ echo 1 > events/sched/sched_switch/enable
$ echo 1 > tracing_on
$ cat trace
```

Tracing on multicore

- One ringbuffer per cpu
- trace contains ALL events
- the per_cpu directory contains a trace for each cpu
- tracing_cpumask can limit tracing to specific cores

Tracers

- Already have some special logic
- Latency hunting
- Callgraphs
- Kernel profiling
- ...

Tracers

available_tracers contains the tracers which are enabled in the kernel configuration. The tracer ist set by the current_tracer file:

- function: Can turn all functions into trace events
- function_graph: Similiar to function, but contains a call graph
- wakeup / wakeup_rt: Measure the wakeup time for tasks / rt tasks
- irqsoff: useful for latency hunting. Identifies long sections with IRQs turned off
- ...

Tracer: function

```
# tracer: function
#
# TASK-PID   CPU#    TIMESTAMP  FUNCTION
#  | |       |          |         |
wnck-2022   [003]  5766.659915: skb_release
wnck-2022   [003]  5766.659916: sock_wfree
wnck-2022   [003]  5766.659917: unix_write_free
wnck-2022   [003]  5766.659917: skb_releasee_skb
wnck-2022   [003]  5766.659918: kfree <-skb
```

Tracer: function_graph

```
$ echo function_graph > current_tracer
$ echo 1 > tracing_on
$ sleep 1
$ echo 0 > tracing_on
$ less trace
# tracer: function_graph
# CPU  DURATION            FUNCTION CALLS
# |     |   |                |   |   |   |
 1)               |          enqueue_entity() {
 1)               |            update_curr() {
 1)   0.336 us    |              task_of();
 1)   1.524 us    |            }
 1)   0.420 us    |            place_entity();
```

function_graph: Set a trigger function

You can set a trigger function for the function_graph tracer if you just want to record specific functions and their childs:

```
echo do_IRQ > set_graph_function
# Additionals triggers can be set with
echo another_function >> set_graph_function
```

Tracer: function / latency_format

```
$ echo 1 > options/latency_format
# tracer: function
#
# function latency trace v1.1.5 on 3.9.4-x1-00124-g0bfd8ff
# --------------------------------------------------------------------
# latency: 0 us, #204955/25306195, CPU#0 | (M:desktop VP:0, KP:0, SP:0 HP:0 #P:4)
#    -----------------
#    | task: -0 (uid:0 nice:0 policy:0 rt_prio:0)
#    -----------------
#
#                  _------=> CPU#
#                 / _-----=> irqs-off
#                | / _----=> need-resched
#                || / _---=> hardirq/softirq
#                ||| / _--=> preempt-depth
#                |||| /     delay
#  cmd     pid   ||||| time  |   caller
#     \   /      |||||  \    |   /
terminol-11964   1.... 11639243us : ep_read_events_proc <-ep_scan_ready_list.isra.8
```

Custom application tracepoints: "simple method"

```
$ echo 1 > tracing_on
$ echo "MARK" > trace_marker
$ echo 0 > tracing_on
$ less trace
...
 bash-4328  [003]  5603.687935: get_slab
 bash-4328  [003]  5603.687935: _cond_re
 bash-4328  [003]  5603.687936: _cond_re
 bash-4328  [003]  5603.687939: 0: MARK
 bash-4328  [003]  5603.687939: kfree <-
...
```

trace_printk()

- trace_printk() can be used to write messages to the tracing ring buffer
- Usage is similar to printk()

Tracing related kernel parameters

`ftrace=`

Set and start specified tracer as early as possible.

`ftrace_dump_on_oops[=orig_cpu]`

Dump the tracing ring buffer if an Oops occurs. Using orig_cpu it will only dump the buffer of the CPU which triggered the Oops.

`ftrace_filter=`

Only trace specific functions.

`ftrace_notrace=`

Don't trace specific functions.

`trace_event=`

Just enable trace events (comma separated list)

Dump trace buffer

The trace buffer can also be dumped by:
SysRQ-z
or

```
echo z > /proc/sysrq-trigger
```

Trace instances

You can have separate trace instances with their own buffers and events:

```
$ cd /sys/kernel/debug/tracing
$ mkdir instances/my_inst1
$ cd instances/my_inst1
$ echo 1 > events/sched/enable
$ cat trace
[...]
```

Dynamic kernel tracepoints: KPROBES

- Similar to Tracepoints
- Can be added / removed dynamically

Dynamic kernel tracepoints: KPROBES

```
$ echo 'p:my_k_event do_IRQ' > kprobe_events
$ echo 1 > events/kprobes/my_k_event/enabled
$ echo 1 > tracing_on
$ cat trace
<idle>-0 [000] d... 545.173709: my_k_event: (do_IRQ+0x0/0xc0)
<idle>-0 [000] d... 545.331051: my_k_event: (do_IRQ+0x0/0xc0)
<idle>-0 [000] d... 545.331490: my_k_event: (do_IRQ+0x0/0xc0)
<idle>-0 [000] d... 545.490730: my_k_event: (do_IRQ+0x0/0xc0)
```

Dynamic kernel tracepoints: KPROBES for custom modules

Let's assume we want to have a tracepoint for the function hello_init in the module hello.ko

```
# Note: >> will append a new event
$ echo 'p:my_mod_event hello:hello_init' \
           >> kprobe_events
$ echo 1 > events/kprobes/my_mod_event/enable
$ insmod hello.ko
$ cat trace
insmod-9586  [000] d... 13278.003468: my_mod_event: (0xf878d080)
```

KPROBES statistics

```
$ cat kprobe_profile
my_mod_event_ret                2                   0
my_mod_event                    2                   0
```

Dynamic Userspace Tracepoints: uprobes

- Similar to kprobes
- For userspace applications
- A uprobe event is set on a specific offset in a userland process
- Powerful method to correlate your kernel and userland events!

Dynamic Userspace Tracepoints: uprobes

```
$ gcc -Wall -g -o pthread_example \
      pthread_example.c -lpthread
$ objdump -F -D -S pthread_example | less

08048594 <my_test_thread> (File Offset: 0x594):
[...]
void *my_test_thread(void *x_void_ptr)
[...]
        for (i = 0; i < 10; i++) {
80485a1:  c7 45 f4 00 00 00 00    movl   $0x0,-0xc(%ebp)
80485a8:  eb 1c                   jmp   80485c6 <my_test_thread+0x32> (File Offset
          printf("The answer is 42!\n");
80485aa:  c7 04 24 50 87 04 08    movl   $0x8048750,(%esp)
```

So, the file offset for the printf call is 0x5aa !

Dynamic Userspace Tracepoints: uprobes II

```
echo \
'p:my_ev /home/devel/pthread/pthread_example:0x5aa' \
       >  /sys/kernel/debug/tracing/uprobe_events
```

Dynamic Userspace Tracepoints: uprobes III

```
$ cd /sys/kernel/debug/tracing/
$ echo 1 > events/uprobes/my_ev/enable
$ echo 1 > tracing on
$ /home/devel/pthread_example/pthread_example
$ echo 0 > tracing_on
$ less trace
#      TASK-PID   CPU#  ||||    TIMESTAMP  FUNCTION
#         | |       |   ||||       |         |
ARTHUR_DENT-5223  [000] d...  5653.154822: my_ev: (0x80485aa)
ARTHUR_DENT-5223  [000] d...  5654.155723: my_ev: (0x80485aa)
```

uprobes: statistics

```
$  cat uprobe_profile
/home/devel/pthread/pthread_example my_ev    10
```

trace-cmd

What is trace-cmd?

trace-cmd is a commandline utility for controlling and analysing kernel traces.

trace-cmd: Usage

```
$ trace-cmd
[...]
record - record a trace into a trace.dat file
start - start tracing without recording into a file
extract - extract a trace from the kernel
stop - stop the kernel from recording trace data
reset - disable all kernel tracing / clear trace buffers
report - read out the trace stored in a trace.dat file
split - parse a trace.dat file into smaller file(s)
listen - listen on a network socket for trace clients
list - list the available events, plugins or options
restore - restore a crashed record
stack - output, enable or disable kernel stack tracing
```

trace-cmd: Usage

```
# Recording a sched_switch trace
$ trace-cmd -p sched_switch
  plugin sched_switch
Hit Ctrl^C to stop recording
Hit Ctrl^C to stop recording
offset=ae000
[...]

CPU: 0
entries: 0
overrun: 0
commit overrun: 0
```

trace-cmd: Usage

```
# Analysing a trace
$ trace-cmd report
version = 6
cpus=1
trace-cmd-29057 [000]  6901.652365: wakeup:
29057:120:1 ==+ 29057:120:1 [000]
trace-cmd-29057 [000]  6901.652388: wakeup:
29057:120:0 ==+ 323:120:0 [000]
trace-cmd-29057 [000]  6901.652393: context_switch:
29057:120:0 ==> 323:120:0 [000]
kworker/0:1-323   [000]  6901.652397: wakeup:
323:120:0 ==+ 28355:120:0 [000]
```

trace-cmd: Usage

- trace-cmd record generates a file called trace.dat. This can be overridden by the -o option
- trace-cmd report uses the -i option for specifying an input file

trace-cmd: Record specific events

```
trace-cmd record -e sched
# or a specific scheduler event
trace-cmd record -e sched_wait_task
# List availabe events and options
trace-cmd report --events
```

trace-cmd: Filters

Based on the options from "trace-cmd report --events":

```
trace-cmd record -e context_switch \
                 -f 'next_pid == 323'
```

trace-cmd: Tracing a specific command

Enable tracing while a specific command is being executed:

```
$ trace-cmd record -p function ls
```

trace-cmd: Recording traces via network

On the host:

```
trace-cmd listen -p 1234 -o trace_remote
```

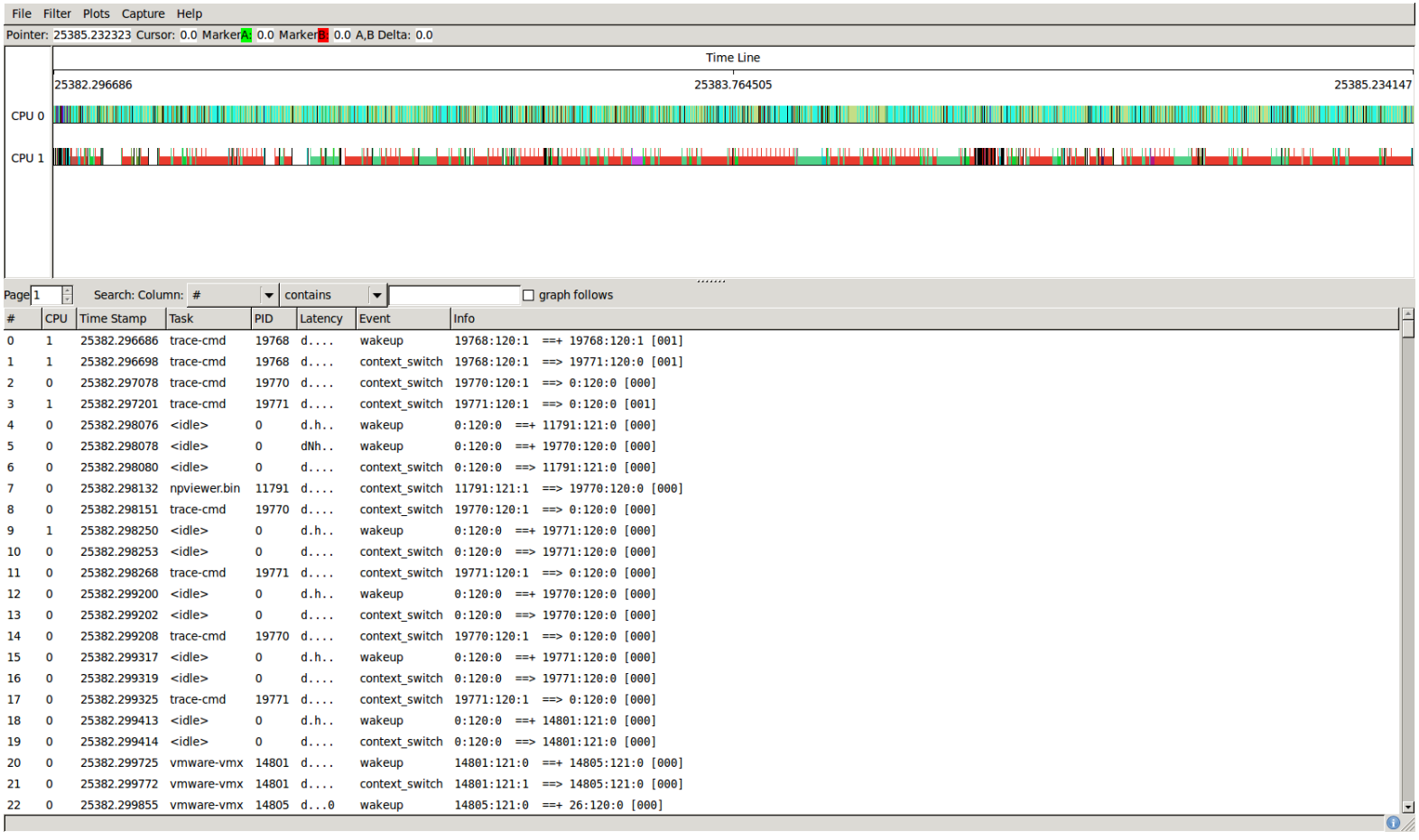
On the target:

```
trace-cmd record -p sched_switch \
       -N 192.168.0.182:1234 /bin/ls
```

Kernelshark: A graphical front-end

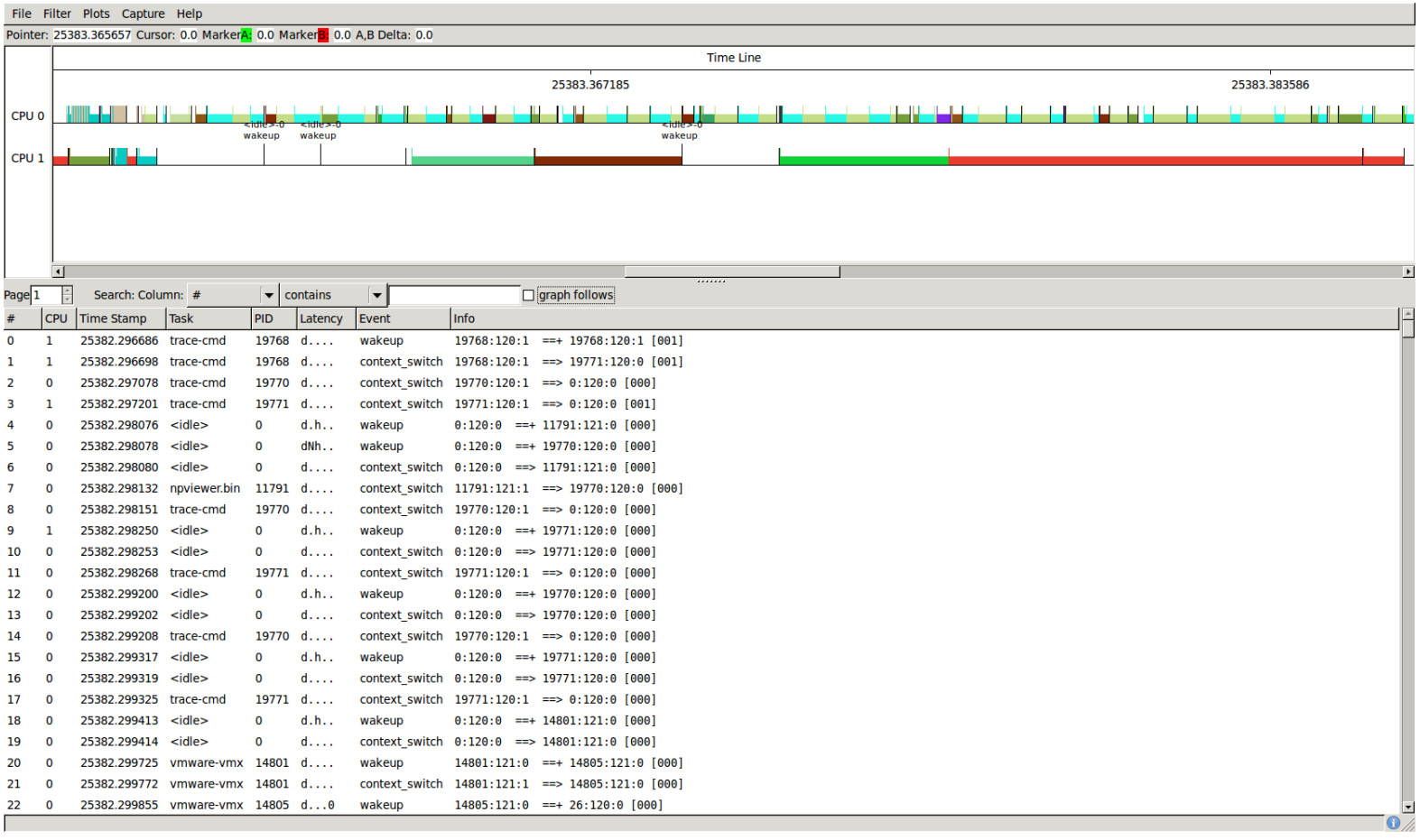
```
$ kernelshark
# or
$ kernelshark -i mytrace.dat
```

Kernelshark



#	CPU	Time Stamp	Task	PID	Latency	Event	Info
0	1	25382.296686	trace-cmd	19768	d....	wakeup	19768:120:1 ==+ 19768:120:1 [001]
1	1	25382.296698	trace-cmd	19768	d....	context_switch	19768:120:1 ==> 19771:120:0 [001]
2	0	25382.297078	trace-cmd	19770	d....	context_switch	19770:120:1 ==> 0:120:0 [000]
3	1	25382.297201	trace-cmd	19771	d....	context_switch	19771:120:1 ==> 0:120:0 [001]
4	0	25382.298076	<idle>	0	d.h..	wakeup	0:120:0 ==+ 11791:121:0 [000]
5	0	25382.298078	<idle>	0	dNh..	wakeup	0:120:0 ==+ 19770:120:0 [000]
6	0	25382.298080	<idle>	0	d....	context_switch	0:120:0 ==> 11791:121:0 [000]
7	0	25382.298132	npviewer.bin	11791	d....	context_switch	11791:121:1 ==> 19770:120:0 [000]
8	0	25382.298151	trace-cmd	19770	d....	context_switch	19770:120:1 ==> 0:120:0 [000]
9	1	25382.298250	<idle>	0	d.h..	wakeup	0:120:0 ==+ 19771:120:0 [000]
10	0	25382.298253	<idle>	0	d....	context_switch	0:120:0 ==> 19771:120:0 [000]
11	0	25382.298268	trace-cmd	19771	d....	context_switch	19771:120:1 ==> 0:120:0 [000]
12	0	25382.299200	<idle>	0	d.h..	wakeup	0:120:0 ==+ 19770:120:0 [000]
13	0	25382.299202	<idle>	0	d....	context_switch	0:120:0 ==> 19770:120:0 [000]
14	0	25382.299208	trace-cmd	19770	d....	context_switch	19770:120:1 ==> 0:120:0 [000]
15	0	25382.299317	<idle>	0	d.h..	wakeup	0:120:0 ==+ 19771:120:0 [000]
16	0	25382.299319	<idle>	0	d....	context_switch	0:120:0 ==> 19771:120:0 [000]
17	0	25382.299325	trace-cmd	19771	d....	context_switch	19771:120:1 ==> 0:120:0 [000]
18	0	25382.299413	<idle>	0	d.h..	wakeup	0:120:0 ==+ 14801:121:0 [000]
19	0	25382.299414	<idle>	0	d....	context_switch	0:120:0 ==> 14801:121:0 [000]
20	0	25382.299725	vmware-vmx	14801	d....	wakeup	14801:121:0 ==+ 14805:121:0 [000]
21	0	25382.299772	vmware-vmx	14801	d....	context_switch	14801:121:1 ==> 14805:121:0 [000]
22	0	25382.299855	vmware-vmx	14805	d...0	wakeup	14805:121:0 ==+ 26:120:0 [000]

Kernelshark



#	CPU	Time Stamp	Task	PID	Latency	Event	Info
0	1	25382.296686	trace-cmd	19768	d....	wakeup	19768:120:1 ==+ 19768:120:1 [001]
1	1	25382.296698	trace-cmd	19768	d....	context_switch	19768:120:1 ==> 19771:120:0 [001]
2	0	25382.297078	trace-cmd	19770	d....	context_switch	19770:120:1 ==> 0:120:0 [000]
3	1	25382.297201	trace-cmd	19771	d....	context_switch	19771:120:1 ==> 0:120:0 [001]
4	0	25382.298076	<idle>	0	d.h..	wakeup	0:120:0 ==+ 11791:121:0 [000]
5	0	25382.298078	<idle>	0	dNh..	wakeup	0:120:0 ==+ 19770:120:0 [000]
6	0	25382.298080	<idle>	0	d....	context_switch	0:120:0 ==> 11791:121:0 [000]
7	0	25382.298132	npviewer.bin	11791	d....	context_switch	11791:121:1 ==> 19770:120:0 [000]
8	0	25382.298151	trace-cmd	19770	d....	context_switch	19770:120:1 ==> 0:120:0 [000]
9	1	25382.298250	<idle>	0	d.h..	wakeup	0:120:0 ==+ 19771:120:0 [000]
10	0	25382.298253	<idle>	0	d....	context_switch	0:120:0 ==> 19771:120:0 [000]
11	0	25382.298268	trace-cmd	19771	d....	context_switch	19771:120:1 ==> 0:120:0 [000]
12	0	25382.299200	<idle>	0	d.h..	wakeup	0:120:0 ==+ 19770:120:0 [000]
13	0	25382.299202	<idle>	0	d....	context_switch	0:120:0 ==> 19770:120:0 [000]
14	0	25382.299208	trace-cmd	19770	d....	context_switch	19770:120:1 ==> 0:120:0 [000]
15	0	25382.299317	<idle>	0	d.h..	wakeup	0:120:0 ==+ 19771:120:0 [000]
16	0	25382.299319	<idle>	0	d....	context_switch	0:120:0 ==> 19771:120:0 [000]
17	0	25382.299325	trace-cmd	19771	d....	context_switch	19771:120:1 ==> 0:120:0 [000]
18	0	25382.299413	<idle>	0	d.h..	wakeup	0:120:0 ==+ 14801:121:0 [000]
19	0	25382.299414	<idle>	0	d....	context_switch	0:120:0 ==> 14801:121:0 [000]
20	0	25382.299725	vmware-vmx	14801	d....	wakeup	14801:121:0 ==+ 14805:121:0 [000]
21	0	25382.299772	vmware-vmx	14801	d....	context_switch	14801:121:1 ==> 14805:121:0 [000]
22	0	25382.299855	vmware-vmx	14805	d...0	wakeup	14805:121:0 ==+ 26:120:0 [000]

Tracecompass

- Uses the C ommon T race F ormat
- perf can convert traces to CTF
- perf uses libbabeltrace for the convertion
- A recent version of libbabeltrace is needed

Build perf for your Target

```
cd kernel_source/tools/perf
make ARCH=arm CROSS_COMPILE=arm-linux-gnueabihf-
# Now copy the perf executable to the target
```

Setup the tools on your host: libbabeltrace

```
git clone https://github.com/efficios/babeltrace.git
cd babeltrace
# This is a known working commit.
# Recent commits seem to be broken for perf-ctf
git checkout 9aac8f729c091ddddb688038f5d417a7b1ce4259
./bootstrap
./configure
make
sudo make install
```

Setup the tools on your host: perf

```
cd kernel_source/tools/perf
make LIBBABELTRACE=1 LIBBABELTRACE_DIR=/usr/local
```

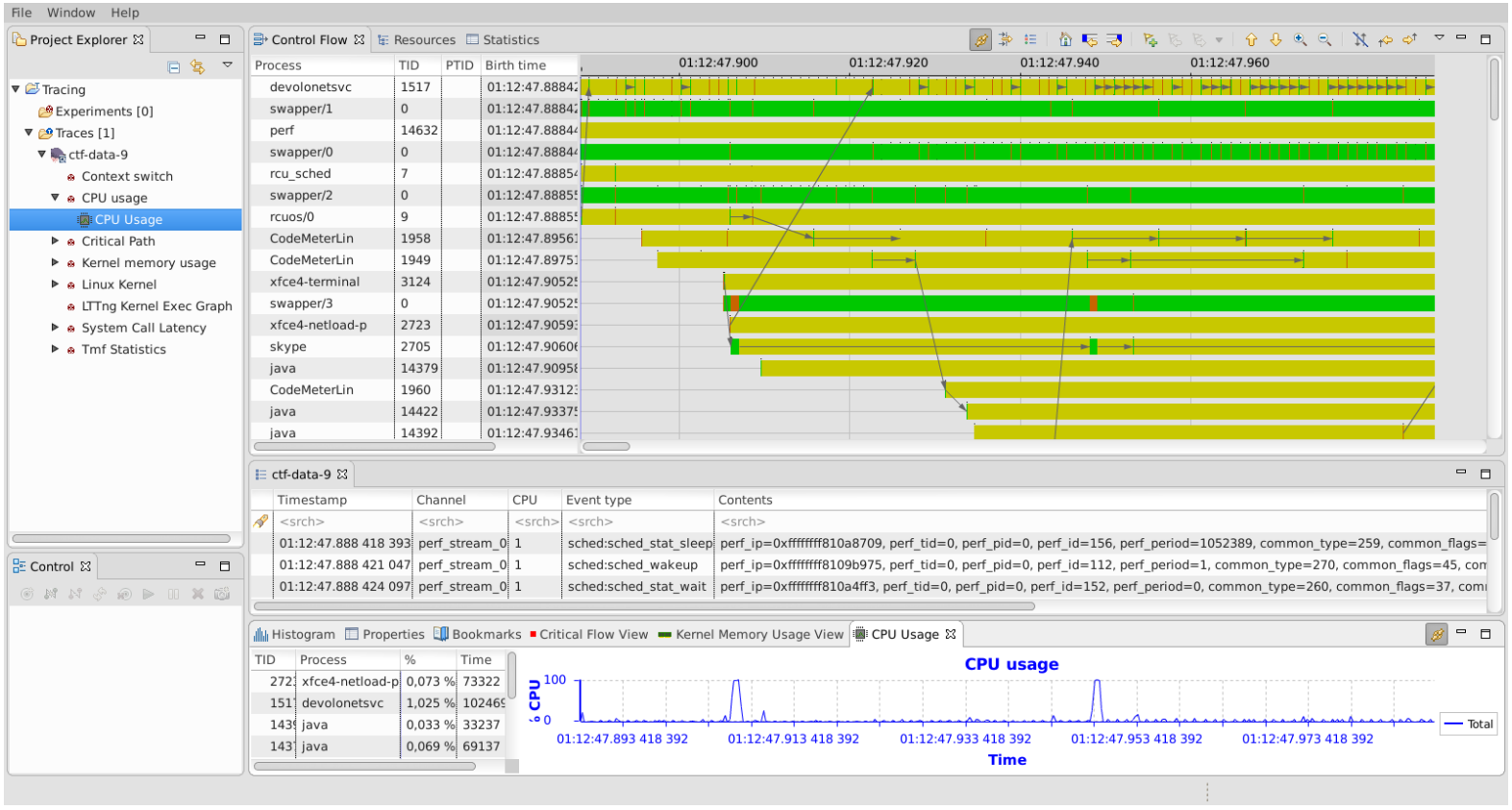
Record a trace on the target

```
./perf record -e 'sched:*' -a
# (stop with Ctrl-C)
# Copy perf.data to the host
```

On the host: Convert perf.data to the proper format

```
LD_LIBRARY_PATH=/usr/local/lib ./perf data convert --to-ctf ./ctf-data
# Now the trace data should be available in ctf-data/
# You can import this directory with Eclipse / Tracecompass
```

Tracecompass



sources


http://lwn.net/Articles/365835/


http://lwn.net/Articles/366796/