



Yocto Project Profiling and Tracing Manual

Tom Zanussi, Intel Corporation <tom.zanussi@intel.com>

by Tom Zanussi

Copyright © 2010-2014 Linux Foundation

Permission is granted to copy, distribute and/or modify this document under the terms of the Creative Commons Attribution-Share Alike 2.0 UK: England & Wales [<http://creativecommons.org/licenses/by-sa/2.0/uk/>] as published by Creative Commons.

Note

For the latest version of this manual associated with this Yocto Project release, see the Yocto Project Profiling and Tracing Manual [<http://www.yoctoproject.org/docs/1.8/profile-manual/profile-manual.html>] from the Yocto Project website.

Table of Contents

1. Yocto Project Profiling and Tracing Manual	1
1.1. Introduction	1
1.2. General Setup	1
2. Overall Architecture of the Linux Tracing and Profiling Tools	3
2.1. Architecture of the Tracing and Profiling Tools	3
3. Basic Usage (with examples) for each of the Yocto Tracing Tools	4
3.1. perf	4
3.1.1. Setup	4
3.1.2. Basic Usage	4
3.1.3. Documentation	32
3.2. ftrace	33
3.2.1. Setup	33
3.2.2. Basic ftrace usage	33
3.2.3. The 'trace events' Subsystem	37
3.2.4. trace-cmd/kernelshark	40
3.2.5. Documentation	44
3.3. systemtap	45
3.3.1. Setup	46
3.3.2. Running a Script on a Target	46
3.3.3. Documentation	47
3.4. oprofile	47
3.4.1. Setup	47
3.4.2. Basic Usage	48
3.4.3. OProfileUI - A GUI for OProfile	53
3.4.4. Documentation	58
3.5. Sysprof	59
3.5.1. Setup	59
3.5.2. Basic Usage	59
3.5.3. Documentation	61
3.6. LTTng (Linux Trace Toolkit, next generation)	61
3.6.1. Setup	61
3.6.2. Collecting and Viewing Traces	61
3.6.3. Documentation	67
3.7. blktrace	67
3.7.1. Setup	67
3.7.2. Basic Usage	68
3.7.3. Documentation	73
4. Real-World Examples	74
4.1. Slow Write Speed on Live Images	74

Chapter 1. Yocto Project Profiling and Tracing Manual

1.1. Introduction

Yocto bundles a number of tracing and profiling tools - this 'HOWTO' describes their basic usage and shows by example how to make use of them to examine application and system behavior.

The tools presented are for the most part completely open-ended and have quite good and/or extensive documentation of their own which can be used to solve just about any problem you might come across in Linux. Each section that describes a particular tool has links to that tool's documentation and website.

The purpose of this 'HOWTO' is to present a set of common and generally useful tracing and profiling idioms along with their application (as appropriate) to each tool, in the context of a general-purpose 'drill-down' methodology that can be applied to solving a large number (90%) of problems. For help with more advanced usages and problems, please see the documentation and/or websites listed for each tool.

The final section of this 'HOWTO' is a collection of real-world examples which we'll be continually adding to as we solve more problems using the tools - feel free to add your own examples to the list!

1.2. General Setup

Most of the tools are available only in 'sdk' images or in images built after adding 'tools-profile' to your local.conf. So, in order to be able to access all of the tools described here, please first build and boot an 'sdk' image e.g.

```
$ bitbake core-image-sato-sdk
```

or alternatively by adding 'tools-profile' to the EXTRA_IMAGE_FEATURES line in your local.conf:

```
EXTRA_IMAGE_FEATURES = "debug-tweaks tools-profile"
```

If you use the 'tools-profile' method, you don't need to build an sdk image - the tracing and profiling tools will be included in non-sdk images as well e.g.:

```
$ bitbake core-image-sato
```

Note

By default, the Yocto build system strips symbols from the binaries it packages, which makes it difficult to use some of the tools.

You can prevent that by putting the following in your local.conf when you build the image:

```
INHIBIT_PACKAGE_STRIP = "1"
```

The above setting will noticeably increase the size of your image.

If you've already built a stripped image, you can generate debug packages (xxx-dbg) which you can manually install as needed.

To generate debug info for packages, you can add dbg-pkgs to EXTRA_IMAGE_FEATURES in local.conf. For example:

```
EXTRA_IMAGE_FEATURES = "debug-tweaks tools-profile dbg-pkgs"
```

Additionally, in order to generate the right type of debuginfo, we also need to add the following to local.conf:

```
PACKAGE_DEBUG_SPLIT_STYLE = 'debug-file-directory'
```

Chapter 2. Overall Architecture of the Linux Tracing and Profiling Tools

2.1. Architecture of the Tracing and Profiling Tools

It may seem surprising to see a section covering an 'overall architecture' for what seems to be a random collection of tracing tools that together make up the Linux tracing and profiling space. The fact is, however, that in recent years this seemingly disparate set of tools has started to converge on a 'core' set of underlying mechanisms:

- static tracepoints
- dynamic tracepoints
 - kprobes
 - uprobes
- the perf_events subsystem
- debugfs

Tying it Together: Rather than enumerating here how each tool makes use of these common mechanisms, textboxes like this will make note of the specific usages in each tool as they come up in the course of the text.

Chapter 3. Basic Usage (with examples) for each of the Yocto Tracing Tools

This chapter presents basic usage examples for each of the tracing tools.

3.1. perf

The 'perf' tool is the profiling and tracing tool that comes bundled with the Linux kernel.

Don't let the fact that it's part of the kernel fool you into thinking that it's only for tracing and profiling the kernel - you can indeed use it to trace and profile just the kernel, but you can also use it to profile specific applications separately (with or without kernel context), and you can also use it to trace and profile the kernel and all applications on the system simultaneously to gain a system-wide view of what's going on.

In many ways, perf aims to be a superset of all the tracing and profiling tools available in Linux today, including all the other tools covered in this HOWTO. The past couple of years have seen perf subsume a lot of the functionality of those other tools and, at the same time, those other tools have removed large portions of their previous functionality and replaced it with calls to the equivalent functionality now implemented by the perf subsystem. Extrapolation suggests that at some point those other tools will simply become completely redundant and go away; until then, we'll cover those other tools in these pages and in many cases show how the same things can be accomplished in perf and the other tools when it seems useful to do so.

The coverage below details some of the most common ways you'll likely want to apply the tool; full documentation can be found either within the tool itself or in the man pages at `perf(1)` [<http://linux.die.net/man/1/perf>].

3.1.1. Setup

For this section, we'll assume you've already performed the basic setup outlined in the General Setup section.

In particular, you'll get the most mileage out of perf if you profile an image built with `INHIBIT_PACKAGE_STRIP = "1"` in your `local.conf`.

perf runs on the target system for the most part. You can archive profile data and copy it to the host for analysis, but for the rest of this document we assume you've ssh'ed to the host and will be running the perf commands on the target.

3.1.2. Basic Usage

The perf tool is pretty much self-documenting. To remind yourself of the available commands, simply type 'perf', which will show you basic usage along with the available perf subcommands:

```
root@crownbay:~# perf
usage: perf [--version] [--help] COMMAND [ARGS]
The most commonly used perf commands are:
  annotate      Read perf.data (created by perf record) and display annotated code
  archive       Create archive with object files with build-ids found in perf.data file
  bench         General framework for benchmark suites
  buildid-cache Manage build-id cache.
  buildid-list   List the buildids in a perf.data file
```

diff	Read two perf.data files and display the differential profile
evlist	List the event names in a perf.data file
inject	Filter to augment the events stream with additional information
kmem	Tool to trace/measure kernel memory(slab) properties
kvm	Tool to trace/measure kvm guest os
list	List all symbolic event types
lock	Analyze lock events
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
test	Runs sanity tests.
timechart	Tool to visualize total system behavior during a workload
top	System profiling tool.

See 'perf help COMMAND' for more information on a specific command.

3.1.2.1. Using perf to do Basic Profiling

As a simple test case, we'll profile the 'wget' of a fairly large file, which is a minimally interesting case because it has both file and network I/O aspects, and at least in the case of standard Yocto images, it's implemented as part of busybox, so the methods we use to analyze it can be used in a very similar way to the whole host of supported busybox applets in Yocto.

```
root@crownbay:~# rm linux-2.6.19.2.tar.bz2; \
wget http://downloads.yoctoproject.org/mirror/sources/linux-2.6.19.2.tar.bz2
```

The quickest and easiest way to get some basic overall data about what's going on for a particular workload is to profile it using 'perf stat'. 'perf stat' basically profiles using a few default counters and displays the summed counts at the end of the run:

```
root@crownbay:~# perf stat wget http://downloads.yoctoproject.org/mirror/sources/linux-2.6.19.2.tar.bz2
Connecting to downloads.yoctoproject.org (140.211.169.59:80)
linux-2.6.19.2.tar.bz2 100% |*****| 41727k 0:00.000
Performance counter stats for 'wget http://downloads.yoctoproject.org/mirror/sources/linux-2.6.19.2.tar.bz2':
4597.223902 task-clock          #    0.077 CPUs utilized
    23568 context-switches       #    0.005 M/sec
        68 CPU-migrations        #    0.015 K/sec
        241 page-faults          #    0.052 K/sec
  3045817293 cycles            #    0.663 GHz
<not supported> stalled-cycles-frontend
<not supported> stalled-cycles-backend
    858909167 instructions      #    0.28  insns per cycle
   165441165 branches          #    35.987 M/sec
   19550329 branch-misses      #  11.82% of all branches

59.836627620 seconds time elapsed
```

Many times such a simple-minded test doesn't yield much of interest, but sometimes it does (see Real-world Yocto bug (slow loop-mounted write speed)).

Also, note that 'perf stat' isn't restricted to a fixed set of counters - basically any event listed in the output of 'perf list' can be tallied by 'perf stat'. For example, suppose we wanted to see a summary of all the events related to kernel memory allocation/freeing along with cache hits and misses:

```
root@crownbay:~# perf stat -e kmem:* -e cache-references -e cache-misses wget http://downloads.yoctoproject.org/mirror/sources/linux-2.6.19.2.tar.b
Connecting to downloads.yoctoproject.org (140.211.169.59:80)
linux-2.6.19.2.tar.b 100% |*****| 41727k 0:00:00.000
Performance counter stats for 'wget http://downloads.yoctoproject.org/mirror/sources/linux-2.6.19.2.tar.b' on a 3.2 GHz Intel(R) Xeon(R) CPU E5-2620 v3 @ 3.20GHz:
      5566 kmem:kmalloc
  125517 kmem:kmem_cache_alloc
      0 kmem:kmalloc_node
      0 kmem:kmem_cache_alloc_node
  34401 kmem:kfree
  69920 kmem:kmem_cache_free
     133 kmem:mm_page_free
      41 kmem:mm_page_free_batched
  11502 kmem:mm_page_alloc
  11375 kmem:mm_page_alloc_zone_locked
      0 kmem:mm_page_pcpte_drain
      0 kmem:mm_page_alloc_extfrag
 66848602 cache-references
 2917740 cache-misses          #      4.365 % of all cache refs
44.831023415 seconds time elapsed
```

So 'perf stat' gives us a nice easy way to get a quick overview of what might be happening for a set of events, but normally we'd need a little more detail in order to understand what's going on in a way that we can act on in a useful way.

To dive down into a next level of detail, we can use 'perf record'/'perf report' which will collect profiling data and present it to use using an interactive text-based UI (or simply as text if we specify --stdio to 'perf report').

As our first attempt at profiling this workload, we'll simply run 'perf record', handing it the workload we want to profile (everything after 'perf record' and any perf options we hand it - here none - will be executed in a new shell). perf collects samples until the process exits and records them in a file named 'perf.data' in the current working directory.

```
root@crownbay:~# perf record wget http://downloads.yoctoproject.org/mirror/sources/linux-2.6.19.2.tar.b
Connecting to downloads.yoctoproject.org (140.211.169.59:80)
linux-2.6.19.2.tar.b 100% |*****| 41727k 0:00:00.000
[ perf record: Woken up 1 times to write data ]
[ perf record: Captured and wrote 0.176 MB perf.data (~7700 samples) ]
```

To see the results in a 'text-based UI' (tui), simply run 'perf report', which will read the perf.data file in the current working directory and display the results in an interactive UI:

```
root@crownbay:~# perf report
```

```

trz@empanada:~
```

File Edit View Search Terminal Help

Events: 4K cycles, Thread: wget(1231)

Time (%)	Function	Symbol
3.86%	wget	[kernel.kallsyms]
3.47%	wget	[kernel.kallsyms]
3.16%	wget	[kernel.kallsyms]
1.95%	wget	[kernel.kallsyms]
1.92%	wget	[kernel.kallsyms]
1.82%	wget	[kernel.kallsyms]
1.76%	wget	[kernel.kallsyms]
1.67%	wget	[kernel.kallsyms]
1.67%	busybox	[.] 0x000651e3
1.54%	wget	[kernel.kallsyms]
1.37%	wget	[kernel.kallsyms]
1.22%	wget	[kernel.kallsyms]
1.16%	wget	[kernel.kallsyms]
1.10%	wget	[kernel.kallsyms]
1.07%	wget	[kernel.kallsyms]
1.02%	wget	[kernel.kallsyms]
1.01%	wget	[kernel.kallsyms]
0.97%	wget	[kernel.kallsyms]
0.94%	wget	[kernel.kallsyms]
0.88%	wget	[kernel.kallsyms]
0.84%	wget	[kernel.kallsyms]
0.82%	wget	[kernel.kallsyms]
0.79%	wget	[kernel.kallsyms]
0.78%	wget	[kernel.kallsyms]
0.74%	wget	libc-2.16.so
0.73%	wget	[kernel.kallsyms]
0.73%	wget	[kernel.kallsyms]
0.72%	wget	libc-2.16.so
0.67%	wget	[kernel.kallsyms]
0.67%	wget	[kernel.kallsyms]
0.67%	wget	[kernel.kallsyms]
0.66%	wget	[kernel.kallsyms]
0.64%	wget	[kernel.kallsyms]
0.62%	wget	[kernel.kallsyms]
0.62%	wget	[kernel.kallsyms]
0.61%	wget	[kernel.kallsyms]
0.60%	wget	[kernel.kallsyms]
0.59%	wget	[kernel.kallsyms]
0.58%	wget	[kernel.kallsyms]
0.57%	wget	[kernel.kallsyms]

Press '?' for help on key bindings

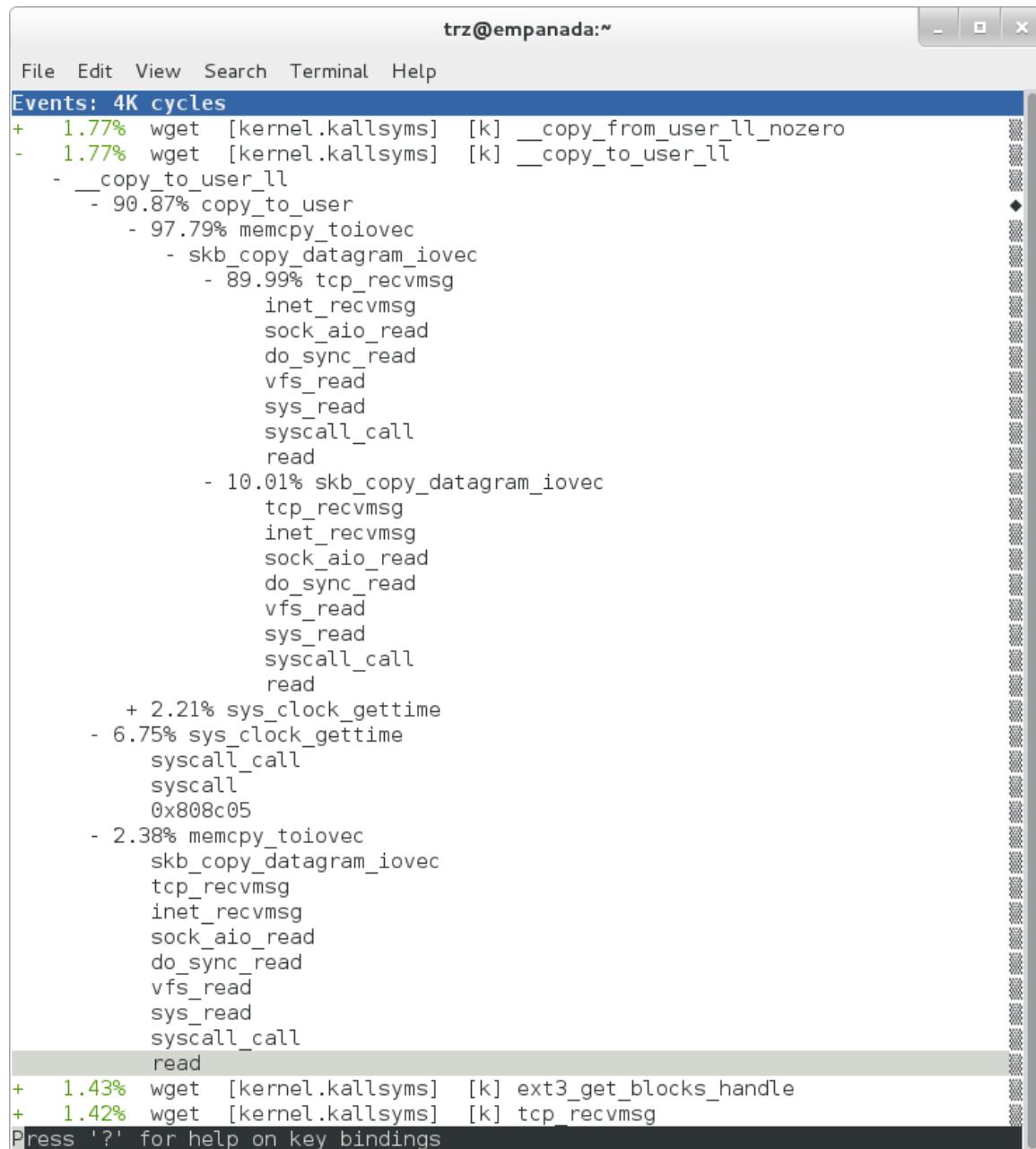
The above screenshot displays a 'flat' profile, one entry for each 'bucket' corresponding to the functions that were profiled during the profiling run, ordered from the most popular to the least (perf has options to sort in various orders and keys as well as display entries only above a certain threshold and so on - see the perf documentation for details). Note that this includes both userspace functions (entries containing a [.]) and kernel functions accounted to the process (entries containing a [K]). (perf has command-line modifiers that can be used to restrict the profiling to kernel or userspace, among others).

Notice also that the above report shows an entry for 'busybox', which is the executable that implements 'wget' in Yocto, but that instead of a useful function name in that entry, it displays a not-so-friendly hex value instead. The steps below will show how to fix that problem.

Before we do that, however, let's try running a different profile, one which shows something a little more interesting. The only difference between the new profile and the previous one is that we'll add the -g option, which will record not just the address of a sampled function, but the entire callchain to the sampled function as well:

```
root@crownbay:~# perf record -g wget http://downloads.yoctoproject.org/mirror/sources/linux-2.6.19.2.tar.bz2
Connecting to downloads.yoctoproject.org (140.211.169.59:80)
linux-2.6.19.2.tar.bz2 100% |*****| 41727k  0:00:00.000
[ perf record: Woken up 3 times to write data ]
[ perf record: Captured and wrote 0.652 MB perf.data (~28476 samples) ]
```

```
root@crownbay:~# perf report
```



Using the callgraph view, we can actually see not only which functions took the most time, but we can also see a summary of how those functions were called and learn something about how the program interacts with the kernel in the process.

Notice that each entry in the above screenshot now contains a '+' on the left-hand side. This means that we can expand the entry and drill down into the callchains that feed into that entry. Pressing

'enter' on any one of them will expand the callchain (you can also press 'E' to expand them all at the same time or 'C' to collapse them all).

In the screenshot above, we've toggled the `__copy_to_user_ll()` entry and several subnodes all the way down. This lets us see which callchains contributed to the profiled `__copy_to_user_ll()` function which contributed 1.77% to the total profile.

As a bit of background explanation for these callchains, think about what happens at a high level when you run `wget` to get a file out on the network. Basically what happens is that the data comes into the kernel via the network connection (socket) and is passed to the userspace program '`wget`' (which is actually a part of `busybox`, but that's not important for now), which takes the buffers the kernel passes to it and writes it to a disk file to save it.

The part of this process that we're looking at in the above call stacks is the part where the kernel passes the data it's read from the socket down to `wget` i.e. a copy-to-user.

Notice also that here there's also a case where the hex value is displayed in the callstack, here in the expanded `sys_clock_gettime()` function. Later we'll see it resolve to a userspace function call in `busybox`.

```

trz@empanada:~ File Edit View Search Terminal Help
Events: 4K cycles
+ 3.60% wget [kernel.kallsyms] [K] sub_preempt_count
+ 3.12% wget [kernel.kallsyms] [K] read_hpet
+ 2.73% wget [kernel.kallsyms] [K] add_preempt_count
+ 2.48% wget busybox [.] 0x0000c0dd
+ 2.21% wget [kernel.kallsyms] [K] get_parent_ip
+ 1.94% wget [kernel.kallsyms] [K] system_call
+ 1.88% wget [kernel.kallsyms] [K] __find_get_block
- 1.77% wget [kernel.kallsyms] [K] __copy_from_user_ll_nozero
- __copy_from_user_ll_nozero
  - 91.57% iov_iter_copy_from_user_atomic
    generic_file_buffered_write
    __generic_file_aio_write
    generic_file_aio_write
    do_sync_write
    vfs_write
    sys_write
    syscall_call
    write
  - 8.43% generic_file_buffered_write
    __generic_file_aio_write
    generic_file_aio_write
    do_sync_write
    vfs_write
    sys_write
    syscall_call
    write
+ 1.77% wget [kernel.kallsyms] [K] __copy_to_user_ll
+ 1.43% wget [kernel.kallsyms] [K] ext3_get_blocks_handle
+ 1.42% wget [kernel.kallsyms] [K] tcp_recvmsg
+ 1.41% wget [kernel.kallsyms] [K] ext3_new_blocks
+ 1.34% wget [kernel.kallsyms] [K] __block_write_begin
+ 1.32% wget [kernel.kallsyms] [K] in_lock_functions
+ 1.32% wget [kernel.kallsyms] [K] ext3_mark_iloc_dirty
+ 1.17% wget [kernel.kallsyms] [K] memset
+ 1.13% wget [kernel.kallsyms] [K] debug_smp_processor_id
+ 1.08% wget [kernel.kallsyms] [K] __schedule
+ 1.05% wget [kernel.kallsyms] [K] journal_add_journal_head
+ 0.92% wget [kernel.kallsyms] [K] __ext3_get_inode_loc
+ 0.83% wget [kernel.kallsyms] [K] do_sys_poll
+ 0.81% wget [kernel.kallsyms] [K] journal_dirty_metadata
Press '?' for help on key bindings

```

The above screenshot shows the other half of the journey for the data - from the wget program's userspace buffers to disk. To get the buffers to disk, the wget program issues a write(2), which does a copy-from-user to the kernel, which then takes care via some circuitous path (probably also present somewhere in the profile data), to get it safely to disk.

Now that we've seen the basic layout of the profile data and the basics of how to extract useful information out of it, let's get back to the task at hand and see if we can get some basic idea about where the time is spent in the program we're profiling, wget. Remember that wget is actually implemented as an applet in busybox, so while the process name is 'wget', the executable we're actually interested in is busybox. So let's expand the first entry containing busybox:

```

trz@empanada:~
```

File Edit View Search Terminal Help

Events: 4K cycles

```

+ 3.60% wget [kernel.kallsyms] [K] sub_preempt_count
+ 3.12% wget [kernel.kallsyms] [K] read_hpet
+ 2.73% wget [kernel.kallsyms] [K] add_preempt_count
- 2.48% wget busybox [.] 0x0000c0dd
0x808c00
0x80530d
0x804bf1
0x80868e
0x80862e
0x805310
0x804b50
0x80530a
0x80ac1d
0x80ac1b
0x804bbb
0x808c05
0x8086aa
0x808c05
0x80833d
0x808c05
0x808315
0x805307
0x808c03
0x80531a
0x805311
0x805307
0x805309
0x808318
0x808c05
0x808691
0x80531b
0x808c03
0x808c02
0x80868f
0x80869b
0x808699
0x808c05
0x805311
0x808316
0x808c05
```

Press ? for help on key bindings

Again, before we expanded we saw that the function was labeled with a hex value instead of a symbol as with most of the kernel entries. Expanding the busybox entry doesn't make it any better.

The problem is that perf can't find the symbol information for the busybox binary, which is actually stripped out by the Yocto build system.

One way around that is to put the following in your local.conf when you build the image:

```
INHIBIT_PACKAGE_STRIP = "1"
```

However, we already have an image with the binaries stripped, so what can we do to get perf to resolve the symbols? Basically we need to install the debuginfo for the busybox package.

To generate the debug info for the packages in the image, we can add `dbg-pkgs` to `EXTRA_IMAGE_FEATURES` in local.conf. For example:

```
EXTRA_IMAGE_FEATURES = "debug-tweaks tools-profile dbg-pkgs"
```

Additionally, in order to generate the type of debuginfo that perf understands, we also need to add the following to local.conf:

```
PACKAGE_DEBUG_SPLIT_STYLE = 'debug-file-directory'
```

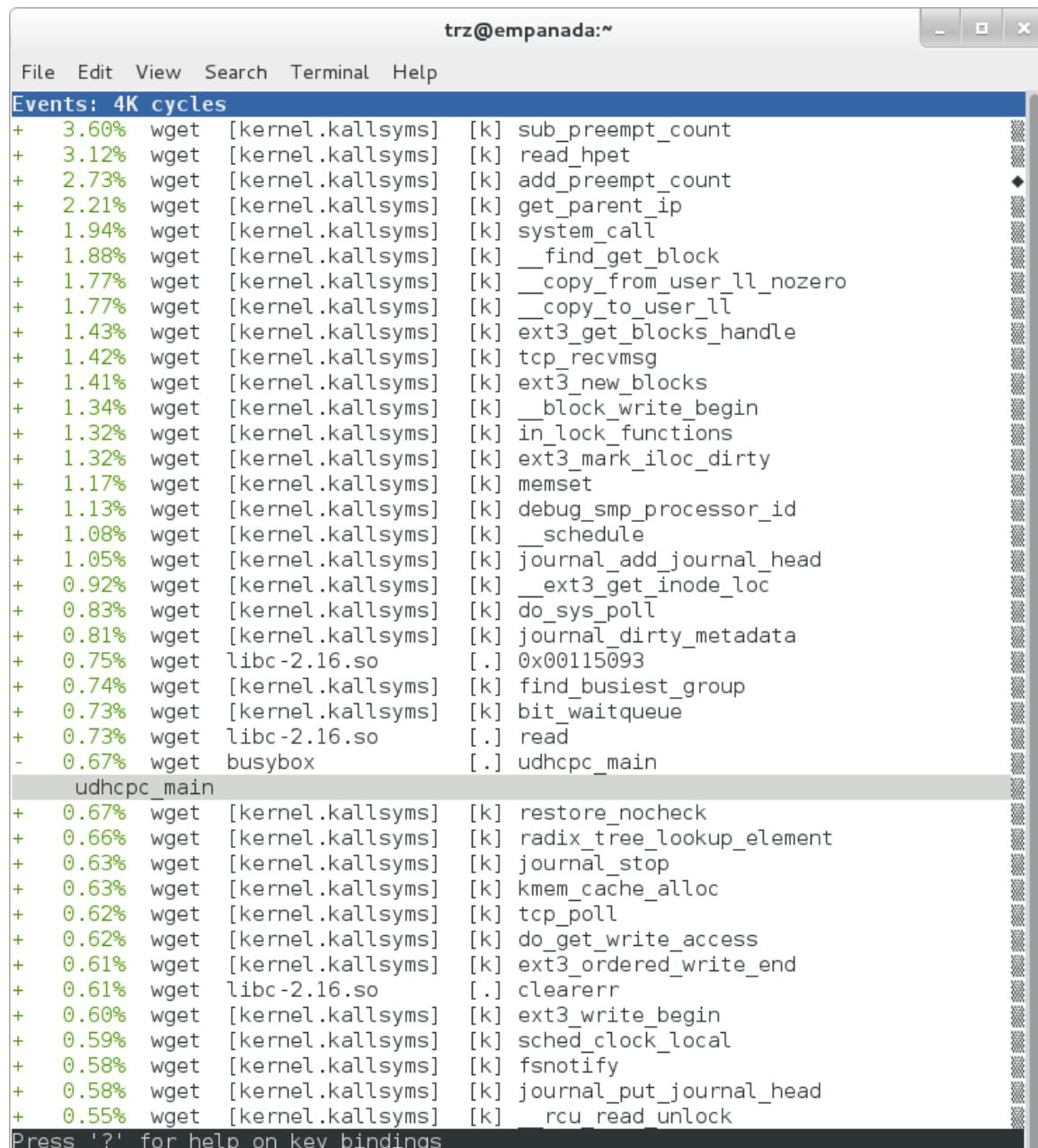
Once we've done that, we can install the debuginfo for busybox. The debug packages once built can be found in build/tmp/deploy/rpm/* on the host system. Find the busybox-dbg-...rpm file and copy it to the target. For example:

```
[trz@empanada core2]$ scp /home/trz/yocto/crownbay-tracing-dbg/build/tmp/deploy/rpm/core2_32
root@192.168.1.31's password:
busybox-dbg-1.20.2-r2.core2_32.rpm                                100% 1826KB  1.8MB/s  00:01
```

Now install the debug rpm on the target:

```
root@crownbay:~# rpm -i busybox-dbg-1.20.2-r2.core2_32.rpm
```

Now that the debuginfo is installed, we see that the busybox entries now display their functions symbolically:



Events: 4K cycles

```

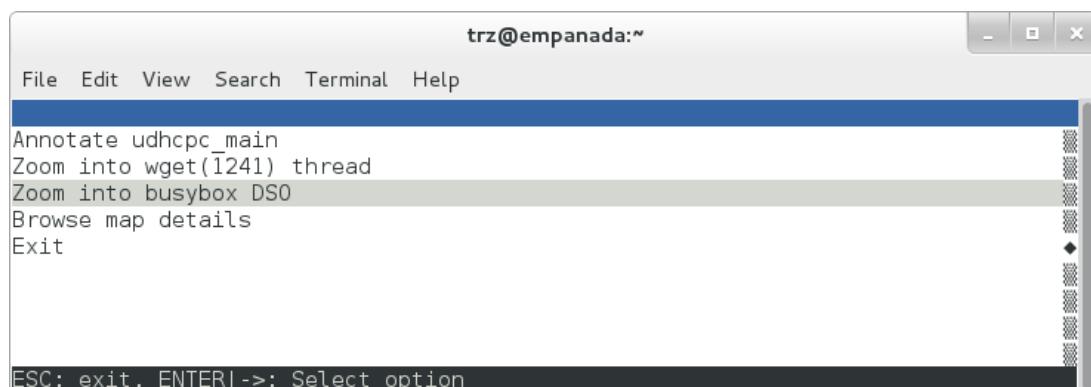
+ 3.60% wget [kernel.kallsyms] [K] sub_preempt_count
+ 3.12% wget [kernel.kallsyms] [K] read_hpet
+ 2.73% wget [kernel.kallsyms] [K] add_preempt_count
+ 2.21% wget [kernel.kallsyms] [K] get_parent_ip
+ 1.94% wget [kernel.kallsyms] [K] system_call
+ 1.88% wget [kernel.kallsyms] [K] __find_get_block
+ 1.77% wget [kernel.kallsyms] [K] __copy_from_user_ll_nozero
+ 1.77% wget [kernel.kallsyms] [K] __copy_to_user_ll
+ 1.43% wget [kernel.kallsyms] [K] ext3_get_blocks_handle
+ 1.42% wget [kernel.kallsyms] [K] tcp_recvmsg
+ 1.41% wget [kernel.kallsyms] [K] ext3_new_blocks
+ 1.34% wget [kernel.kallsyms] [K] __block_write_begin
+ 1.32% wget [kernel.kallsyms] [K] in_lock_functions
+ 1.32% wget [kernel.kallsyms] [K] ext3_mark_iloc_dirty
+ 1.17% wget [kernel.kallsyms] [K] memset
+ 1.13% wget [kernel.kallsyms] [K] debug_smp_processor_id
+ 1.08% wget [kernel.kallsyms] [K] __schedule
+ 1.05% wget [kernel.kallsyms] [K] journal_add_journal_head
+ 0.92% wget [kernel.kallsyms] [K] __ext3_get_inode_loc
+ 0.83% wget [kernel.kallsyms] [K] do_sys_poll
+ 0.81% wget [kernel.kallsyms] [K] journal_dirty_metadata
+ 0.75% wget libc-2.16.so [.] 0x00115093
+ 0.74% wget [kernel.kallsyms] [K] find.busiest_group
+ 0.73% wget [kernel.kallsyms] [K] bit_waitqueue
+ 0.73% wget libc-2.16.so [.] read
- 0.67% wget busybox [.] udhcpc_main

udhcpc_main
+ 0.67% wget [kernel.kallsyms] [K] restore_nocheck
+ 0.66% wget [kernel.kallsyms] [K] radix_tree_lookup_element
+ 0.63% wget [kernel.kallsyms] [K] journal_stop
+ 0.63% wget [kernel.kallsyms] [K] kmem_cache_alloc
+ 0.62% wget [kernel.kallsyms] [K] tcp_poll
+ 0.62% wget [kernel.kallsyms] [K] do_get_write_access
+ 0.61% wget [kernel.kallsyms] [K] ext3_ordered_write_end
+ 0.61% wget libc-2.16.so [.] clearerr
+ 0.60% wget [kernel.kallsyms] [K] ext3_write_begin
+ 0.59% wget [kernel.kallsyms] [K] sched_clock_local
+ 0.58% wget [kernel.kallsyms] [K] fsnotify
+ 0.58% wget [kernel.kallsyms] [K] journal_put_journal_head
+ 0.55% wget [kernel.kallsyms] [K] __rcu_read_unlock

```

Press '?' for help on key bindings

If we expand one of the entries and press 'enter' on a leaf node, we're presented with a menu of actions we can take to get more information related to that entry:

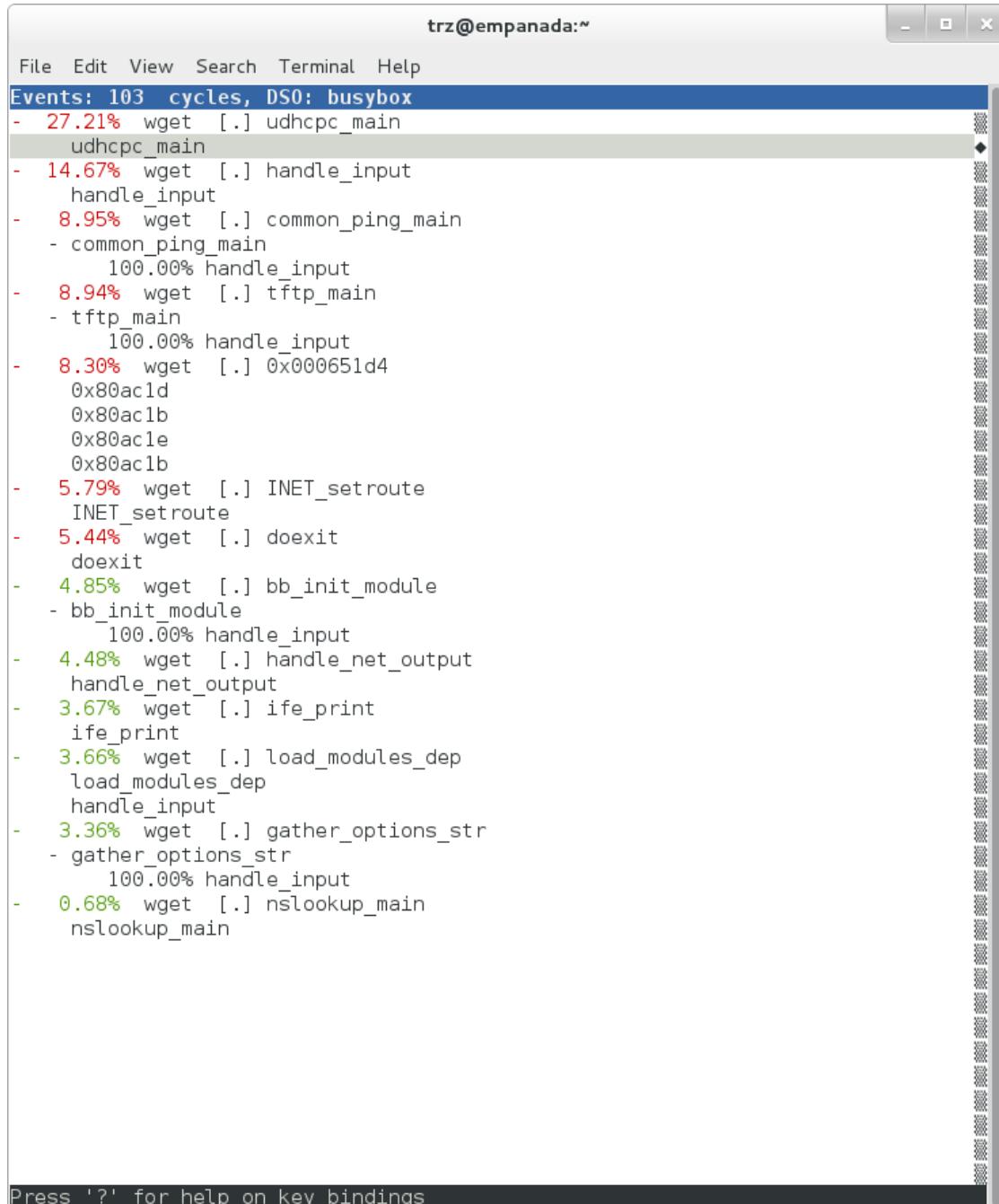


File Edit View Search Terminal Help

Annotate udhcpc_main
 Zoom into wget(1241) thread
 Zoom into busybox DSO
 Browse map details
 Exit

ESC: exit, ENTER: Select option

One of these actions allows us to show a view that displays a busybox-centric view of the profiled functions (in this case we've also expanded all the nodes using the 'E' key):



```
trz@empanada:~
```

File Edit View Search Terminal Help

Events: 103 cycles, DS0: busybox

- 27.21% wget [.].udhcpc_main
- udhcpc_main
- 14.67% wget [.].handle_input
- handle_input
- 8.95% wget [.].common_ping_main
- common_ping_main
- 100.00% handle_input
- 8.94% wget [.].tftp_main
- tftp_main
- 100.00% handle_input
- 8.30% wget [.].0x000651d4
- 0x80ac1d
- 0x80ac1b
- 0x80ac1e
- 0x80ac1b
- 5.79% wget [.].INET_setroute
- INET_setroute
- 5.44% wget [.].doexit
- doexit
- 4.85% wget [.].bb_init_module
- bb_init_module
- 100.00% handle_input
- 4.48% wget [.].handle_net_output
- handle_net_output
- 3.67% wget [.].ife_print
- ife_print
- 3.66% wget [.].load_modules_dep
- load_modules_dep
- handle_input
- 3.36% wget [.].gather_options_str
- gather_options_str
- 100.00% handle_input
- 0.68% wget [.].nslookup_main
- nslookup_main

Press '?' for help on key bindings

Finally, we can see that now that the busybox debuginfo is installed, the previously unresolved symbol in the `sys_clock_gettime()` entry mentioned previously is now resolved, and shows that the `sys_clock_gettime` system call that was the source of 6.75% of the copy-to-user overhead was initiated by the `handle_input()` busybox function:

```

trz@empanada:~
```

File Edit View Search Terminal Help

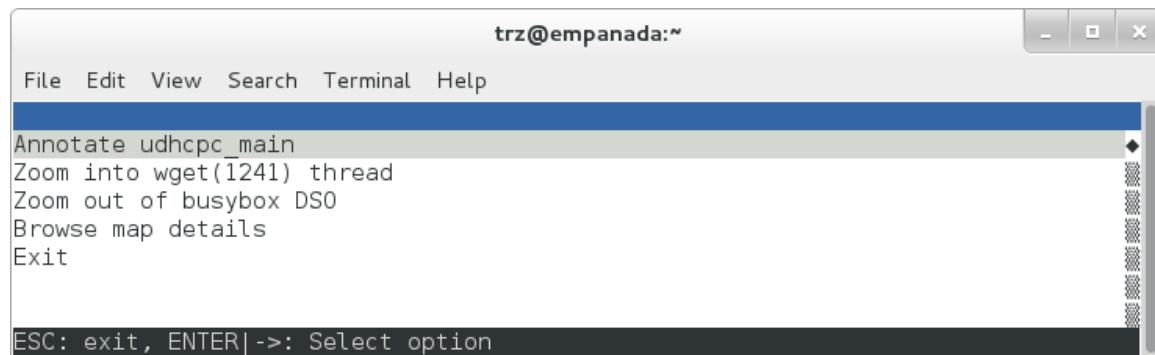
Events: 4K cycles

```

+ 1.77% wget [kernel.kallsyms] [k] __copy_from_user_ll_nozero
- 1.77% wget [kernel.kallsyms] [k] __copy_to_user_ll
  - __copy_to_user_ll
    - 90.87% copy_to_user
      - 97.79% memcpy_toiovec
        - skb_copy_datagram_iovec
          - 89.99% tcp_recvmsg
            inet_recvmsg
            sock_aio_read
            do_sync_read
            vfs_read
            sys_read
            syscall_call
            read
        - 10.01% skb_copy_datagram_iovec
          tcp_recvmsg
          inet_recvmsg
          sock_aio_read
          do_sync_read
          vfs_read
          sys_read
          syscall_call
          read
    + 2.21% sys_clock_gettime
  - 6.75% sys_clock_gettime
    syscall_call
    syscall
    handle_input
  - 2.38% memcpy_toiovec
    skb_copy_datagram_iovec
    tcp_recvmsg
    inet_recvmsg
    sock_aio_read
    do_sync_read
    vfs_read
    sys_read
    syscall_call
    read
+ 1.43% wget [kernel.kallsyms] [k] ext3_get_blocks_handle
+ 1.42% wget [kernel.kallsyms] [k] tcp_recvmsg
Press '?' for help on key bindings

```

At the lowest level of detail, we can dive down to the assembly level and see which instructions caused the most overhead in a function. Pressing 'enter' on the 'udhcpc_main' function, we're again presented with a menu:



Selecting 'Annotate udhcpc_main', we get a detailed listing of percentages by instruction for the `udhcpc_main` function. From the display, we can see that over 50% of the time spent in this function is taken up by a couple tests and the move of a constant (1) to a register:

File Edit View Search Terminal Help

udhcpc main

3.70 :	805307a:	test	%cl,%cl
7.41 :	805307c:	jne	80531aa <fchmod@plt+0x6fda>
0.00 :	8053082:	lea	0x28(%esp),%esi
0.00 :	8053086:	mov	%esi,0x18(%esp)
0.00 :	805308a:	mov	\$0x1000,%edi
0.00 :	805308f:	mov	0x48(%ebx),%esi
0.00 :	8053092:	mov	0x18(%esp),%eax
3.70 :	8053096:	mov	\$0x3e8,%ecx
0.00 :	805309b:	mov	\$0x1,%edx
0.00 :	80530a0:	call	80ac1b5 <fchmod@plt+0x5ffe5>
11.11 :	80530a5:	test	%eax,%eax
0.00 :	80530a7:	je	80531e2 <fchmod@plt+0x7012>
0.00 :	80530ad:	mov	%ebp,(%esp)
3.70 :	80530b0:	call	804bf10 <clearerr@plt>
0.00 :	80530b5:	mov	0x80d3988,%esi
0.00 :	80530bb:	movl	\$0x0,(%esi)
0.00 :	80530c1:	mov	0x1c(%esp),%esi
0.00 :	80530c5:	mov	%ebp,0xc(%esp)
3.70 :	80530c9:	mov	%edi,0x8(%esp)
0.00 :	80530cd:	movl	\$0x1,0x4(%esp)
0.00 :	80530d5:	mov	%esi,(%esp)
0.00 :	80530d8:	call	804b5c0 <fread@plt>
29.63 :	80530dd:	test	%eax,%eax
0.00 :	80530df:	mov	%eax,%esi
0.00 :	80530e1:	jg	80530f8 <fchmod@plt+0x6f28>
0.00 :	80530e3:	mov	0x80d3988,%esi
0.00 :	80530e9:	cmpl	\$0xb,(%esi)
0.00 :	80530ec:	jne	8053210 <fchmod@plt+0x7040>
0.00 :	80530f2:	movzbl	0x55(%ebx),%ecx
0.00 :	80530f6:	jmp	805307a <fchmod@plt+0x6eaa>
0.00 :	80530f8:	mov	0x4c(%ebx),%eax
0.00 :	80530fb:	mov	%esi,%ecx
0.00 :	80530fd:	mov	%esi,%edi
0.00 :	80530ff:	mov	0x1c(%esp),%edx
0.00 :	8053103:	sar	\$0x1f,%edi
0.00 :	8053106:	call	80862ea <fchmod@plt+0x3a11a>
14.81 :	805310b:	mov	\$0x1,%eax
0.00 :	8053110:	add	%esi,0x10(%ebx)
3.70 :	8053113:	adc	%edi,0x14(%ebx)
0.00 :	8053116:	call	808bfff <fchmod@plt+0x3fe2f>
0.00 :	805311b:	movzbl	0x55(%ebx),%ecx
3.70 :	805311f:	test	%cl,%cl
0.00 :	8053121:	je	805308a <fchmod@plt+0x6eba>
0.00 :	8053127:	mov	(%ebx),%eax

<-/ESC: Exit, TAB/shift+TAB: Cycle hot lines, H: Go to hottest line, ->/ENTER: L

As a segue into tracing, let's try another profile using a different counter, something other than the default 'cycles'.

The tracing and profiling infrastructure in Linux has become unified in a way that allows us to use the same tool with a completely different set of counters, not just the standard hardware counters that traditional tools have had to restrict themselves to (of course the traditional tools can also make use of the expanded possibilities now available to them, and in some cases have, as mentioned previously).

We can get a list of the available events that can be used to profile a workload via 'perf list':

```
root@crownbay:~# perf list
```

List of pre-defined events (to be used in -e):

list of pre-defined S

[Hardware event]

stalled-cycles-front

[Hardware event]
[Hardware event]

stalled-cycles-backend OR idle-cycles-backend

[Hardware event]
[Hardware event]

instructions	[Hardware event]
cache-references	[Hardware event]
cache-misses	[Hardware event]
branch-instructions OR branches	[Hardware event]
branch-misses	[Hardware event]
bus-cycles	[Hardware event]
ref-cycles	[Hardware event]
cpu-clock	[Software event]
task-clock	[Software event]
page-faults OR faults	[Software event]
minor-faults	[Software event]
major-faults	[Software event]
context-switches OR cs	[Software event]
cpu-migrations OR migrations	[Software event]
alignment-faults	[Software event]
emulation-faults	[Software event]
L1-dcache-loads	[Hardware cache event]
L1-dcache-load-misses	[Hardware cache event]
L1-dcache-prefetch-misses	[Hardware cache event]
L1-icache-loads	[Hardware cache event]
L1-icache-load-misses	[Hardware cache event]
.	
.	
rNNN	[Raw hardware event descriptor]
cpu/t1=v1[,t2=v2,t3 ...]/modifier	[Raw hardware event descriptor]
(see 'perf list --help' on how to encode it)	
mem:<addr>[:access]	[Hardware breakpoint]
sunrpc:rpc_call_status	[Tracepoint event]
sunrpc:rpc_bind_status	[Tracepoint event]
sunrpc:rpc_connect_status	[Tracepoint event]
sunrpc:rpc_task_begin	[Tracepoint 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]
sock:sock_rcvqueue_full	[Tracepoint event]
sock:sock_exceed_buf_limit	[Tracepoint event]
udp:udp_fail_queue_rcv_skb	[Tracepoint event]
hda:hda_send_cmd	[Tracepoint event]
hda:hda_get_response	[Tracepoint event]
hda:hda_bus_reset	[Tracepoint event]
scsi:scsi_dispatch_cmd_start	[Tracepoint event]
scsi:scsi_dispatch_cmd_error	[Tracepoint event]
scsi:scsi_eh_wakeup	[Tracepoint event]
drm:drm_vblank_event	[Tracepoint event]
drm:drm_vblank_event_queued	[Tracepoint event]
drm:drm_vblank_event_delivered	[Tracepoint event]
random:mix_pool_bytes	[Tracepoint event]
random:mix_pool_bytes_nolock	[Tracepoint event]
random:credit_entropy_bits	[Tracepoint event]
gpio:gpio_direction	[Tracepoint event]
gpio:gpio_value	[Tracepoint event]
block:block_rq_abort	[Tracepoint event]
block:block_rq_requeue	[Tracepoint event]
block:block_rq_issue	[Tracepoint event]

block:block_bio_bounce	[Tracepoint event]
block:block_bio_complete	[Tracepoint event]
block:block_bio_backmerge	[Tracepoint event]
.	
.	
writeback:writeback_wake_thread	[Tracepoint event]
writeback:writeback_wake_forker_thread	[Tracepoint event]
writeback:writeback_bdi_register	[Tracepoint event]
.	
.	
writeback:writeback_single_inode_requeue	[Tracepoint event]
writeback:writeback_single_inode	[Tracepoint event]
kmem:kmalloc	[Tracepoint event]
kmem:kmem_cache_alloc	[Tracepoint event]
kmem:mm_page_alloc	[Tracepoint event]
kmem:mm_page_alloc_zone_locked	[Tracepoint event]
kmem:mm_page_pcpte_drain	[Tracepoint event]
kmem:mm_page_alloc_extfrag	[Tracepoint event]
vmscan:mm_vmscan_kswapd_sleep	[Tracepoint event]
vmscan:mm_vmscan_kswapd_wake	[Tracepoint event]
vmscan:mm_vmscan_wakeup_kswapd	[Tracepoint event]
vmscan:mm_vmscan_direct_reclaim_begin	[Tracepoint event]
.	
.	
module:module_get	[Tracepoint event]
module:module_put	[Tracepoint event]
module:module_request	[Tracepoint event]
sched:sched_kthread_stop	[Tracepoint event]
sched:sched_wakeup	[Tracepoint event]
sched:sched_wakeup_new	[Tracepoint event]
sched:sched_process_fork	[Tracepoint event]
sched:sched_process_exec	[Tracepoint event]
sched:sched_stat_runtime	[Tracepoint event]
rcu:rcu_utilization	[Tracepoint event]
workqueue:workqueue_queue_work	[Tracepoint event]
workqueue:workqueue_execute_end	[Tracepoint event]
signal:signal_generate	[Tracepoint event]
signal:signal_deliver	[Tracepoint event]
timer:timer_init	[Tracepoint event]
timer:timer_start	[Tracepoint event]
timer:hrtimer_cancel	[Tracepoint event]
timer:itimer_state	[Tracepoint event]
timer:itimer_expire	[Tracepoint event]
irq:irq_handler_entry	[Tracepoint event]
irq:irq_handler_exit	[Tracepoint event]
irq:softirq_entry	[Tracepoint event]
irq:softirq_exit	[Tracepoint event]
irq:softirq_raise	[Tracepoint event]
printk:console	[Tracepoint event]
task:task_newtask	[Tracepoint event]
task:task_rename	[Tracepoint event]
syscalls:sys_enter_socketcall	[Tracepoint event]
syscalls:sys_exit_socketcall	[Tracepoint event]
.	
.	
.	
syscalls:sys_enter_unshare	[Tracepoint event]
syscalls:sys_exit_unshare	[Tracepoint event]
raw_syscalls:sys_enter	[Tracepoint event]
raw_syscalls:sys_exit	[Tracepoint event]

Tying it Together: These are exactly the same set of events defined by the trace event subsystem and exposed by ftrace/tracecmd/kernelshark as files in `/sys/kernel/debug/tracing/events`, by SystemTap as `kernel.trace("tracepoint_name")` and (partially) accessed by LTTng.

Only a subset of these would be of interest to us when looking at this workload, so let's choose the most likely subsystems (identified by the string before the colon in the Tracepoint events) and do a 'perf stat' run using only those wildcarded subsystems:

Let's pick one of these tracepoints and tell perf to do a profile using it as the sampling event:

```
root@crownbay:~# perf record -g -e sched:sched_wakeup wget http://downloads.yoctoproject.org
```



The screenshot above shows the results of running a profile using sched:sched_switch tracepoint, which shows the relative costs of various paths to sched_wakeup (note that sched_wakeup is the name of the tracepoint - it's actually defined just inside ttwu_do_wakeup(), which accounts for the function name actually displayed in the profile):

```
/*
 * Mark the task runnable and perform wakeup-preemption.
 */
```

```
static void
ttwu_do_wakeup(struct rq *rq, struct task_struct *p, int wake_flags)
{
    trace_sched_wakeup(p, true);
    ...
}
```

A couple of the more interesting callchains are expanded and displayed above, basically some network receive paths that presumably end up waking up wget (busybox) when network data is ready.

Note that because tracepoints are normally used for tracing, the default sampling period for tracepoints is 1 i.e. for tracepoints perf will sample on every event occurrence (this can be changed using the -c option). This is in contrast to hardware counters such as for example the default 'cycles' hardware counter used for normal profiling, where sampling periods are much higher (in the thousands) because profiling should have as low an overhead as possible and sampling on every cycle would be prohibitively expensive.

3.1.2.2. Using perf to do Basic Tracing

Profiling is a great tool for solving many problems or for getting a high-level view of what's going on with a workload or across the system. It is however by definition an approximation, as suggested by the most prominent word associated with it, 'sampling'. On the one hand, it allows a representative picture of what's going on in the system to be cheaply taken, but on the other hand, that cheapness limits its utility when that data suggests a need to 'dive down' more deeply to discover what's really going on. In such cases, the only way to see what's really going on is to be able to look at (or summarize more intelligently) the individual steps that go into the higher-level behavior exposed by the coarse-grained profiling data.

As a concrete example, we can trace all the events we think might be applicable to our workload:

```
root@crownbay:~# perf record -g -e skb:* -e net:* -e napi:* -e sched:sched_switch -e sched:sched_wakeup -e syscalls:sys_enter_read -e syscalls:sys_exit_read -e syscalls:sys_enter_write -e syscalls:sys_exit_write
wget http://downloads.yoctoproject.org/mirror/sources/linux-2.6.19.2.tar.bz2
```

We can look at the raw trace output using 'perf script' with no arguments:

```
root@crownbay:~# perf script
perf 1262 [000] 11624.857082: sys_exit_read: 0x0
perf 1262 [000] 11624.857193: sched_wakeup: comm=migration/0 pid=6 prio=0 success=1 t
wget 1262 [001] 11624.858021: softirq_raise: vec=1 [action=TIMER]
wget 1262 [001] 11624.858074: softirq_entry: vec=1 [action=TIMER]
wget 1262 [001] 11624.858081: softirq_exit: vec=1 [action=TIMER]
wget 1262 [001] 11624.858166: sys_enter_read: fd: 0x0003, buf: 0xbff82c940, count: 0x0
wget 1262 [001] 11624.858177: sys_exit_read: 0x200
wget 1262 [001] 11624.858878: kfree_skb: skbaddr=0xeb248d80 protocol=0 location=0xc15
wget 1262 [001] 11624.858945: kfree_skb: skbaddr=0xeb248000 protocol=0 location=0xc15
wget 1262 [001] 11624.859020: softirq_raise: vec=1 [action=TIMER]
wget 1262 [001] 11624.859076: softirq_entry: vec=1 [action=TIMER]
wget 1262 [001] 11624.859083: softirq_exit: vec=1 [action=TIMER]
wget 1262 [001] 11624.859167: sys_enter_read: fd: 0x0003, buf: 0xb7720000, count: 0x0
wget 1262 [001] 11624.859192: sys_exit_read: 0x1d7
wget 1262 [001] 11624.859228: sys_enter_read: fd: 0x0003, buf: 0xb7720000, count: 0x0
wget 1262 [001] 11624.859233: sys_exit_read: 0x0
wget 1262 [001] 11624.859573: sys_enter_read: fd: 0x0003, buf: 0xbff82c580, count: 0x0
wget 1262 [001] 11624.859584: sys_exit_read: 0x200
wget 1262 [001] 11624.859864: sys_enter_read: fd: 0x0003, buf: 0xb7720000, count: 0x0
wget 1262 [001] 11624.859888: sys_exit_read: 0x400
wget 1262 [001] 11624.859935: sys_enter_read: fd: 0x0003, buf: 0xb7720000, count: 0x0
```

```
 wget 1262 [001] 11624.859944: sys_exit_read: 0x400
```

This gives us a detailed timestamped sequence of events that occurred within the workload with respect to those events.

In many ways, profiling can be viewed as a subset of tracing - theoretically, if you have a set of trace events that's sufficient to capture all the important aspects of a workload, you can derive any of the results or views that a profiling run can.

Another aspect of traditional profiling is that while powerful in many ways, it's limited by the granularity of the underlying data. Profiling tools offer various ways of sorting and presenting the sample data, which make it much more useful and amenable to user experimentation, but in the end it can't be used in an open-ended way to extract data that just isn't present as a consequence of the fact that conceptually, most of it has been thrown away.

Full-blown detailed tracing data does however offer the opportunity to manipulate and present the information collected during a tracing run in an infinite variety of ways.

Another way to look at it is that there are only so many ways that the 'primitive' counters can be used on their own to generate interesting output; to get anything more complicated than simple counts requires some amount of additional logic, which is typically very specific to the problem at hand. For example, if we wanted to make use of a 'counter' that maps to the value of the time difference between when a process was scheduled to run on a processor and the time it actually ran, we wouldn't expect such a counter to exist on its own, but we could derive one called say 'wakeup_latency' and use it to extract a useful view of that metric from trace data. Likewise, we really can't figure out from standard profiling tools how much data every process on the system reads and writes, along with how many of those reads and writes fail completely. If we have sufficient trace data, however, we could with the right tools easily extract and present that information, but we'd need something other than pre-canned profiling tools to do that.

Luckily, there is a general-purpose way to handle such needs, called 'programming languages'. Making programming languages easily available to apply to such problems given the specific format of data is called a 'programming language binding' for that data and language. Perf supports two programming language bindings, one for Python and one for Perl.

Tying it Together: Language bindings for manipulating and aggregating trace data are of course not a new idea. One of the first projects to do this was IBM's DProbes dpcc compiler, an ANSI C compiler which targeted a low-level assembly language running on an in-kernel interpreter on the target system. This is exactly analogous to what Sun's DTrace did, except that DTrace invented its own language for the purpose. Systemtap, heavily inspired by DTrace, also created its own one-off language, but rather than running the product on an in-kernel interpreter, created an elaborate compiler-based machinery to translate its language into kernel modules written in C.

Now that we have the trace data in perf.data, we can use 'perf script -g' to generate a skeleton script with handlers for the read/write entry/exit events we recorded:

```
root@crownbay:~# perf script -g python
generated Python script: perf-script.py
```

The skeleton script simply creates a python function for each event type in the perf.data file. The body of each function simply prints the event name along with its parameters. For example:

```
def net__netif_rx(event_name, context, common_cpu,
                  common_secs, common_nsecs, common_pid, common_comm,
                  skbaddr, len, name):
    print_header(event_name, common_cpu, common_secs, common_nsecs,
                common_pid, common_comm)

    print "skbaddr=%u, len=%u, name=%s\n" % (skbaddr, len, name),
```

We can run that script directly to print all of the events contained in the perf.data file:

```
root@crownbay:~# perf script -s perf-script.py

in trace_begin
syscalls__sys_exit_read      0 11624.857082795      1262 perf
sched__sched_wakeup          0 11624.857193498      1262 perf
irq__softirq_raise           1 11624.858021635      1262 wget
irq__softirq_entry            1 11624.858074075      1262 wget
irq__softirq_exit             1 11624.858081389      1262 wget
nr=3, ret=0
comm=migration/0,
vec=TIMER
vec=TIMER
vec=TIMER
nr=3, fd=3, bu
nr=3, ret=512
skbaddr=3945041280
skbaddr=3945037824
vec=TIMER
vec=TIMER
vec=TIMER
nr=3, fd=3, bu
nr=3, ret=471
nr=3, fd=3, bu
nr=3, ret=0
nr=3, fd=3, bu
nr=3, ret=512
nr=3, fd=3, bu
nr=3, ret=1024
nr=3, fd=3, bu
nr=3, ret=1024
```

syscalls__sys_enter_read 1 11624.858166434 1262 wget
syscalls__sys_exit_read 1 11624.858177924 1262 wget
skb__kfree_skb 1 11624.858878188 1262 wget
skb__kfree_skb 1 11624.858945608 1262 wget
irq__softirq_raise 1 11624.859020942 1262 wget
irq__softirq_entry 1 11624.859076935 1262 wget
irq__softirq_exit 1 11624.859083469 1262 wget
nr=3, fd=3, bu
nr=3, ret=512
vec=TIMER
vec=TIMER
vec=TIMER
nr=3, fd=3, bu
nr=3, ret=471
nr=3, fd=3, bu
nr=3, ret=0
nr=3, fd=3, bu
nr=3, ret=512
nr=3, fd=3, bu
nr=3, ret=1024
nr=3, fd=3, bu
nr=3, ret=1024

syscalls__sys_enter_read 1 11624.859167565 1262 wget
syscalls__sys_exit_read 1 11624.859192533 1262 wget
syscalls__sys_enter_read 1 11624.859228072 1262 wget
syscalls__sys_exit_read 1 11624.859233707 1262 wget
syscalls__sys_enter_read 1 11624.859573008 1262 wget
syscalls__sys_exit_read 1 11624.859584818 1262 wget
syscalls__sys_enter_read 1 11624.859864562 1262 wget
syscalls__sys_exit_read 1 11624.859888770 1262 wget
syscalls__sys_enter_read 1 11624.859935140 1262 wget
syscalls__sys_exit_read 1 11624.859944032 1262 wget

That in itself isn't very useful; after all, we can accomplish pretty much the same thing by simply running 'perf script' without arguments in the same directory as the perf.data file.

We can however replace the print statements in the generated function bodies with whatever we want, and thereby make it infinitely more useful.

As a simple example, let's just replace the print statements in the function bodies with a simple function that does nothing but increment a per-event count. When the program is run against a perf.data file, each time a particular event is encountered, a tally is incremented for that event. For example:

```
def net__netif_rx(event_name, context, common_cpu,
                  common_secs, common_nsecs, common_pid, common_comm,
                  skbaddr, len, name):
    inc_counts(event_name)
```

Each event handler function in the generated code is modified to do this. For convenience, we define a common function called inc_counts() that each handler calls; inc_counts() simply tallies a count for each event using the 'counts' hash, which is a specialized hash function that does Perl-like autovivification, a capability that's extremely useful for kinds of multi-level aggregation commonly used in processing traces (see perf's documentation on the Python language binding for details):

```
counts = autodict()

def inc_counts(event_name):
    try:
        counts[event_name] += 1
    except TypeError:
        counts[event_name] = 1
```

Finally, at the end of the trace processing run, we want to print the result of all the per-event tallies. For that, we use the special 'trace_end()' function:

```
def trace_end():
    for event_name, count in counts.iteritems():
        print "%-40s %10s\n" % (event_name, count)
```

The end result is a summary of all the events recorded in the trace:

skb__skb_copy_datagram_iovec	13148
irq__softirq_entry	4796
irq__irq_handler_exit	3805
irq__softirq_exit	4795
syscalls__sys_enter_write	8990
net__net_dev_xmit	652
skb__kfree_skb	4047
sched__sched_wakeup	1155
irq__irq_handler_entry	3804
irq__softirq_raise	4799
net__net_dev_queue	652
syscalls__sys_enter_read	17599
net__netif_receive_skb	1743
syscalls__sys_exit_read	17598
net__netif_rx	2
napi__napi_poll	1877
syscalls__sys_exit_write	8990

Note that this is pretty much exactly the same information we get from 'perf stat', which goes a little way to support the idea mentioned previously that given the right kind of trace data, higher-level profiling-type summaries can be derived from it.

Documentation on using the 'perf script' python binding [<http://linux.die.net/man/1/perf-script-python>].

3.1.2.3. System-Wide Tracing and Profiling

The examples so far have focused on tracing a particular program or workload - in other words, every profiling run has specified the program to profile in the command-line e.g. 'perf record wget ...'.

It's also possible, and more interesting in many cases, to run a system-wide profile or trace while running the workload in a separate shell.

To do system-wide profiling or tracing, you typically use the -a flag to 'perf record'.

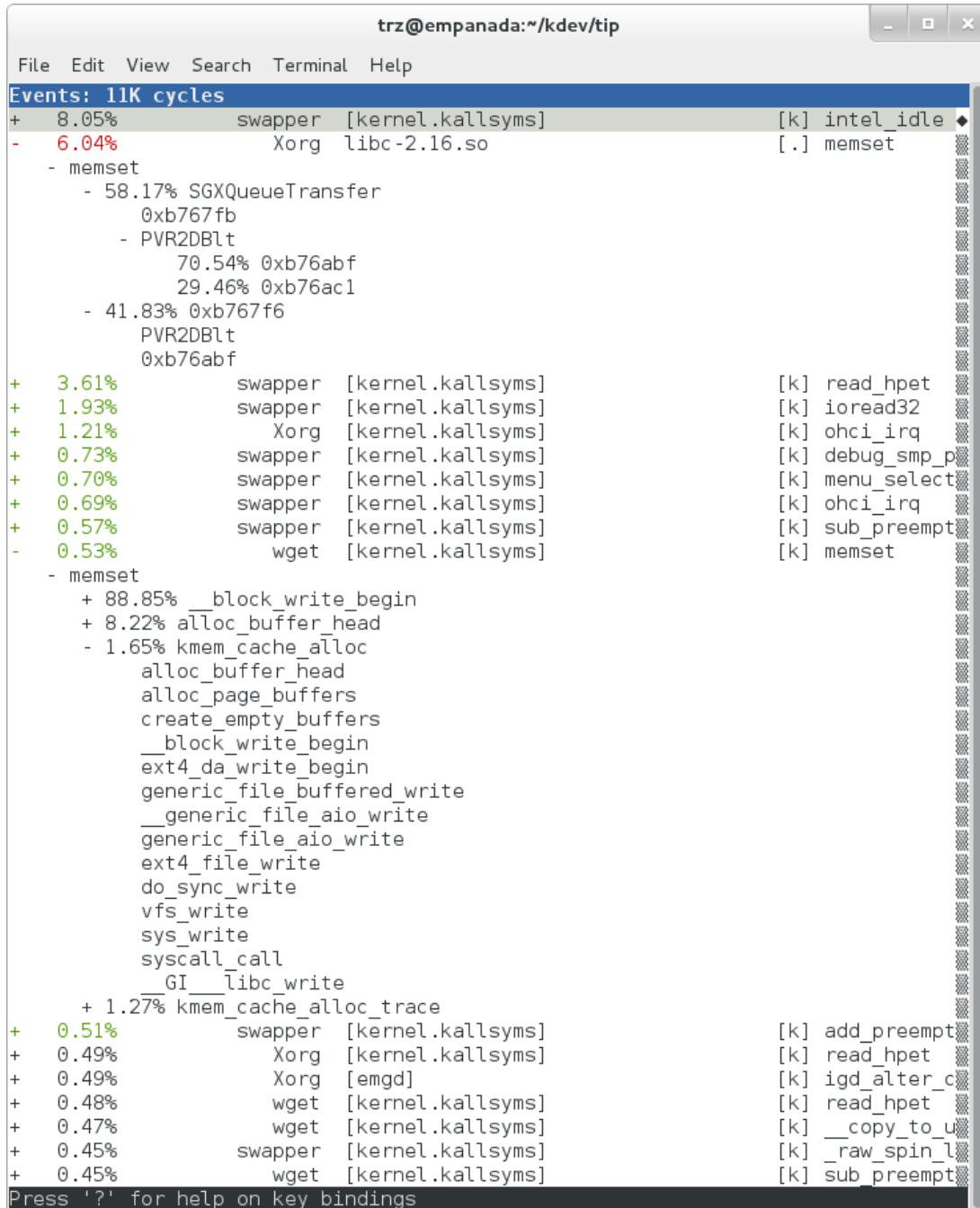
To demonstrate this, open up one window and start the profile using the -a flag (press Ctrl-C to stop tracing):

```
root@crownbay:~# perf record -g -a
^C[ perf record: Woken up 6 times to write data ]
[ perf record: Captured and wrote 1.400 MB perf.data (~61172 samples) ]
```

In another window, run the wget test:

```
root@crownbay:~# wget http://downloads.yoctoproject.org/mirror/sources/linux-2.6.19.2.tar.bz2
Connecting to downloads.yoctoproject.org (140.211.169.59:80)
linux-2.6.19.2.tar.bz2 100% |*****| 41727k 0:00:00 ETA
```

Here we see entries not only for our wget load, but for other processes running on the system as well:



In the snapshot above, we can see callchains that originate in libc, and a callchain from Xorg that demonstrates that we're using a proprietary X driver in userspace (notice the presence of 'PVR' and some other unresolvable symbols in the expanded Xorg callchain).

Note also that we have both kernel and userspace entries in the above snapshot. We can also tell perf to focus on userspace but providing a modifier, in this case 'u', to the 'cycles' hardware counter when we record a profile:

```
root@crownbay:~# perf record -g -a -e cycles:u
^C[ perf record: Woken up 2 times to write data ]
[ perf record: Captured and wrote 0.376 MB perf.data (~16443 samples) ]
```

```

trz@empanada:~/kdev/tip
File Edit View Search Terminal Help
Events: 4K cycles
- 12.84% wget [kernel.kallsyms] [k] system_call
  - system_call
    39.73% __read_nocancel
    20.38% __GI__libc_poll
    19.90% syscall
    19.66% __GI__libc_write
+ 7.01% wget busybox [.]
+ 5.71% wget libc-2.16.so [.]
+ 4.49% wget libc-2.16.so [.]
+ 4.36% wget libc-2.16.so [.]
+ 3.84% wget libc-2.16.so [.]
+ 3.69% wget libc-2.16.so [.]
+ 3.42% wget busybox [.]
+ 3.16% wget libc-2.16.so [.]
+ 3.11% wget busybox [.]
+ 3.04% wget libc-2.16.so [.]
+ 2.95% wget libc-2.16.so [.]
+ 2.95% wget libc-2.16.so [.]
+ 2.55% wget busybox [.]
+ 2.54% wget busybox [.]
- 2.32% wget libc-2.16.so [.]
  - __x86.get_pc_thunk.bx
    - 68.83% fprintf
      progress_meter
    - 31.17% buffered_vfprintf
      fprintf
      progress_meter
+ 1.79% wget busybox [.]
+ 1.71% wget busybox [.]
+ 1.65% wget libc-2.16.so [.]
+ 1.57% wget libc-2.16.so [.]
+ 1.43% wget busybox [.]
+ 1.09% wget libc-2.16.so [.]
+ 0.85% wget libc-2.16.so [.]
+ 0.80% dropbear dropbearmulti [.]
+ 0.78% perf perf [.]
+ 0.71% dropbear dropbearmulti [.]
+ 0.60% wget busybox [.]
+ 0.57% dropbear libc-2.16.so [.]
+ 0.57% wget busybox [.]
+ 0.55% dropbear dropbearmulti [.]
+ 0.39% perf libc-2.16.so [.]
+ 0.38% dropbear libc-2.16.so [.]
+ 0.36% wget libc-2.16.so [.]
+ 0.36% wget libc-2.16.so [.]
Press '?' for help on key bindings

```

Notice in the screenshot above, we see only userspace entries ([.])

Finally, we can press 'enter' on a leaf node and select the 'Zoom into DSO' menu item to show only entries associated with a specific DSO. In the screenshot below, we've zoomed into the 'libc' DSO which shows all the entries associated with the libc-xxx.so DSO.

```

trz@empanada:~/kdev/tip
File Edit View Search Terminal Help
Events: 1K cycles, DS0: libc-2.16.so
- 60.86% Xorg [.] memset
  - memset
    - 58.17% SGXQueueTransfer
      0xb767fb
    - PVR2DBlt
      70.54% 0xb76abf
      29.46% 0xb76ac1
  - 41.83% 0xb767f6
    PVR2DBlt
    0xb76abf
- 2.61% pcmanfm [.] strcmp
  - strcmp
    + 50.21% __gconv_find_transform
      49.79% __dgettext
- 2.08% pcmanfm [.] __int_malloc
  __int_malloc
- 1.92% Xorg [.] __int_malloc
  __int_malloc
- 1.49% Xorg [.] memcpy
  - memcpy
    - 100.00% SGXQueueTransfer
      0xb767fb
      PVR2DBlt
      0xb76abf
+ 1.29% wget [.] __GI__libc_poll
+ 1.06% wget [.] __read_nocancel
+ 0.97% wget [.] __IO_file_xsgetn
+ 0.93% wget [.] clearerr
+ 0.90% wget [.] syscall
+ 0.79% pcmanfm [.] malloc
+ 0.73% leafpad [.] strcmp
+ 0.70% wget [.] __underflow
+ 0.68% Xorg [.] __int_free
+ 0.64% pcmanfm [.] memcpy
+ 0.61% wget [.] __IO_fread
+ 0.60% leafpad [.] __int_malloc
+ 0.59% Xorg [.] free
+ 0.49% Xorg [.] __select
+ 0.49% pcmanfm [.] __x86.get_pc_thunk.bx
+ 0.47% pcmanfm [.] memset
+ 0.46% slant [.] strcmp
+ 0.44% wget [.] __x86.get_pc_thunk.bx
+ 0.44% matchbox-deskt... [.] memcpy
+ 0.39% slant [.] __x86.get_pc_thunk.bx
+ 0.38% matchbox-deskt... [.] __int_malloc
Press '?' for help on key bindings

```

We can also use the system-wide `-a` switch to do system-wide tracing. Here we'll trace a couple of scheduler events:

```

root@crownbay:~# perf record -a -e sched:sched_switch -e sched:sched_wakeup
^C[ perf record: Woken up 38 times to write data ]
[ perf record: Captured and wrote 9.780 MB perf.data (~427299 samples) ]

```

We can look at the raw output using 'perf script' with no arguments:

```

root@crownbay:~# perf script

```

```

perf 1383 [001] 6171.460045: sched_wakeup: comm=kworker/1:1 pid=21 prio=120 su...
perf 1383 [001] 6171.460066: sched_switch: prev_comm=perf prev_pid=1383 prev_pr...
kworker/1:1      21 [001] 6171.460093: sched_switch: prev_comm=kworker/1:1 prev_pid=21 pr...

```

```

        swapper      0 [000]  6171.468063: sched_wakeup: comm=kworker/0:3 pid=1209 prio=120 su
        swapper      0 [000]  6171.468107: sched_switch: prev_comm=swapper/0 prev_pid=0 prev_
kworker/0:3  1209 [000]  6171.468143: sched_switch: prev_comm=kworker/0:3 prev_pid=1209
        perf 1383 [001]  6171.470039: sched_wakeup: comm=kworker/1:1 pid=21 prio=120 su
        perf 1383 [001]  6171.470058: sched_switch: prev_comm=perf prev_pid=1383 prev_
kworker/1:1  21 [001]  6171.470082: sched_switch: prev_comm=kworker/1:1 prev_pid=21 pr
        perf 1383 [001]  6171.480035: sched_wakeup: comm=kworker/1:1 pid=21 prio=120 su
    
```

3.1.2.3.1. Filtering

Notice that there are a lot of events that don't really have anything to do with what we're interested in, namely events that schedule 'perf' itself in and out or that wake perf up. We can get rid of those by using the '--filter' option - for each event we specify using -e, we can add a --filter after that to filter out trace events that contain fields with specific values:

```

root@crownbay:~# perf record -a -e sched:sched_switch --filter 'next_comm != perf && prev_
^C[ perf record: Woken up 38 times to write data ]
[ perf record: Captured and wrote 9.688 MB perf.data (~423279 samples) ]
    
```

```
root@crownbay:~# perf script
```

```

        swapper      0 [000]  7932.162180: sched_switch: prev_comm=swapper/0 prev_pid=0 prev_
kworker/0:3  1209 [000]  7932.162236: sched_switch: prev_comm=kworker/0:3 prev_pid=1209
        perf 1407 [001]  7932.170048: sched_wakeup: comm=kworker/1:1 pid=21 prio=120 su
        perf 1407 [001]  7932.180044: sched_wakeup: comm=kworker/1:1 pid=21 prio=120 su
        perf 1407 [001]  7932.190038: sched_wakeup: comm=kworker/1:1 pid=21 prio=120 su
        perf 1407 [001]  7932.200044: sched_wakeup: comm=kworker/1:1 pid=21 prio=120 su
        perf 1407 [001]  7932.210044: sched_wakeup: comm=kworker/1:1 pid=21 prio=120 su
        perf 1407 [001]  7932.220044: sched_wakeup: comm=kworker/1:1 pid=21 prio=120 su
        swapper      0 [001]  7932.230111: sched_wakeup: comm=kworker/1:1 pid=21 prio=120 su
        swapper      0 [001]  7932.230146: sched_switch: prev_comm=swapper/1 prev_pid=0 prev_
kworker/1:1  21 [001]  7932.230205: sched_switch: prev_comm=kworker/1:1 prev_pid=21 pr
        swapper      0 [000]  7932.326109: sched_wakeup: comm=kworker/0:3 pid=1209 prio=120 su
        swapper      0 [000]  7932.326171: sched_switch: prev_comm=swapper/0 prev_pid=0 prev_
kworker/0:3  1209 [000]  7932.326214: sched_switch: prev_comm=kworker/0:3 prev_pid=1209
    
```

In this case, we've filtered out all events that have 'perf' in their 'comm' or 'comm_prev' or 'comm_next' fields. Notice that there are still events recorded for perf, but notice that those events don't have values of 'perf' for the filtered fields. To completely filter out anything from perf will require a bit more work, but for the purpose of demonstrating how to use filters, it's close enough.

Tying it Together: These are exactly the same set of event filters defined by the trace event subsystem. See the ftrace/tracecmd/kernelshark section for more discussion about these event filters.

Tying it Together: These event filters are implemented by a special-purpose pseudo-interpreter in the kernel and are an integral and indispensable part of the perf design as it relates to tracing. kernel-based event filters provide a mechanism to precisely throttle the event stream that appears in user space, where it makes sense to provide bindings to real programming languages for postprocessing the event stream. This architecture allows for the intelligent and flexible partitioning of processing between the kernel and user space. Contrast this with other tools such as SystemTap, which does all of its processing in the kernel and as such requires a special project-defined language in order to accommodate that design, or LTTng, where everything is sent to userspace and as such requires a super-efficient kernel-to-userspace transport mechanism in order to function properly. While perf certainly can benefit from for instance advances in the design of the transport, it doesn't fundamentally depend on them. Basically, if you find that your perf tracing application is causing buffer I/O overruns, it probably means that you aren't taking enough advantage of the kernel filtering engine.

3.1.2.4. Using Dynamic Tracepoints

perf isn't restricted to the fixed set of static tracepoints listed by 'perf list'. Users can also add their own 'dynamic' tracepoints anywhere in the kernel. For instance, suppose we want to define our own tracepoint on `do_fork()`. We can do that using the 'perf probe' perf subcommand:

```
root@crownbay:~# perf probe do_fork
Added new event:
  probe:do_fork      (on do_fork)
```

You can now use it in all perf tools, such as:

```
perf record -e probe:do_fork -aR sleep 1
```

Adding a new tracepoint via 'perf probe' results in an event with all the expected files and format in /sys/kernel/debug/tracing/events, just the same as for static tracepoints (as discussed in more detail in the trace events subsystem section):

```
root@crownbay:/sys/kernel/debug/tracing/events/probe/do_fork# ls -al
drwxr-xr-x  2 root  root          0 Oct 28 11:42 .
drwxr-xr-x  3 root  root          0 Oct 28 11:42 ..
-rw-r--r--  1 root  root          0 Oct 28 11:42 enable
-rw-r--r--  1 root  root          0 Oct 28 11:42 filter
-r--r--r--  1 root  root          0 Oct 28 11:42 format
-r--r--r--  1 root  root          0 Oct 28 11:42 id

root@crownbay:/sys/kernel/debug/tracing/events/probe/do_fork# cat format
name: do_fork
ID: 944
format:
  field:unsigned short common_type; offset:0; size:2; signed:0;
  field:unsigned char common_flags; offset:2; size:1; signed:0;
  field:unsigned char common_preempt_count; offset:3; size:1; signed:0;
  field:int common_pid; offset:4; size:4; signed:1;
  field:int common_padding; offset:8; size:4; signed:1;

  field:unsigned long __probe_ip; offset:12; size:4; signed:0;
print fmt: "(%lx)", REC->__probe_ip
```

We can list all dynamic tracepoints currently in existence:

```
root@crownbay:~# perf probe -l
probe:do_fork      (on do_fork)
probe:schedule     (on schedule)
```

Let's record system-wide ('sleep 30' is a trick for recording system-wide but basically do nothing and then wake up after 30 seconds):

```
root@crownbay:~# perf record -g -a -e probe:do_fork sleep 30
[ perf record: Woken up 1 times to write data ]
[ perf record: Captured and wrote 0.087 MB perf.data (~3812 samples) ]
```

Using 'perf script' we can see each do_fork event that fired:

```
root@crownbay:~# perf script
# =====
# captured on: Sun Oct 28 11:55:18 2012
# hostname : crownbay
# os release : 3.4.11-yocto-standard
# perf version : 3.4.11
```

```
# arch : i686
# nrcpus online : 2
# nrcpus avail : 2
# cpudesc : Intel(R) Atom(TM) CPU E660 @ 1.30GHz
# cpuid : GenuineIntel,6,38,1
# total memory : 1017184 kB
# cmdline : /usr/bin/perf record -g -a -e probe:do_fork sleep 30
# event : name = probe:do_fork, type = 2, config = 0x3b0, config1 = 0x0, config2 = 0x0, excl
= 0, id = { 5, 6 }
# HEADER_CPU_TOPOLOGY info available, use -I to display
# =====
#
matchbox-deskto 1197 [001] 34211.378318: do_fork: (c1028460)
matchbox-deskto 1295 [001] 34211.380388: do_fork: (c1028460)
    pcmanfm 1296 [000] 34211.632350: do_fork: (c1028460)
    pcmanfm 1296 [000] 34211.639917: do_fork: (c1028460)
matchbox-deskto 1197 [001] 34217.541603: do_fork: (c1028460)
matchbox-deskto 1299 [001] 34217.543584: do_fork: (c1028460)
    gthumb 1300 [001] 34217.697451: do_fork: (c1028460)
    gthumb 1300 [001] 34219.085734: do_fork: (c1028460)
    gthumb 1300 [000] 34219.121351: do_fork: (c1028460)
    gthumb 1300 [001] 34219.264551: do_fork: (c1028460)
    pcmanfm 1296 [000] 34219.590380: do_fork: (c1028460)
matchbox-deskto 1197 [001] 34224.955965: do_fork: (c1028460)
matchbox-deskto 1306 [001] 34224.957972: do_fork: (c1028460)
matchbox-termin 1307 [000] 34225.038214: do_fork: (c1028460)
matchbox-termin 1307 [001] 34225.044218: do_fork: (c1028460)
matchbox-termin 1307 [000] 34225.046442: do_fork: (c1028460)
matchbox-deskto 1197 [001] 34237.112138: do_fork: (c1028460)
matchbox-deskto 1311 [001] 34237.114106: do_fork: (c1028460)
    gaku 1312 [000] 34237.202388: do_fork: (c1028460)
```

And using 'perf report' on the same file, we can see the callgraphs from starting a few programs during those 30 seconds:

```

trz@empanada:~/danny-met.../intel-release
File Edit View Search Terminal Help
Events: 19 probe:do_fork
- 42.11% matchbox-deskt... [kernel.kallsyms] [k] do_fork
  do_fork
  ptregs_clone
  __libc_fork
  fork_exec_with_pipes
- 21.05% gthumb [kernel.kallsyms] [k] do_fork
  do_fork
  ptregs_clone
  clone
  0
- 15.79% pcmanfm [kernel.kallsyms] [k] do_fork
  do_fork
  ptregs_clone
  clone
  0
- 15.79% matchbox-termin [kernel.kallsyms] [k] do_fork
  - do_fork
  - ptregs_clone
    - 66.67% __libc_fork
      50.00% vte_pty_initable_init
      50.00% fork_exec_with_pipes
    - 33.33% __clone
      0
- 5.26% gaku [kernel.kallsyms] [k] do_fork
  do_fork
  ptregs_clone
  __libc_fork
  fork

Press '?' for help on key bindings

```

Tying it Together: The trace events subsystem accommodate static and dynamic tracepoints in exactly the same way - there's no difference as far as the infrastructure is concerned. See the ftrace section for more details on the trace event subsystem.

Tying it Together: Dynamic tracepoints are implemented under the covers by kprobes and uprobes. kprobes and uprobes are also used by and in fact are the main focus of SystemTap.

3.1.3. Documentation

Online versions of the man pages for the commands discussed in this section can be found here:

- The 'perf stat' manpage [<http://linux.die.net/man/1/perf-stat>].
- The 'perf record' manpage [<http://linux.die.net/man/1/perf-record>].
- The 'perf report' manpage [<http://linux.die.net/man/1/perf-report>].
- The 'perf probe' manpage [<http://linux.die.net/man/1/perf-probe>].

- The 'perf script' manpage [<http://linux.die.net/man/1/perf-script>].
- Documentation on using the 'perf script' python binding [<http://linux.die.net/man/1/perf-script-python>].
- The top-level perf(1) manpage [<http://linux.die.net/man/1/perf>].

Normally, you should be able to invoke the man pages via perf itself e.g. 'perf help' or 'perf help record'.

However, by default Yocto doesn't install man pages, but perf invokes the man pages for most help functionality. This is a bug and is being addressed by a Yocto bug: Bug 3388 - perf: enable man pages for basic 'help' functionality [https://bugzilla.yoctoproject.org/show_bug.cgi?id=3388].

The man pages in text form, along with some other files, such as a set of examples, can be found in the 'perf' directory of the kernel tree:

```
tools/perf/Documentation
```

There's also a nice perf tutorial on the perf wiki that goes into more detail than we do here in certain areas: Perf Tutorial [<https://perf.wiki.kernel.org/index.php/Tutorial>]

3.2. ftrace

'ftrace' literally refers to the 'ftrace function tracer' but in reality this encompasses a number of related tracers along with the infrastructure that they all make use of.

3.2.1. Setup

For this section, we'll assume you've already performed the basic setup outlined in the General Setup section.

ftrace, trace-cmd, and kernelshark run on the target system, and are ready to go out-of-the-box - no additional setup is necessary. For the rest of this section we assume you've ssh'd to the host and will be running ftrace on the target. kernelshark is a GUI application and if you use the '-X' option to ssh you can have the kernelshark GUI run on the target but display remotely on the host if you want.

3.2.2. Basic ftrace usage

'ftrace' essentially refers to everything included in the /tracing directory of the mounted debugfs filesystem (Yocto follows the standard convention and mounts it at /sys/kernel/debug). Here's a listing of all the files found in /sys/kernel/debug/tracing on a Yocto system:

```
root@sugarbay:/sys/kernel/debug/tracing# ls
README                      kprobe_events          trace
available_events              kprobe_profile        trace_clock
available_filter_functions    options             trace_marker
available_tracers             per_cpu             trace_options
buffer_size_kb                printk_formats       trace_pipe
buffer_total_size_kb          saved_cmdlines      tracing_cpumask
current_tracer                set_event           tracing_enabled
dyn_ftrace_total_info         set_ftrace_filter  tracing_on
enabled_functions             set_ftrace_notrace tracing_thresh
events                       set_ftrace_pid      set_graph_function
```

The files listed above are used for various purposes - some relate directly to the tracers themselves, others are used to set tracing options, and yet others actually contain the tracing output when a tracer is in effect. Some of the functions can be guessed from their names, others need explanation; in any case, we'll cover some of the files we see here below but for an explanation of the others, please see the ftrace documentation.

We'll start by looking at some of the available built-in tracers.

cat'ing the 'available_tracers' file lists the set of available tracers:

```
root@sugarbay:/sys/kernel/debug/tracing# cat available_tracers
blk function_graph function nop
```

The 'current_tracer' file contains the tracer currently in effect:

```
root@sugarbay:/sys/kernel/debug/tracing# cat current_tracer
nop
```

The above listing of current_tracer shows that the 'nop' tracer is in effect, which is just another way of saying that there's actually no tracer currently in effect.

echo'ing one of the available_tracers into current_tracer makes the specified tracer the current tracer:

```
root@sugarbay:/sys/kernel/debug/tracing# echo function > current_tracer
root@sugarbay:/sys/kernel/debug/tracing# cat current_tracer
function
```

The above sets the current tracer to be the 'function tracer'. This tracer traces every function call in the kernel and makes it available as the contents of the 'trace' file. Reading the 'trace' file lists the currently buffered function calls that have been traced by the function tracer:

```
root@sugarbay:/sys/kernel/debug/tracing# cat trace | less

# tracer: function
#
# entries-in-buffer/entries-written: 310629/766471 #P:8
#
#           -----> irqs-off
#           /-----> need_resched
#           | /-----> hardirq/softirq
#           || /-----> preempt_depth
#           ||| /-----> delay
#
#           TASK-PID    CPU#    |-----> TIMESTAMP    FUNCTION
#           | |        | |        | |        | |
<idle>-0    [004] d..1    470.867169: ktime_get_real <-intel_idle
<idle>-0    [004] d..1    470.867170: getnstimeofday <-ktime_get_real
<idle>-0    [004] d..1    470.867171: ns_to_timeval <-intel_idle
<idle>-0    [004] d..1    470.867171: ns_to_timespec <-ns_to_timeval
<idle>-0    [004] d..1    470.867172: smp_apic_timer_interrupt <-apic_timer_interrupt
<idle>-0    [004] d..1    470.867172: native_apic_mem_write <-smp_apic_timer_interrupt
<idle>-0    [004] d..1    470.867172: irq_enter <-smp_apic_timer_interrupt
<idle>-0    [004] d..1    470.867172: rcu_irq_enter <-irq_enter
<idle>-0    [004] d..1    470.867173: rcu_idle_exit_common.isra.33 <-rcu_irq_enter
<idle>-0    [004] d..1    470.867173: local_bh_disable <-irq_enter
<idle>-0    [004] d..1    470.867173: add_preempt_count <-local_bh_disable
<idle>-0    [004] d..1    470.867174: tick_check_idle <-irq_enter
<idle>-0    [004] d..1    470.867174: tick_check_oneshot_broadcast <-tick_check_id
<idle>-0    [004] d..1    470.867174: ktime_get <-tick_check_idle
<idle>-0    [004] d..1    470.867174: tick_nohz_stop_id <-tick_check_id
<idle>-0    [004] d..1    470.867175: update_ts_time_stats <-tick_nohz_stop_id
<idle>-0    [004] d..1    470.867175: nr_iowait_cpu <-update_ts_time_stats
<idle>-0    [004] d..1    470.867175: tick_do_update_jiffies64 <-tick_check_id
<idle>-0    [004] d..1    470.867175: _raw_spin_lock <-tick_do_update_jiffies64
<idle>-0    [004] d..1    470.867176: add_preempt_count <-_raw_spin_lock
<idle>-0    [004] d..2    470.867176: do_timer <-tick_do_update_jiffies64
<idle>-0    [004] d..2    470.867176: _raw_spin_lock <-do_timer
<idle>-0    [004] d..2    470.867176: add_preempt_count <-_raw_spin_lock
<idle>-0    [004] d..3    470.867177: ntp_tick_length <-do_timer
```

```
<idle>-0      [004] d.s3  470.867177: _raw_spin_lock_irqsave <-ntp_tick_length
.
.
.
```

Each line in the trace above shows what was happening in the kernel on a given cpu, to the level of detail of function calls. Each entry shows the function called, followed by its caller (after the arrow).

The function tracer gives you an extremely detailed idea of what the kernel was doing at the point in time the trace was taken, and is a great way to learn about how the kernel code works in a dynamic sense.

Tying it Together: The ftrace function tracer is also available from within perf, as the ftrace:function tracepoint.

It is a little more difficult to follow the call chains than it needs to be - luckily there's a variant of the function tracer that displays the callchains explicitly, called the 'function_graph' tracer:

```
root@sugarbay:/sys/kernel/debug/tracing# echo function_graph > current_tracer
root@sugarbay:/sys/kernel/debug/tracing# cat trace | less

tracer: function_graph

CPU  DURATION          FUNCTION CALLS
|  |  |
7)  0.046 us  |
7)  0.043 us  | pick_next_task_fair();
7)  0.042 us  | pick_next_task_stop();
7)  0.032 us  | pick_next_task_rt();
7)  0.030 us  | pick_next_task_fair();
7)  0.033 us  | pick_next_task_idle();
7)  0.258 us  | _raw_spin_unlock_irq() {
7)  0.032 us  |   sub_preempt_count();
7) + 13.341 us  | } /* __schedule */
7)  0.095 us  | } /* sub_preempt_count */
7)  0.060 us  | schedule() {
7)  0.044 us  |   __schedule() {
7)  0.033 us  |     add_preempt_count();
7)  0.247 us  |     rcu_note_context_switch();
7)  0.031 us  |     _raw_spin_lock_irq() {
7)  0.246 us  |       add_preempt_count();
7)  0.030 us  |     }
7)  0.029 us  |     idle_balance() {
7)  0.484 us  |       _raw_spin_unlock() {
7)  0.030 us  |         sub_preempt_count();
7)  0.031 us  |       }
7)  0.029 us  |       update_shares() {
7)  0.035 us  |         __rcu_read_lock();
7)  0.030 us  |         __rcu_read_unlock();
7)  0.906 us  |       }
7)  1.141 us  |     }
7)  0.022 us  |     msecs_to_jiffies();
7)  0.031 us  |     load_balance() {
7)  0.031 us  |       find_busiest_group() {
7)  0.031 us  |         idle_cpu();
7)  0.031 us  |       }
7)  0.031 us  |     }
7)  0.031 us  |   }
7)  0.031 us  | }
```



```
3) + 13.784 us | }
3) | sys_ioctl() {
```

As you can see, the function_graph display is much easier to follow. Also note that in addition to the function calls and associated braces, other events such as scheduler events are displayed in context. In fact, you can freely include any tracepoint available in the trace events subsystem described in the next section by simply enabling those events, and they'll appear in context in the function graph display. Quite a powerful tool for understanding kernel dynamics.

Also notice that there are various annotations on the left hand side of the display. For example if the total time it took for a given function to execute is above a certain threshold, an exclamation point or plus sign appears on the left hand side. Please see the ftrace documentation for details on all these fields.

3.2.3. The 'trace events' Subsystem

One especially important directory contained within the /sys/kernel/debug/tracing directory is the 'events' subdirectory, which contains representations of every tracepoint in the system. Listing out the contents of the 'events' subdirectory, we see mainly another set of subdirectories:

```
root@sugarbay:/sys/kernel/debug/tracing# cd events
root@sugarbay:/sys/kernel/debug/tracing/events# ls -al
drwxr-xr-x 38 root root 0 Nov 14 23:19 .
drwxr-xr-x 5 root root 0 Nov 14 23:19 ..
drwxr-xr-x 19 root root 0 Nov 14 23:19 block
drwxr-xr-x 32 root root 0 Nov 14 23:19 btrfs
drwxr-xr-x 5 root root 0 Nov 14 23:19 drm
-rw-r--r-- 1 root root 0 Nov 14 23:19 enable
drwxr-xr-x 40 root root 0 Nov 14 23:19 ext3
drwxr-xr-x 79 root root 0 Nov 14 23:19 ext4
drwxr-xr-x 14 root root 0 Nov 14 23:19 ftrace
drwxr-xr-x 8 root root 0 Nov 14 23:19 hda
-r--r--r-- 1 root root 0 Nov 14 23:19 header_event
-r--r--r-- 1 root root 0 Nov 14 23:19 header_page
drwxr-xr-x 25 root root 0 Nov 14 23:19 i915
drwxr-xr-x 7 root root 0 Nov 14 23:19 irq
drwxr-xr-x 12 root root 0 Nov 14 23:19 jbd
drwxr-xr-x 14 root root 0 Nov 14 23:19 jbd2
drwxr-xr-x 14 root root 0 Nov 14 23:19 kmem
drwxr-xr-x 7 root root 0 Nov 14 23:19 module
drwxr-xr-x 3 root root 0 Nov 14 23:19 napi
drwxr-xr-x 6 root root 0 Nov 14 23:19 net
drwxr-xr-x 3 root root 0 Nov 14 23:19 oom
drwxr-xr-x 12 root root 0 Nov 14 23:19 power
drwxr-xr-x 3 root root 0 Nov 14 23:19 printk
drwxr-xr-x 8 root root 0 Nov 14 23:19 random
drwxr-xr-x 4 root root 0 Nov 14 23:19 raw_syscalls
drwxr-xr-x 3 root root 0 Nov 14 23:19 rcu
drwxr-xr-x 6 root root 0 Nov 14 23:19 rpm
drwxr-xr-x 20 root root 0 Nov 14 23:19 sched
drwxr-xr-x 7 root root 0 Nov 14 23:19 scsi
drwxr-xr-x 4 root root 0 Nov 14 23:19 signal
drwxr-xr-x 5 root root 0 Nov 14 23:19 skb
drwxr-xr-x 4 root root 0 Nov 14 23:19 sock
drwxr-xr-x 10 root root 0 Nov 14 23:19 sunrpc
drwxr-xr-x 538 root root 0 Nov 14 23:19 syscalls
drwxr-xr-x 4 root root 0 Nov 14 23:19 task
drwxr-xr-x 14 root root 0 Nov 14 23:19 timer
drwxr-xr-x 3 root root 0 Nov 14 23:19 udp
drwxr-xr-x 21 root root 0 Nov 14 23:19 vmscan
drwxr-xr-x 3 root root 0 Nov 14 23:19 vsyscall
drwxr-xr-x 6 root root 0 Nov 14 23:19 workqueue
drwxr-xr-x 26 root root 0 Nov 14 23:19 writeback
```

Each one of these subdirectories corresponds to a 'subsystem' and contains yet again more subdirectories, each one of those finally corresponding to a tracepoint. For example, here are the contents of the 'kmem' subsystem:

```
root@sugarbay:/sys/kernel/debug/tracing/events# cd kmem
root@sugarbay:/sys/kernel/debug/tracing/events/kmem# ls -al
drwxr-xr-x 14 root root 0 Nov 14 23:19 .
drwxr-xr-x 38 root root 0 Nov 14 23:19 ..
-rw-r--r-- 1 root root 0 Nov 14 23:19 enable
-rw-r--r-- 1 root root 0 Nov 14 23:19 filter
drwxr-xr-x 2 root root 0 Nov 14 23:19 kfree
drwxr-xr-x 2 root root 0 Nov 14 23:19 kmalloc
drwxr-xr-x 2 root root 0 Nov 14 23:19 kmalloc_node
drwxr-xr-x 2 root root 0 Nov 14 23:19 kmem_cache_alloc
drwxr-xr-x 2 root root 0 Nov 14 23:19 kmem_cache_alloc_node
drwxr-xr-x 2 root root 0 Nov 14 23:19 kmem_cache_free
drwxr-xr-x 2 root root 0 Nov 14 23:19 mm_page_alloc
drwxr-xr-x 2 root root 0 Nov 14 23:19 mm_page_alloc_extfrag
drwxr-xr-x 2 root root 0 Nov 14 23:19 mm_page_alloc_zone_locked
drwxr-xr-x 2 root root 0 Nov 14 23:19 mm_page_free
drwxr-xr-x 2 root root 0 Nov 14 23:19 mm_page_free_batched
drwxr-xr-x 2 root root 0 Nov 14 23:19 mm_page_pcpu_drain
```

Let's see what's inside the subdirectory for a specific tracepoint, in this case the one for kmalloc:

```
root@sugarbay:/sys/kernel/debug/tracing/events/kmem# cd kmalloc
root@sugarbay:/sys/kernel/debug/tracing/events/kmem/kmalloc# ls -al
drwxr-xr-x 2 root root 0 Nov 14 23:19 .
drwxr-xr-x 14 root root 0 Nov 14 23:19 ..
-rw-r--r-- 1 root root 0 Nov 14 23:19 enable
-rw-r--r-- 1 root root 0 Nov 14 23:19 filter
-r--r--r-- 1 root root 0 Nov 14 23:19 format
-r--r--r-- 1 root root 0 Nov 14 23:19 id
```

The 'format' file for the tracepoint describes the event in memory, which is used by the various tracing tools that now make use of these tracepoint to parse the event and make sense of it, along with a 'print fmt' field that allows tools like ftrace to display the event as text. Here's what the format of the kmalloc event looks like:

```
root@sugarbay:/sys/kernel/debug/tracing/events/kmem/kmalloc# cat format
name: kmalloc
ID: 313
format:
  field:unsigned short common_type; offset:0; size:2; signed:0;
  field:unsigned char common_flags; offset:2; size:1; signed:0;
  field:unsigned char common_preempt_count; offset:3; size:1; signed:0;
  field:int common_pid; offset:4; size:4; signed:1;
  field:int common_padding; offset:8; size:4; signed:1;

  field:unsigned long call_site; offset:16; size:8; signed:0;
  field:const void * ptr; offset:24; size:8; signed:0;
  field:size_t bytes_req; offset:32; size:8; signed:0;
  field:size_t bytes_alloc; offset:40; size:8; signed:0;
  field:gfp_t gfp_flags; offset:48; size:4; signed:0;

print fmt: "call_site=%lx ptr=%p bytes_req=%zu bytes_alloc=%zu gfp_flags=%s", REC->call_site
(REC->gfp_flags) ? __print_flags(REC->gfp_flags, "|", {(unsigned long)(((( gfp_t)0x10u) | (( gfp_t)0x20000u) | (( gfp_t)0x02u) | (( gfp_t)0x08u)) | (( gfp_t)0x4000u) | (( gfp_t)0x10000u) | (( gfp_t)0x04u) | (( gfp_t)0x01u) | (( gfp_t)0x00u)) : 0;
```

```
gfp_t)0x400000u)), "GFP_TRANSHUGE"}, {(unsigned long)(( gfp_t)0x10u) | (( gfp_t)0x40u) | (( gfp_t)0x02u) | (( gfp_t)0x08u)), "GFP_HIGHUSER_MOVABLE"}, {(unsigned long)(( gfp_t)0x10u) | (( gfp_t)0x200000u) | (( gfp_t)0x02u)), "GFP_HIGHUSER"}, {(unsigned long)(( gfp_t)0x10u) | (( gfp_t)0x200000u)), "GFP_USER"}, {(unsigned long)(( gfp_t)0x10u) | (( gfp_t)0x40u) | (( gfp_t)0x80u)), "GFP_KERNEL"}, {(unsigned long)(( gfp_t)0x10u) | (( gfp_t)0x40u) | (( gfp_t)0x20u)), "GFP_NOFS"}, {(unsigned long)(( gfp_t)0x20u)), "GFP_ATOMIC"}, {(unsigned long)(( gfp_t)0x10u) | (( gfp_t)0x20u)), "GFP_HIGH"}, {(unsigned long)(( gfp_t)0x10u)), "GFP_WAIT"}, {(unsigned long)(( gfp_t)0x100u)), "GFP_COLD"}, {(unsigned long)(( gfp_t)0x200u)), "GFP_NOWARN"}, {(unsigned long)(( gfp_t)0x800u)), "GFP_NOFAIL"}, {(unsigned long)(( gfp_t)0x1000u)), "GFP_NORETRY"}, {(unsigned long)(( gfp_t)0x8000u)), "GFP_ZERO"}, {(unsigned long)(( gfp_t)0x10000u)), "GFP_NOMMU"}, {"GFP_HARDWALL"}, {(unsigned long)(( gfp_t)0x40000u)), "GFP_THISNODE"}, {(unsigned long)(( gfp_t)0x08u)), "GFP_MOVABLE"}, {(unsigned long)(( gfp_t)0)), "GFP_NOTRACK"}, {(unsigned long)(( gfp_t)0x800000u)), "GFP_OTHER_NODE"} ) : "GFP_NOWAIT"
```

The 'enable' file in the tracepoint directory is what allows the user (or tools such as trace-cmd) to actually turn the tracepoint on and off. When enabled, the corresponding tracepoint will start appearing in the ftrace 'trace' file described previously. For example, this turns on the kmalloc tracepoint:

```
root@sugarbay:/sys/kernel/debug/tracing/events/kmem/kmalloc# echo 1 > enable
```

At the moment, we're not interested in the function tracer or some other tracer that might be in effect, so we first turn it off, but if we do that, we still need to turn tracing on in order to see the events in the output buffer:

```
root@sugarbay:/sys/kernel/debug/tracing# echo nop > current_tracer
root@sugarbay:/sys/kernel/debug/tracing# echo 1 > tracing_on
```

Now, if we look at the the 'trace' file, we see nothing but the kmalloc events we just turned on:

```
root@sugarbay:/sys/kernel/debug/tracing# cat trace | less
# tracer: nop
#
# entries-in-buffer/entries-written: 1897/1897    #P:8
#
#           -----> irqs-off
#           /-----> need-resched
#           / /-----> hardirq/softirq
#           / / /-----> preempt-depth
#           / / / /-----> delay
#
#           TASK-PID    CPU#    TIMESTAMP    FUNCTION
#           | | | | | | | | | |
dropbear-1465 [000] ...1 18154.620753: kmalloc: call_site=ffffffff816650d4 ptr=ffff8
<idle>-0 [000] ..s3 18154.621640: kmalloc: call_site=ffffffff81619b36 ptr=ffff8
<idle>-0 [000] ..s3 18154.621656: kmalloc: call_site=ffffffff81619b36 ptr=ffff8
matchbox-termin-1361 [001] ...1 18154.755472: kmalloc: call_site=ffffffff81614050 ptr=ffff8
Xorg-1264 [002] ...1 18154.755581: kmalloc: call_site=ffffffff8141abe8 ptr=ffff8
Xorg-1264 [002] ...1 18154.755583: kmalloc: call_site=ffffffff814192a3 ptr=ffff8
Xorg-1264 [002] ...1 18154.755589: kmalloc: call_site=ffffffff81419edb ptr=ffff8
matchbox-termin-1361 [001] ...1 18155.354594: kmalloc: call_site=ffffffff81614050 ptr=ffff8
Xorg-1264 [002] ...1 18155.354703: kmalloc: call_site=ffffffff8141abe8 ptr=ffff8
Xorg-1264 [002] ...1 18155.354705: kmalloc: call_site=ffffffff814192a3 ptr=ffff8
Xorg-1264 [002] ...1 18155.354711: kmalloc: call_site=ffffffff81419edb ptr=ffff8
<idle>-0 [000] ..s3 18155.673319: kmalloc: call_site=ffffffff81619b36 ptr=ffff8
dropbear-1465 [000] ...1 18155.673525: kmalloc: call_site=ffffffff816650d4 ptr=ffff8
<idle>-0 [000] ..s3 18155.674821: kmalloc: call_site=ffffffff81619b36 ptr=ffff8
<idle>-0 [000] ..s3 18155.793014: kmalloc: call_site=ffffffff81619b36 ptr=ffff8
dropbear-1465 [000] ...1 18155.793219: kmalloc: call_site=ffffffff816650d4 ptr=ffff8
<idle>-0 [000] ..s3 18155.794147: kmalloc: call_site=ffffffff81619b36 ptr=ffff8
```

```

<idle>-0      [000] ..s3 18155.936705: kmalloc: call_site=ffffffff81619b36 ptr=fffff8
dropbear-1465  [000] ...1 18155.936910: kmalloc: call_site=ffffffff816650d4 ptr=fffff8
<idle>-0      [000] ..s3 18155.937869: kmalloc: call_site=ffffffff81619b36 ptr=fffff8
matchbox-termin-1361 [001] ...1 18155.953667: kmalloc: call_site=ffffffff81614050 ptr=fffff8
    Xorg-1264   [002] ...1 18155.953775: kmalloc: call_site=ffffffff8141abe8 ptr=fffff8
    Xorg-1264   [002] ...1 18155.953777: kmalloc: call_site=ffffffff814192a3 ptr=fffff8
    Xorg-1264   [002] ...1 18155.953783: kmalloc: call_site=ffffffff81419edb ptr=fffff8
<idle>-0      [000] ..s3 18156.176053: kmalloc: call_site=ffffffff81619b36 ptr=fffff8
dropbear-1465  [000] ...1 18156.176257: kmalloc: call_site=ffffffff816650d4 ptr=fffff8
<idle>-0      [000] ..s3 18156.177717: kmalloc: call_site=ffffffff81619b36 ptr=fffff8
<idle>-0      [000] ..s3 18156.399229: kmalloc: call_site=ffffffff81619b36 ptr=fffff8
dropbear-1465  [000] ...1 18156.399434: kmalloc: call_site=ffffffff816650d4 ptr=fffff8
<idle>-0      [000] ..s3 18156.400660: kmalloc: call_site=ffffffff81619b36 ptr=fffff8
matchbox-termin-1361 [001] ...1 18156.552800: kmalloc: call_site=ffffffff81614050 ptr=fffff8

```

To again disable the kmalloc event, we need to send 0 to the enable file:

```
root@sugarbay:/sys/kernel/debug/tracing/events/kmem/kmalloc# echo 0 > enable
```

You can enable any number of events or complete subsystems (by using the 'enable' file in the subsystem directory) and get an arbitrarily fine-grained idea of what's going on in the system by enabling as many of the appropriate tracepoints as applicable.

A number of the tools described in this HOWTO do just that, including trace-cmd and kernelshark in the next section.

Tying it Together: These tracepoints and their representation are used not only by ftrace, but by many of the other tools covered in this document and they form a central point of integration for the various tracers available in Linux. They form a central part of the instrumentation for the following tools: perf, lttng, ftrace, blktrace and SystemTap

Tying it Together: Eventually all the special-purpose tracers currently available in /sys/kernel/debug/tracing will be removed and replaced with equivalent tracers based on the 'trace events' subsystem.

3.2.4. trace-cmd/kernelshark

trace-cmd is essentially an extensive command-line 'wrapper' interface that hides the details of all the individual files in /sys/kernel/debug/tracing, allowing users to specify specific particular events within the /sys/kernel/debug/tracing/events/ subdirectory and to collect traces and avoid having to deal with those details directly.

As yet another layer on top of that, kernelshark provides a GUI that allows users to start and stop traces and specify sets of events using an intuitive interface, and view the output as both trace events and as a per-CPU graphical display. It directly uses 'trace-cmd' as the plumbing that accomplishes all that underneath the covers (and actually displays the trace-cmd command it uses, as we'll see).

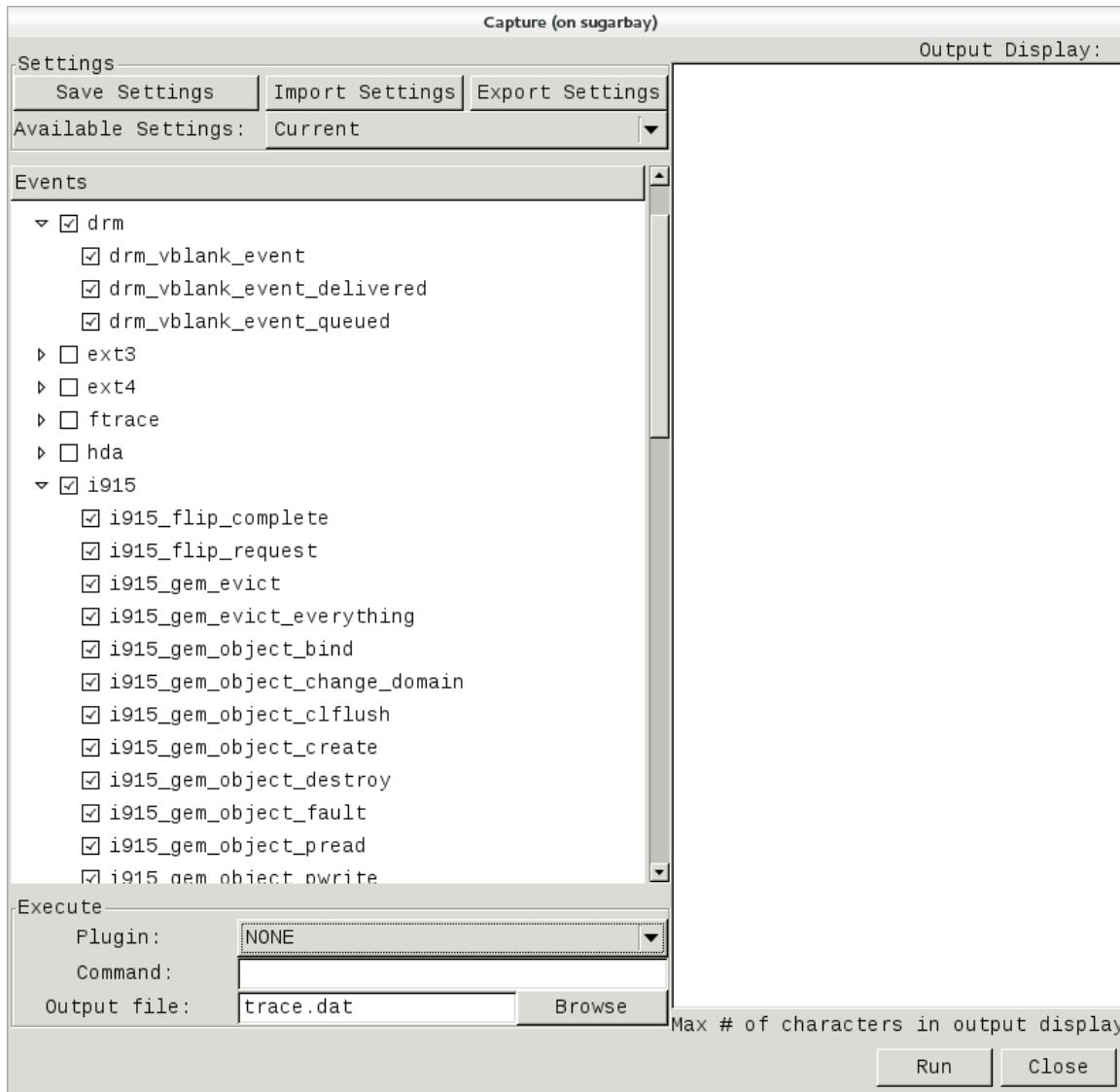
To start a trace using kernelshark, first start kernelshark:

```
root@sugarbay:~# kernelshark
```

Then bring up the 'Capture' dialog by choosing from the kernelshark menu:

Capture | Record

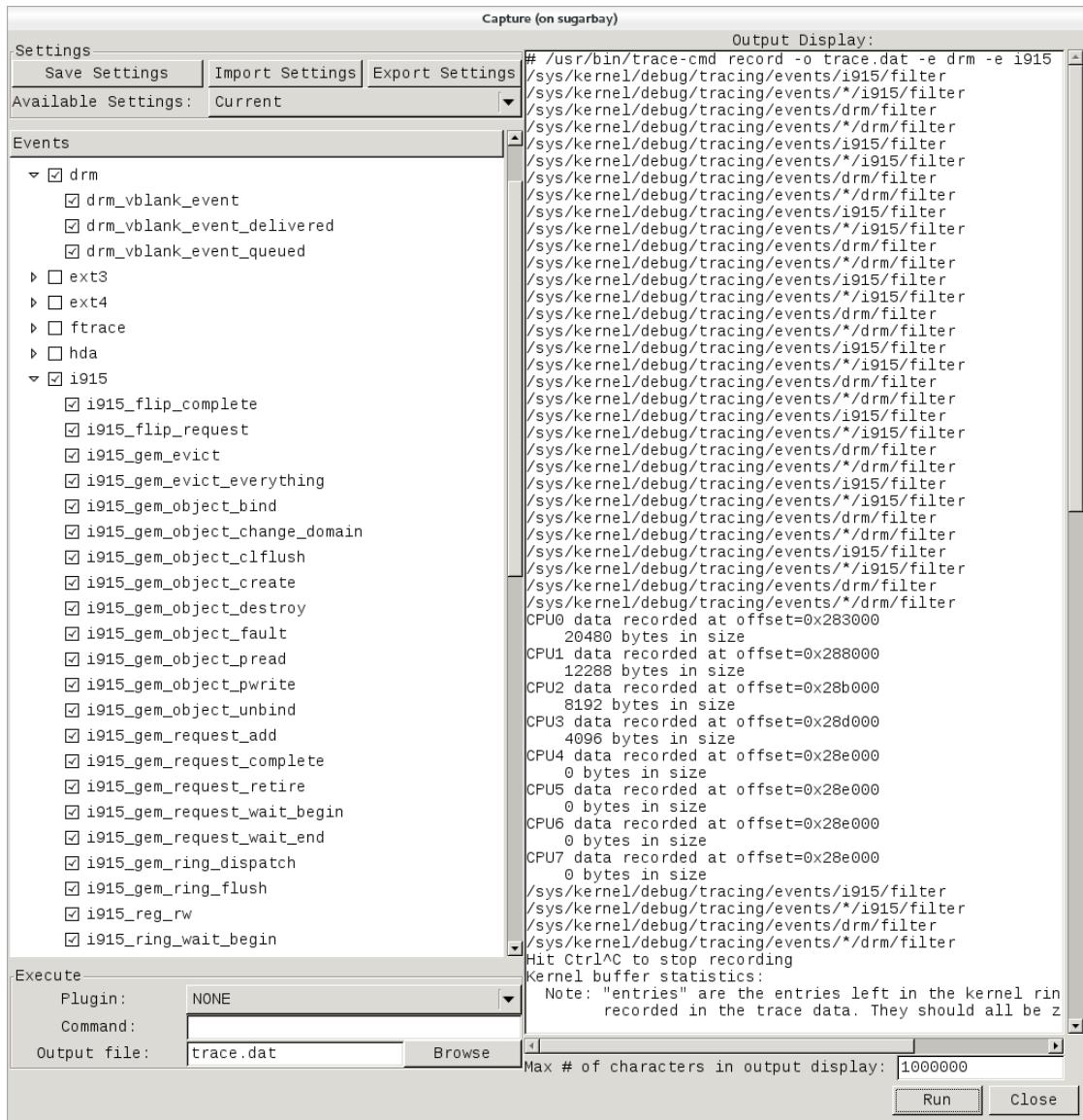
That will display the following dialog, which allows you to choose one or more events (or even one or more complete subsystems) to trace:



Note that these are exactly the same sets of events described in the previous trace events subsystem section, and in fact is where trace-cmd gets them for kernelshark.

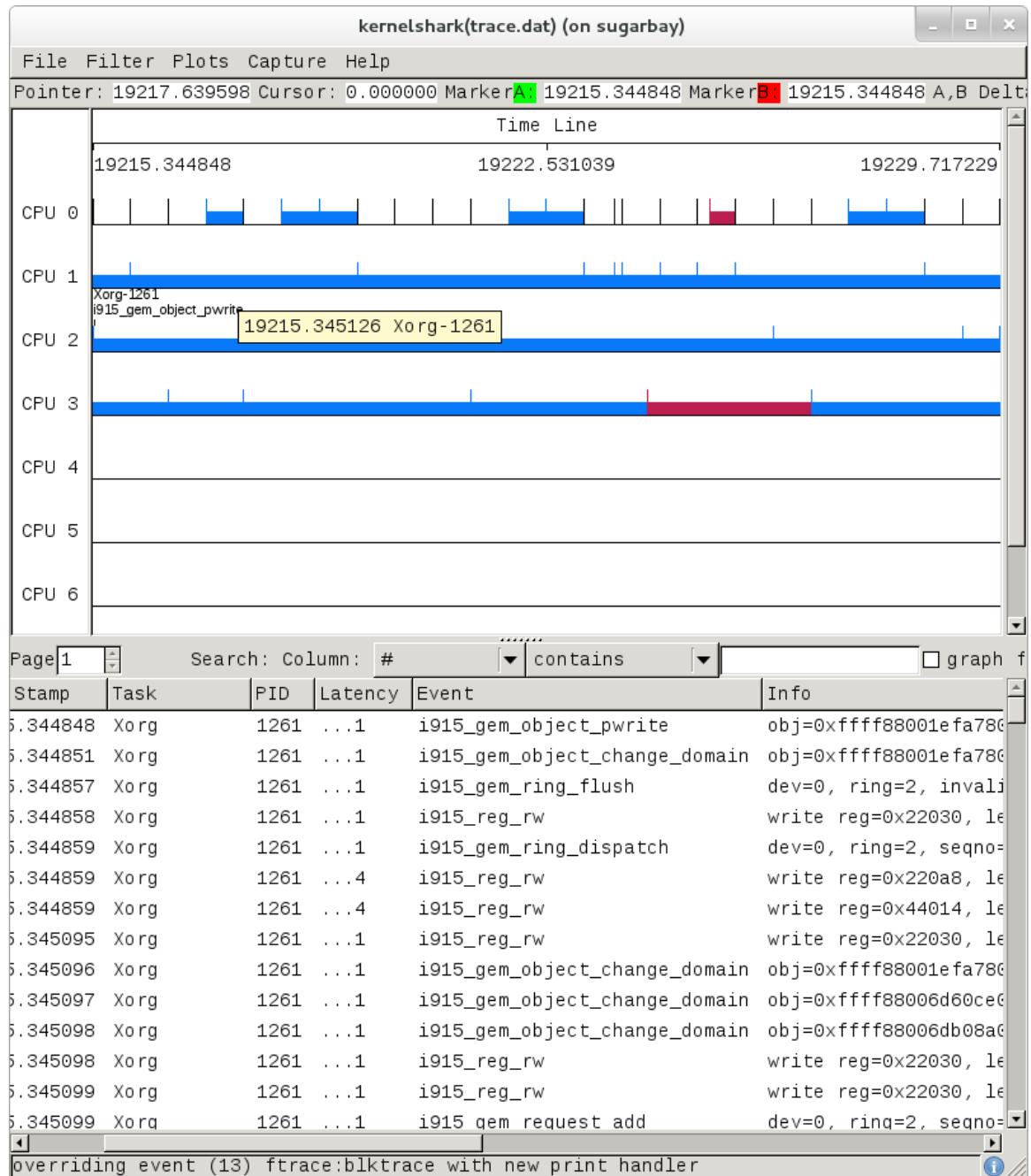
In the above screenshot, we've decided to explore the graphics subsystem a bit and so have chosen to trace all the tracepoints contained within the 'i915' and 'drm' subsystems.

After doing that, we can start and stop the trace using the 'Run' and 'Stop' button on the lower right corner of the dialog (the same button will turn into the 'Stop' button after the trace has started):



Notice that the right-hand pane shows the exact trace-cmd command-line that's used to run the trace, along with the results of the trace-cmd run.

Once the 'Stop' button is pressed, the graphical view magically fills up with a colorful per-cpu display of the trace data, along with the detailed event listing below that:



Here's another example, this time a display resulting from tracing 'all events':



The tool is pretty self-explanatory, but for more detailed information on navigating through the data, see the kernelshark website [<http://rostedt.homelinux.com/kernelshark/>].

3.2.5. Documentation

The documentation for ftrace can be found in the kernel Documentation directory:

`Documentation/trace/ftrace.txt`

The documentation for the trace event subsystem can also be found in the kernel Documentation directory:

`Documentation/trace/events.txt`

There is a nice series of articles on using ftrace and trace-cmd at LWN:

- Debugging the kernel using Ftrace - part 1 [<http://lwn.net/Articles/365835/>]
- Debugging the kernel using Ftrace - part 2 [<http://lwn.net/Articles/366796/>]
- Secrets of the Ftrace function tracer [<http://lwn.net/Articles/370423/>]
- trace-cmd: A front-end for Ftrace [<https://lwn.net/Articles/410200/>]

There's more detailed documentation kernelshark usage here: KernelShark [<http://rostedt.homelinux.com/kernelshark/>]

An amusing yet useful README (a tracing mini-HOWTO) can be found in `/sys/kernel/debug/tracing/README`.

3.3. systemtap

SystemTap is a system-wide script-based tracing and profiling tool.

SystemTap scripts are C-like programs that are executed in the kernel to gather/print/aggregate data extracted from the context they end up being invoked under.

For example, this probe from the SystemTap tutorial [<http://sourceware.org/systemtap/tutorial/>] simply prints a line every time any process on the system open()s a file. For each line, it prints the executable name of the program that opened the file, along with its PID, and the name of the file it opened (or tried to open), which it extracts from the open syscall's argstr.

```
probe syscall.open
{
    printf ("%s(%d) open (%s)\n", execname(), pid(), argstr)
}

probe timer.ms(4000) # after 4 seconds
{
    exit ()
}
```

Normally, to execute this probe, you'd simply install systemtap on the system you want to probe, and directly run the probe on that system e.g. assuming the name of the file containing the above text is `trace_open.stp`:

```
# stap trace_open.stp
```

What systemtap does under the covers to run this probe is 1) parse and convert the probe to an equivalent 'C' form, 2) compile the 'C' form into a kernel module, 3) insert the module into the kernel, which arms it, and 4) collect the data generated by the probe and display it to the user.

In order to accomplish steps 1 and 2, the 'stap' program needs access to the kernel build system that produced the kernel that the probed system is running. In the case of a typical embedded system (the 'target'), the kernel build system unfortunately isn't typically part of the image running on the target. It is normally available on the 'host' system that produced the target image however; in such cases, steps 1 and 2 are executed on the host system, and steps 3 and 4 are executed on the target system, using only the systemtap 'runtime'.

The systemtap support in Yocto assumes that only steps 3 and 4 are run on the target; it is possible to do everything on the target, but this section assumes only the typical embedded use-case.

So basically what you need to do in order to run a systemtap script on the target is to 1) on the host system, compile the probe into a kernel module that makes sense to the target, 2) copy the module onto the target system and 3) insert the module into the target kernel, which arms it, and 4) collect the data generated by the probe and display it to the user.

3.3.1. Setup

Those are a lot of steps and a lot of details, but fortunately Yocto includes a script called 'crosstab' that will take care of those details, allowing you to simply execute a systemtap script on the remote target, with arguments if necessary.

In order to do this from a remote host, however, you need to have access to the build for the image you booted. The 'crosstab' script provides details on how to do this if you run the script on the host without having done a build:

Note

SystemTap, which uses 'crosstab', assumes you can establish an ssh connection to the remote target. Please refer to the crosstab wiki page for details on verifying ssh connections at https://wiki.yoctoproject.org/wiki/Tracing_and_Profiling#systemtap. Also, the ability to ssh into the target system is not enabled by default in *-minimal images.

```
$ crosstab root@192.168.1.88 trace_open.stp
```

```
Error: No target kernel build found.  
Did you forget to create a local build of your image?
```

```
'crosstab' requires a local sdk build of the target system  
(or a build that includes 'tools-profile') in order to build  
kernel modules that can probe the target system.
```

Practically speaking, that means you need to do the following:

- If you're running a pre-built image, download the release and/or BSP tarballs used to build the image.
- If you're working from git sources, just clone the metadata and BSP layers needed to build the image you'll be booting.
- Make sure you're properly set up to build a new image (see the BSP README and/or the widely available basic documentation that discusses how to build images).
- Build an -sdk version of the image e.g.:
 \$ bitbake core-image-sato-sdk

OR

- Build a non-sdk image but include the profiling tools:
 [edit local.conf and add 'tools-profile' to the end of
 the EXTRA_IMAGE_FEATURES variable]
 \$ bitbake core-image-sato

Once you've build the image on the host system, you're ready to boot it (or the equivalent pre-built image) and use 'crosstab' to probe it (you need to source the environment as usual first):

```
$ source oe-init-build-env  
$ cd ~/my/systemtap/scripts  
$ crosstab root@192.168.1.xxx myscript.stp
```

So essentially what you need to do is build an SDK image or image with 'tools-profile' as detailed in the "General Setup" section of this manual, and boot the resulting target image.

Note

If you have a build directory containing multiple machines, you need to have the MACHINE you're connecting to selected in local.conf, and the kernel in that machine's build directory must match the kernel on the booted system exactly, or you'll get the above 'crosstab' message when you try to invoke a script.

3.3.2. Running a Script on a Target

Once you've done that, you should be able to run a systemtap script on the target:

```
$ cd /path/to/yocto
$ source oe-init-build-env

### Shell environment set up for builds. ###

You can now run 'bitbake target'

Common targets are:
core-image-minimal
core-image-sato
meta-toolchain
adt-installer
meta-ide-support

You can also run generated qemu images with a command like 'runqemu qemux86'
```

Once you've done that, you can cd to whatever directory contains your scripts and use 'crosstab' to run the script:

```
$ cd /path/to/my/systemap/script
$ crosstab root@192.168.7.2 trace_open.stp
```

If you get an error connecting to the target e.g.:

```
$ crosstab root@192.168.7.2 trace_open.stp
error establishing ssh connection on remote 'root@192.168.7.2'
```

Try ssh'ing to the target and see what happens:

```
$ ssh root@192.168.7.2
```

A lot of the time, connection problems are due specifying a wrong IP address or having a 'host key verification error'.

If everything worked as planned, you should see something like this (enter the password when prompted, or press enter if it's set up to use no password):

```
$ crosstab root@192.168.7.2 trace_open.stp
root@192.168.7.2's password:
matchbox-termin(1036) open ("/tmp/vte3FS2LW", 0_RDWR|0_CREAT|0_EXCL|0_LARGEFILE, 0600)
matchbox-termin(1036) open ("/tmp/vteJMC7LW", 0_RDWR|0_CREAT|0_EXCL|0_LARGEFILE, 0600)
```

3.3.3. Documentation

The SystemTap language reference can be found here: SystemTap Language Reference [<http://sourceware.org/systemtap/langref/>]

Links to other SystemTap documents, tutorials, and examples can be found here: SystemTap documentation page [<http://sourceware.org/systemtap/documentation.html>]

3.4. oprofile

oprofile itself is a command-line application that runs on the target system.

3.4.1. Setup

For this section, we'll assume you've already performed the basic setup outlined in the "General Setup" section.

For the section that deals with running oprofile from the command-line, we assume you've ssh'ed to the host and will be running oprofile on the target.

oprofileui (oprofile-viewer) is a GUI-based program that runs on the host and interacts remotely with the target. See the oprofileui section for the exact steps needed to install oprofileui on the host.

3.4.2. Basic Usage

Oprofile as configured in Yocto is a system-wide profiler (i.e. the version in Yocto doesn't yet make use of the `perf_events` interface which would allow it to profile specific processes and workloads). It relies on hardware counter support in the hardware (but can fall back to a timer-based mode), which means that it doesn't take advantage of tracepoints or other event sources for example.

It consists of a kernel module that collects samples and a userspace daemon that writes the sample data to disk.

The '`opcontrol`' shell script is used for transparently managing these components and starting and stopping profiles, and the '`opreport`' command is used to display the results.

The oprofile daemon should already be running, but before you start profiling, you may need to change some settings and some of these settings may require the daemon to not be running. One of these settings is the path to the `vmlinux` file, which you'll want to set using the `--vmlinux` option if you want the kernel profiled:

```
root@crownbay:~# opcontrol --vmlinux=/boot/vmlinux-`uname -r`  
The profiling daemon is currently active, so changes to the configuration  
will be used the next time you restart oprofile after a --shutdown or --deinit.
```

You can check if `vmlinux` file: is set using `opcontrol --status`:

```
root@crownbay:~# opcontrol --status  
Daemon paused: pid 1334  
Separate options: library  
vmlinux file: none  
Image filter: none  
Call-graph depth: 6
```

If it's not, you need to shutdown the daemon, add the setting and restart the daemon:

```
root@crownbay:~# opcontrol --shutdown  
Killing daemon.  
  
root@crownbay:~# opcontrol --vmlinux=/boot/vmlinux-`uname -r`  
root@crownbay:~# opcontrol --start-daemon  
Using default event: CPU_CLK_UNHALTED:100000:0:1:1  
Using 2.6+ OProfile kernel interface.  
Reading module info.  
Using log file /var/lib/oprofile/samples/oprofiled.log  
Daemon started.
```

If we check the status again we now see our updated settings:

```
root@crownbay:~# opcontrol --status  
Daemon paused: pid 1649  
Separate options: library  
vmlinux file: /boot/vmlinux-3.4.11-yocto-standard  
Image filter: none  
Call-graph depth: 6
```

We're now in a position to run a profile. For that we use '`opcontrol --start`':

```
root@crownbay:~# opcontrol --start
Profiler running.
```

In another window, run our wget workload:

```
root@crownbay:~# rm linux-2.6.19.2.tar.bz2; wget http://downloads.yoctoproject.org/mirror/sc
Connecting to downloads.yoctoproject.org (140.211.169.59:80)
linux-2.6.19.2.tar.b 100% |*****| 41727k 0:00:00 ETA
```

To stop the profile we use 'opcontrol --shutdown', which not only stops the profile but shuts down the daemon as well:

```
root@crownbay:~# opcontrol --shutdown
Stopping profiling.
Killing daemon.
```

Oprofile writes sample data to /var/lib/oprofile/samples, which you can look at if you're interested in seeing how the samples are structured. This is also interesting because it's related to how you dive down to get further details about specific executables in OProfile.

To see the default display output for a profile, simply type 'opreport', which will show the results using the data in /var/lib/oprofile/samples:

```
root@crownbay:~# opreport
WARNING! The OProfile kernel driver reports sample buffer overflows.
Such overflows can result in incorrect sample attribution, invalid sample
files and other symptoms. See the oprofiled.log for details.
You should adjust your sampling frequency to eliminate (or at least minimize)
these overflows.
CPU: Intel Architectural Perfmon, speed 1.3e+06 MHz (estimated)
Counted CPU_CLK_UNHALTED events (Clock cycles when not halted) with a unit mask of 0x00 (No
CPU_CLK_UNHALT...|
samples| %|
-----
464365 79.8156 vmlinux-3.4.11-yocto-standard
65108 11.1908 oprofiled
CPU_CLK_UNHALT...|
samples| %|
-----
64416 98.9372 oprofiled
692 1.0628 libc-2.16.so
36959 6.3526 no-vmlinux
4378 0.7525 busybox
CPU_CLK_UNHALT...|
samples| %|
-----
2844 64.9612 libc-2.16.so
1337 30.5391 busybox
193 4.4084 ld-2.16.so
2 0.0457 libnss_compat-2.16.so
1 0.0228 libnsl-2.16.so
1 0.0228 libnss_files-2.16.so
4344 0.7467 bash
CPU_CLK_UNHALT...|
samples| %|
-----
2657 61.1648 bash
1665 38.3287 libc-2.16.so
```

```

18 0.4144 ld-2.16.so
3 0.0691 libtinfo.so.5.9
1 0.0230 libdl-2.16.so
3118 0.5359 nf_conntrack
686 0.1179 matchbox-terminal
CPU_CLK_UNHALT...|
samples| %|
-----
214 31.1953 libglib-2.0.so.0.3200.4
114 16.6181 libc-2.16.so
79 11.5160 libcairo.so.2.11200.2
78 11.3703 libgdk-x11-2.0.so.0.2400.8
51 7.4344 libpthread-2.16.so
45 6.5598 libgobject-2.0.so.0.3200.4
29 4.2274 libvte.so.9.2800.2
25 3.6443 libX11.so.6.3.0
19 2.7697 libxcb.so.1.1.0
17 2.4781 libgtk-x11-2.0.so.0.2400.8
12 1.7493 libert-2.16.so
3 0.4373 libXrender.so.1.3.0
671 0.1153 emgd
411 0.0706 nf_conntrack_ipv4
391 0.0672 iptable_nat
378 0.0650 nf_nat
263 0.0452 Xorg
CPU_CLK_UNHALT...|
samples| %|
-----
106 40.3042 Xorg
53 20.1521 libc-2.16.so
31 11.7871 libpixman-1.so.0.27.2
26 9.8859 emgd_drv.so
16 6.0837 libemgdsrv_um.so.1.5.15.3226
11 4.1825 libEMGD2d.so.1.5.15.3226
9 3.4221 libfb.so
7 2.6616 libpthread-2.16.so
1 0.3802 libudev.so.0.9.3
1 0.3802 libdrm.so.2.4.0
1 0.3802 libextmod.so
1 0.3802 mouse_drv.so
.
.
.
9 0.0015 connmand
CPU_CLK_UNHALT...|
samples| %|
-----
4 44.4444 libglib-2.0.so.0.3200.4
2 22.2222 libpthread-2.16.so
1 11.1111 connmand
1 11.1111 libc-2.16.so
1 11.1111 libert-2.16.so
6 0.0010 oprofile-server
CPU_CLK_UNHALT...|
samples| %|
-----
3 50.0000 libc-2.16.so
1 16.6667 oprofile-server
1 16.6667 libpthread-2.16.so
1 16.6667 libglib-2.0.so.0.3200.4
5 8.6e-04 gconfd-2
CPU_CLK_UNHALT...|
samples| %|

```

```
2 40.0000 libdbus-1.so.3.7.2
2 40.0000 libglib-2.0.so.0.3200.4
1 20.0000 libc-2.16.so
```

The output above shows the breakdown or samples by both number of samples and percentage for each executable. Within an executable, the sample counts are broken down further into executable and shared libraries (DSOs) used by the executable.

To get even more detailed breakdowns by function, we need to have the full paths to the DSOs, which we can get by using -f with oreport:

```
root@crownbay:~# oreport -f

CPU: Intel Architectural Perfmon, speed 1.3e+06 MHz (estimated)
Counted CPU_CLK_UNHALTED events (Clock cycles when not halted) with a unit mask of 0x00 (No
CPU_CLK_UNHALT...|
samples|      %|

464365 79.8156 /boot/vmlinux-3.4.11-yocto-standard
65108 11.1908 /usr/bin/oprofiled
CPU_CLK_UNHALT...|
samples|      %|

-----
64416 98.9372 /usr/bin/oprofiled
692 1.0628 /lib/libc-2.16.so
36959 6.3526 /no-vmlinux
4378 0.7525 /bin/busybox
CPU_CLK_UNHALT...|
samples|      %|

-----
2844 64.9612 /lib/libc-2.16.so
1337 30.5391 /bin/busybox
193 4.4084 /lib/ld-2.16.so
2 0.0457 /lib/libnss_compat-2.16.so
1 0.0228 /lib/libnsl-2.16.so
1 0.0228 /lib/libnss_files-2.16.so
4344 0.7467 /bin/bash
CPU_CLK_UNHALT...|
samples|      %|

-----
2657 61.1648 /bin/bash
1665 38.3287 /lib/libc-2.16.so
18 0.4144 /lib/ld-2.16.so
3 0.0691 /lib/libtinfo.so.5.9
1 0.0230 /lib/libdl-2.16.so

.
.
```

Using the paths shown in the above output and the -l option to oreport, we can see all the functions that have hits in the profile and their sample counts and percentages. Here's a portion of what we get for the kernel:

```
root@crownbay:~# oreport -l /boot/vmlinux-3.4.11-yocto-standard

CPU: Intel Architectural Perfmon, speed 1.3e+06 MHz (estimated)
Counted CPU_CLK_UNHALTED events (Clock cycles when not halted) with a unit mask of 0x00 (No
samples % symbol name
233981 50.3873 intel_idle
15437 3.3243 rb_get_reader_page
14503 3.1232 ring_buffer_consume
```

```
14092 3.0347 mutex_spin_on_owner
13024 2.8047 read_hpet
8039 1.7312 sub_preempt_count
7096 1.5281 ioread32
6997 1.5068 add_preempt_count
3985 0.8582 rb_advance_reader
3488 0.7511 add_event_entry
3303 0.7113 get_parent_ip
3104 0.6684 rb_buffer_peek
2960 0.6374 op_cpu_buffer_read_entry
2614 0.5629 sync_buffer
2545 0.5481 debug_smp_processor_id
2456 0.5289 ohci_irq
2397 0.5162 memset
2349 0.5059 __copy_to_user_ll
2185 0.4705 ring_buffer_event_length
1918 0.4130 in_lock_functions
1850 0.3984 __schedule
1767 0.3805 __copy_from_user_ll_nozero
1575 0.3392 rb_event_data_length
1256 0.2705 memcpy
1233 0.2655 system_call
1213 0.2612 menu_select
```

Notice that above we see an entry for the `__copy_to_user_ll()` function that we've looked at with other profilers as well.

Here's what we get when we do the same thing for the busybox executable:

```
CPU: Intel Architectural Perfmon, speed 1.3e+06 MHz (estimated)
Counted CPU_CLK_UNHALTED events (Clock cycles when not halted) with a unit mask of 0x00 (No
samples % image name symbol name
349 8.4198 busybox retrieve_file_data
308 7.4306 libc-2.16.so __IO_file_xsgetn
283 6.8275 libc-2.16.so __read_nocancel
235 5.6695 libc-2.16.so __syscall
233 5.6212 libc-2.16.so clearerr
215 5.1870 libc-2.16.so fread
181 4.3667 libc-2.16.so __write_nocancel
158 3.8118 libc-2.16.so __underflow
151 3.6429 libc-2.16.so __dl_addr
150 3.6188 busybox progress_meter
150 3.6188 libc-2.16.so __poll_nocancel
148 3.5706 libc-2.16.so __IO_file_underflow@@GLIBC_2.1
137 3.3052 busybox safe_poll
125 3.0157 busybox bb_progress_update
122 2.9433 libc-2.16.so __x86.get_pc_thunk.bx
95 2.2919 busybox full_write
81 1.9542 busybox safe_write
77 1.8577 busybox xwrite
72 1.7370 libc-2.16.so __IO_file_read
71 1.7129 libc-2.16.so __IO_sgetn
67 1.6164 libc-2.16.so poll
52 1.2545 libc-2.16.so __IO_switch_to_get_mode
45 1.0856 libc-2.16.so read
34 0.8203 libc-2.16.so write
32 0.7720 busybox monotonic_sec
25 0.6031 libc-2.16.so vfprintf
22 0.5308 busybox get_mono
14 0.3378 ld-2.16.so strcmp
14 0.3378 libc-2.16.so __x86.get_pc_thunk.cx
.
.
```

Since we recorded the profile with a callchain depth of 6, we should be able to see our `__copy_to_user_ll()` callchains in the output, and indeed we can if we search around a bit in the 'opreport --callgraph' output:

```
root@crownbay:~# opreport --callgraph /boot/vmlinux-3.4.11-yocto-standard

 392      6.9639  vmlinux-3.4.11-yocto-standard sock_aio_read
 736     13.0751  vmlinux-3.4.11-yocto-standard __generic_file_aio_write
 3255     57.8255  vmlinux-3.4.11-yocto-standard inet_recvmsg
 785     0.1690  vmlinux-3.4.11-yocto-standard tcp_recvmsg
 1790    31.7940  vmlinux-3.4.11-yocto-standard local_bh_enable
 1238    21.9893  vmlinux-3.4.11-yocto-standard __kfree_skb
 992     17.6199  vmlinux-3.4.11-yocto-standard lock_sock_nested
 785    13.9432  vmlinux-3.4.11-yocto-standard tcp_recvmsg [self]
 525     9.3250  vmlinux-3.4.11-yocto-standard release_sock
 112     1.9893  vmlinux-3.4.11-yocto-standard tcp_cleanup_rbuf
 72      1.2789  vmlinux-3.4.11-yocto-standard skb_copy_datagram_iovec

170      0.0366  vmlinux-3.4.11-yocto-standard skb_copy_datagram_iovec
1491    73.3038  vmlinux-3.4.11-yocto-standard memcpy_toiovec
 327    16.0767  vmlinux-3.4.11-yocto-standard skb_copy_datagram_iovec
 170     8.3579  vmlinux-3.4.11-yocto-standard skb_copy_datagram_iovec [self]
 20      0.9833  vmlinux-3.4.11-yocto-standard copy_to_user

 2588    98.2909  vmlinux-3.4.11-yocto-standard copy_to_user
2349     0.5059  vmlinux-3.4.11-yocto-standard __copy_to_user_ll
 2349     89.2138  vmlinux-3.4.11-yocto-standard __copy_to_user_ll [self]
 166     6.3046  vmlinux-3.4.11-yocto-standard do_page_fault
```

Remember that by default OProfile sessions are cumulative i.e. if you start and stop a profiling session, then start a new one, the new one will not erase the previous run(s) but will build on it. If you want to restart a profile from scratch, you need to reset:

```
root@crownbay:~# opcontrol --reset
```

3.4.3. OProfileUI - A GUI for OProfile

Yocto also supports a graphical UI for controlling and viewing OProfile traces, called OProfileUI. To use it, you first need to clone the oprofileui git repo, then configure, build, and install it:

```
[trz@empanada tmp]$ git clone git://git.yoctoproject.org/oprofileui
[trz@empanada tmp]$ cd oprofileui
[trz@empanada oprofileui]$ ./autogen.sh
[trz@empanada oprofileui]$ sudo make install
```

OprofileUI replaces the 'opreport' functionality with a GUI, and normally doesn't require the user to use 'opcontrol' either. If you want to profile the kernel, however, you need to either use the UI to specify a vmlinux or use 'opcontrol' to specify it on the target:

First, on the target, check if vmlinux file: is set:

```
root@crownbay:~# opcontrol --status
```

If not:

```
root@crownbay:~# opcontrol --shutdown
root@crownbay:~# opcontrol --vmlinux=/boot/vmlinux-`uname -r`
root@crownbay:~# opcontrol --start-daemon
```

Now, start the oprofile UI on the host system:

```
[trz@empanada oprofileui]$ oprofile-viewer
```

To run a profile on the remote system, first connect to the remote system by pressing the 'Connect' button and supplying the IP address and port of the remote system (the default port is 4224).

The oprofile server should automatically be started already. If not, the connection will fail and you either typed in the wrong IP address and port (see below), or you need to start the server yourself:

```
root@crownbay:~# oprofile-server
```

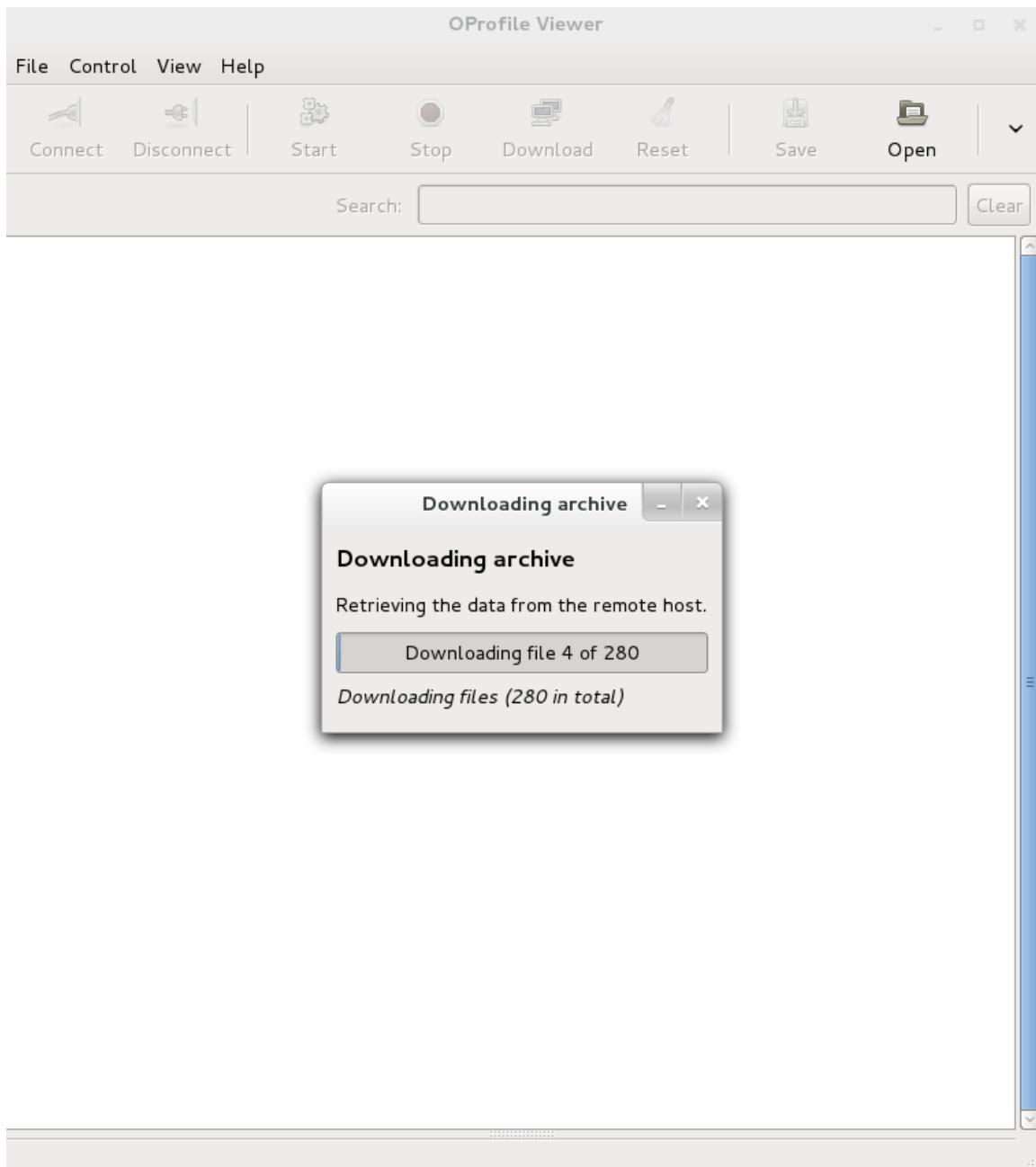
Or, to specify a specific port:

```
root@crownbay:~# oprofile-server --port 8888
```

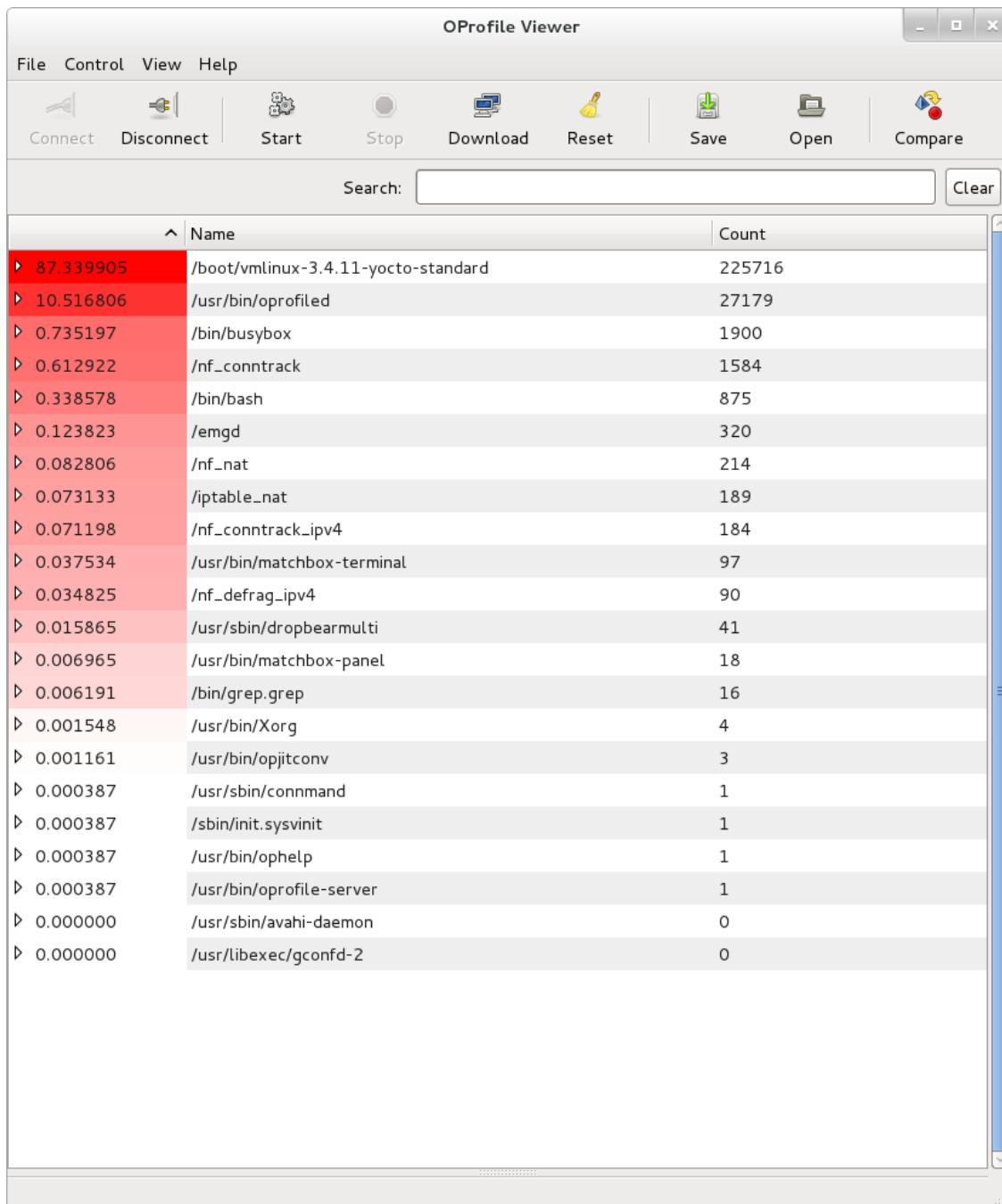
Once connected, press the 'Start' button and then run the wget workload on the remote system:

```
root@crownbay:~# rm linux-2.6.19.2.tar.bz2; wget http://downloads.yoctoproject.org/mirror/sc
Connecting to downloads.yoctoproject.org (140.211.169.59:80)
linux-2.6.19.2.tar.b 100% |*****| 41727k 0:00:00 ETA
```

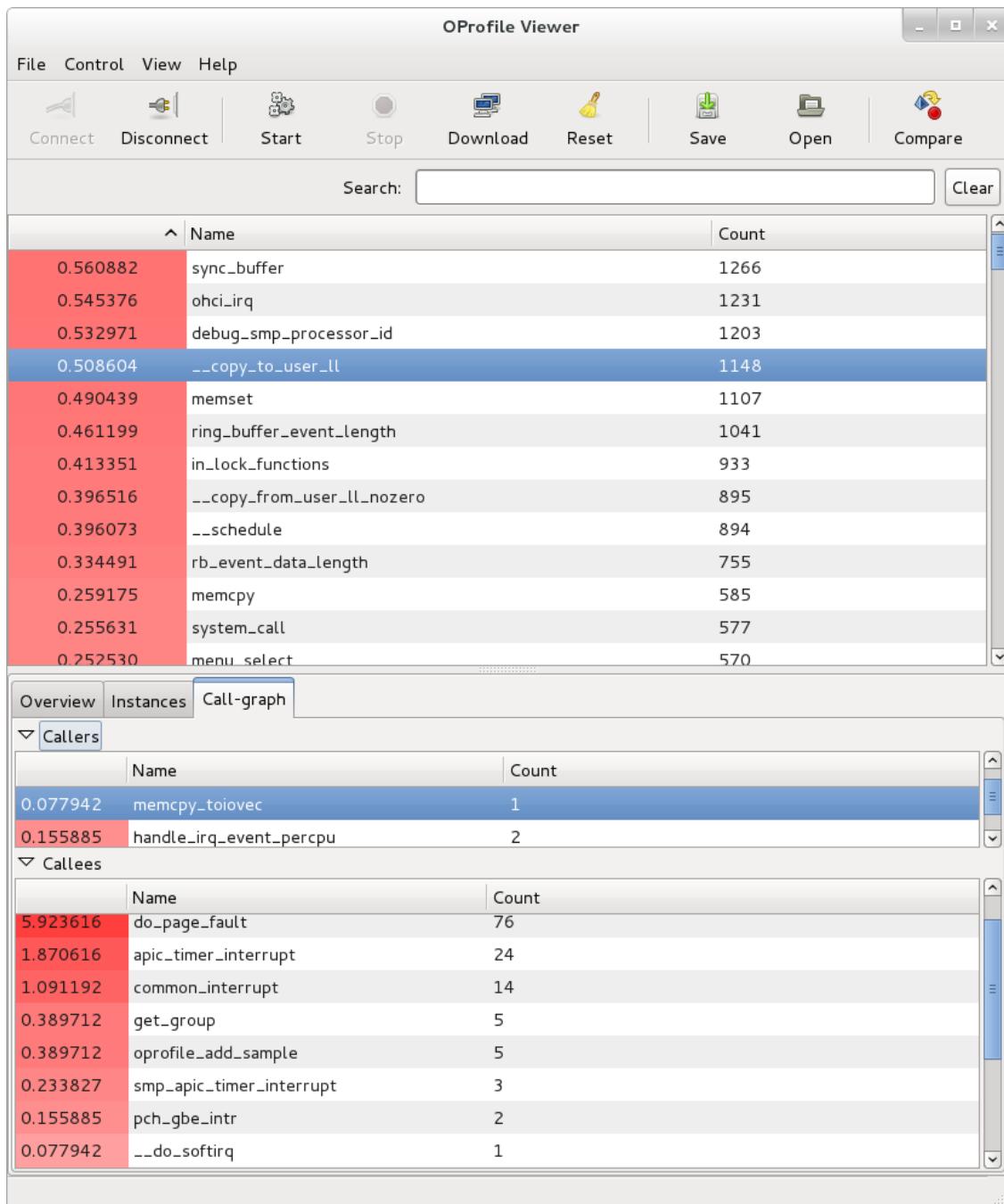
Once the workload completes, press the 'Stop' button. At that point the OProfile viewer will download the profile files it's collected (this may take some time, especially if the kernel was profiled). While it downloads the files, you should see something like the following:



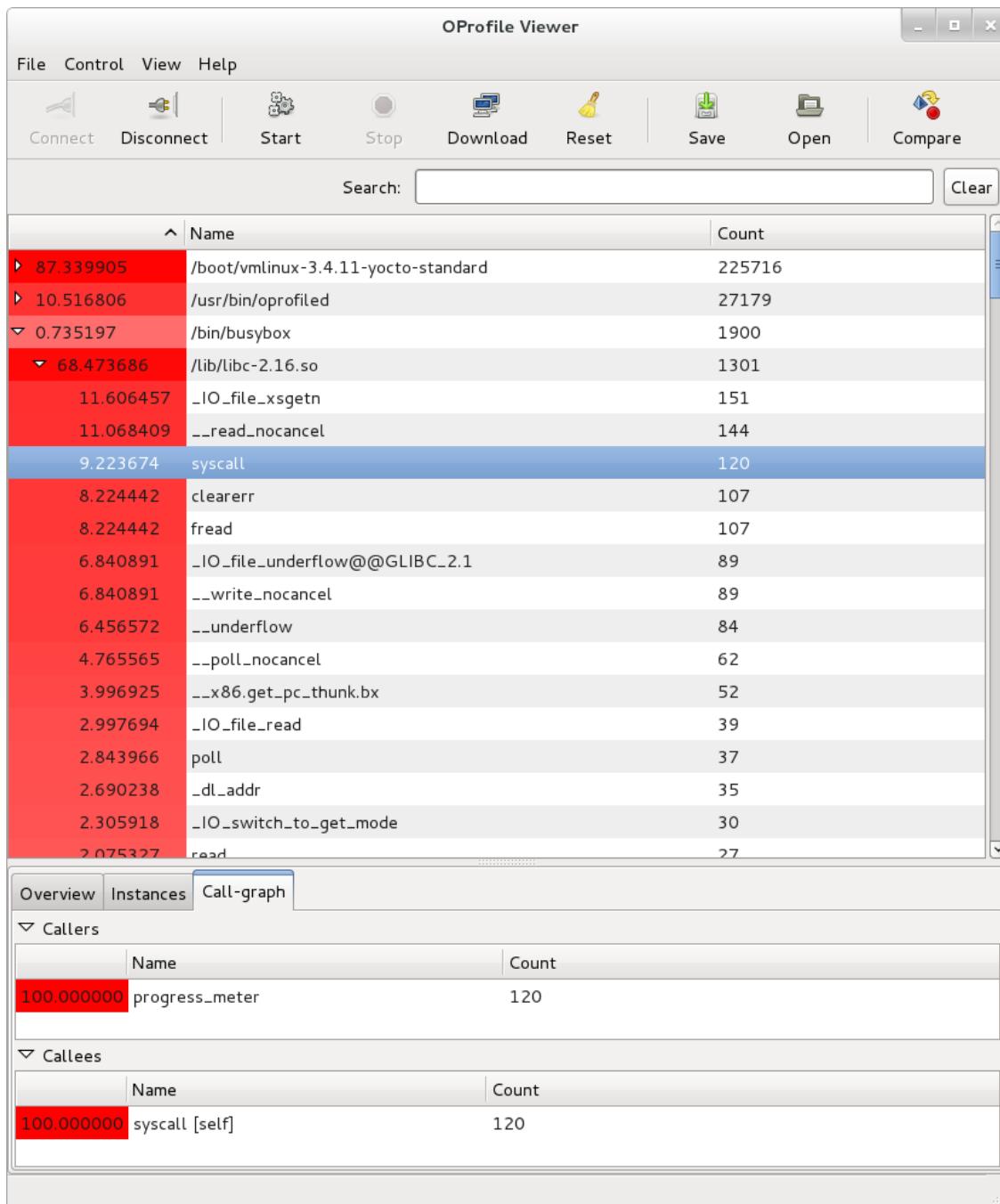
Once the profile files have been retrieved, you should see a list of the processes that were profiled:



If you select one of them, you should see all the symbols that were hit during the profile. Selecting one of them will show a list of callers and callees of the chosen function in two panes below the top pane. For example, here's what we see when we select `__copy_to_user_ll()`:



As another example, we can look at the busybox process and see that the progress meter made a system call:



3.4.4. Documentation

Yocto already has some information on setting up and using OProfile and oprofileui. As this document doesn't cover everything in detail, it may be worth taking a look at the "Profiling with OProfile [<http://www.yoctoproject.org/docs/1.8/dev-manual/dev-manual.html#platdev-oprofile>]" section in the Yocto Project Development Manual

The OProfile manual can be found here: OProfile manual [<http://oprofile.sourceforge.net/doc/index.html>]

The OProfile website contains links to the above manual and bunch of other items including an extensive set of examples: About OProfile [<http://oprofile.sourceforge.net/about/>]

3.5. Sysprof

Sysprof is a very easy to use system-wide profiler that consists of a single window with three panes and a few buttons which allow you to start, stop, and view the profile from one place.

3.5.1. Setup

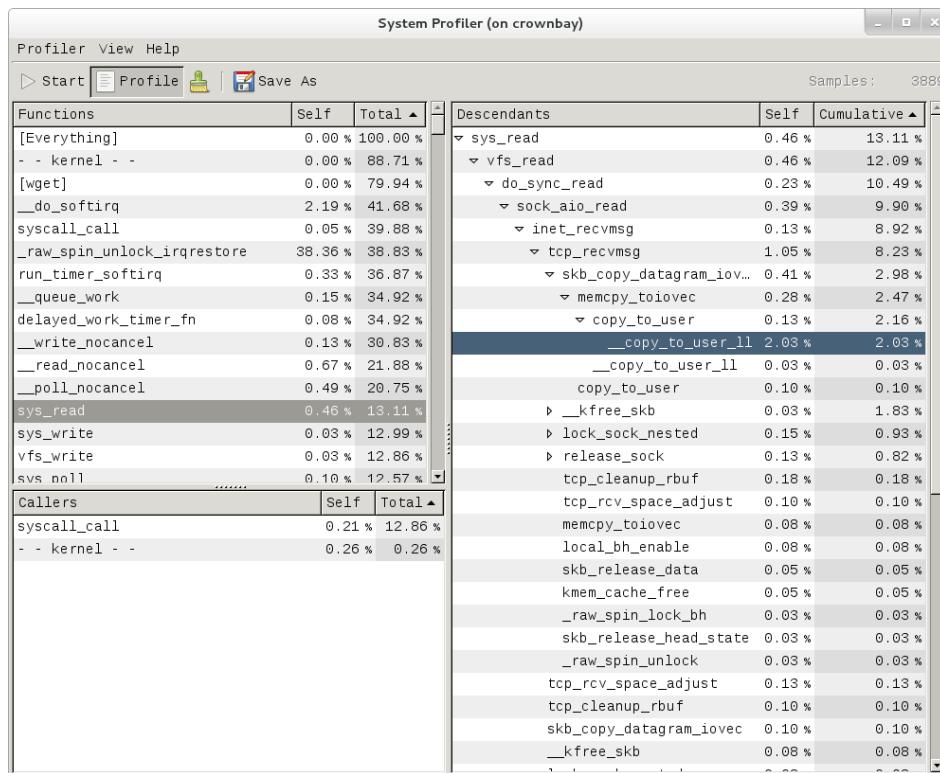
For this section, we'll assume you've already performed the basic setup outlined in the General Setup section.

Sysprof is a GUI-based application that runs on the target system. For the rest of this document we assume you've ssh'd to the host and will be running Sysprof on the target (you can use the '-X' option to ssh and have the Sysprof GUI run on the target but display remotely on the host if you want).

3.5.2. Basic Usage

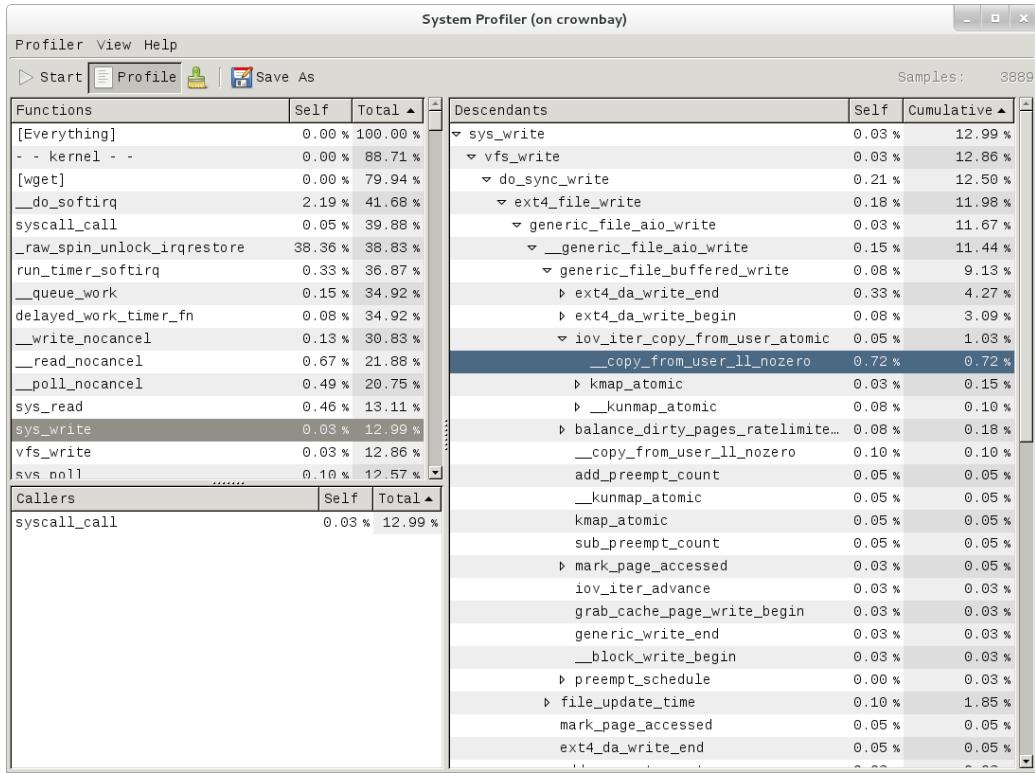
To start profiling the system, you simply press the 'Start' button. To stop profiling and to start viewing the profile data in one easy step, press the 'Profile' button.

Once you've pressed the profile button, the three panes will fill up with profiling data:



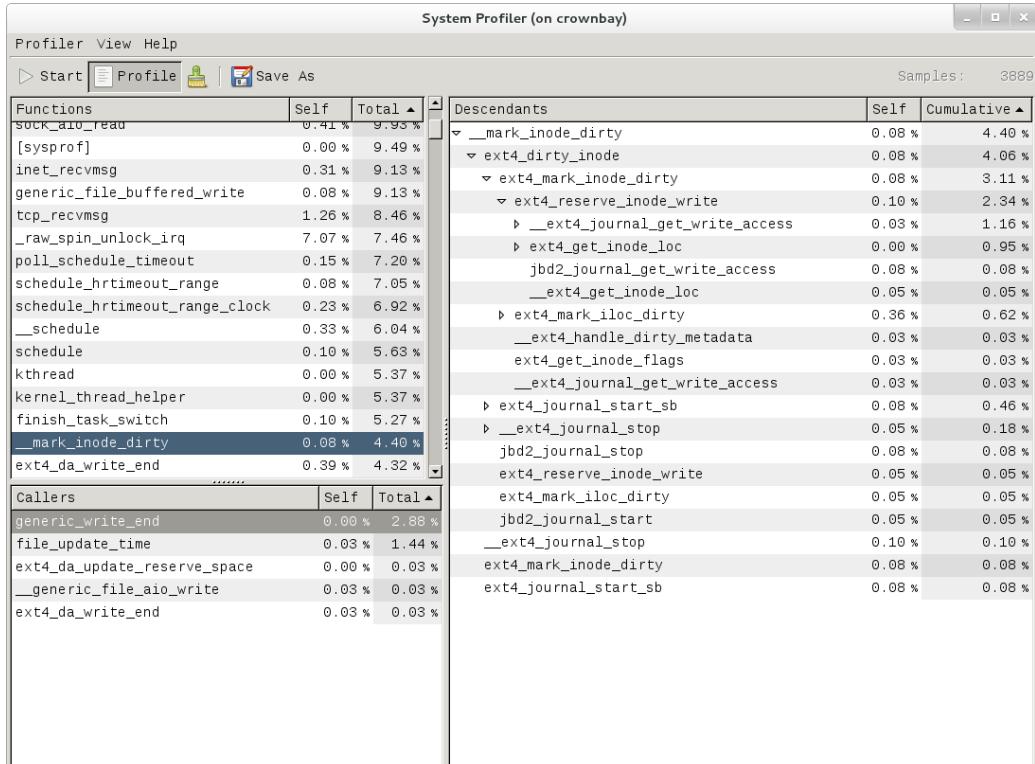
The left pane shows a list of functions and processes. Selecting one of those expands that function in the right pane, showing all its callees. Note that this caller-oriented display is essentially the inverse of perf's default callee-oriented callchain display.

In the screenshot above, we're focusing on `__copy_to_user_ll()` and looking up the callchain we can see that one of the callers of `__copy_to_user_ll` is `sys_read()` and the complete callpath between them. Notice that this is essentially a portion of the same information we saw in the perf display shown in the perf section of this page.



Similarly, the above is a snapshot of the Sysprof display of a copy-from-user callchain.

Finally, looking at the third Sysprof pane in the lower left, we can see a list of all the callers of a particular function selected in the top left pane. In this case, the lower pane is showing all the callers of `_mark_inode_dirty`:



Double-clicking on one of those functions will in turn change the focus to the selected function, and so on.

Tying it Together: If you like sysprof's 'caller-oriented' display, you may be able to approximate it in other tools as well. For example, 'perf report' has the -g (--call-graph) option that you can experiment with; one of the options is 'caller' for an inverted caller-based callgraph display.

3.5.3. Documentation

There doesn't seem to be any documentation for Sysprof, but maybe that's because it's pretty self-explanatory. The Sysprof website, however, is here: Sysprof, System-wide Performance Profiler for Linux [<http://sysprof.com/>]

3.6. LTTng (Linux Trace Toolkit, next generation)

3.6.1. Setup

For this section, we'll assume you've already performed the basic setup outlined in the General Setup section.

LTTng is run on the target system by ssh'ing to it. However, if you want to see the traces graphically, install Eclipse as described in section "Manually copying a trace to the host and viewing it in Eclipse (i.e. using Eclipse without network support)" and follow the directions to manually copy traces to the host and view them in Eclipse (i.e. using Eclipse without network support).

Note

Be sure to download and install/run the 'SR1' or later Juno release of eclipse e.g.: http://www.eclipse.org/downloads/download.php?file=/technology/epp/downloads/release/juno/SR1/eclipse-cpp-juno-SR1-linux-gtk-x86_64.tar.gz

3.6.2. Collecting and Viewing Traces

Once you've applied the above commits and built and booted your image (you need to build the core-image-sato-sdk image or use one of the other methods described in the General Setup section), you're ready to start tracing.

3.6.2.1. Collecting and viewing a trace on the target (inside a shell)

First, from the host, ssh to the target:

```
$ ssh -l root 192.168.1.47
The authenticity of host '192.168.1.47 (192.168.1.47)' can't be established.
RSA key fingerprint is 23:bd:c8:b1:a8:71:52:00:ee:00:4f:64:9e:10:b9:7e.
Are you sure you want to continue connecting (yes/no)? yes
Warning: Permanently added '192.168.1.47' (RSA) to the list of known hosts.
root@192.168.1.47's password:
```

Once on the target, use these steps to create a trace:

```
root@crownbay:~# ltng create
Spawning a session daemon
Session auto-20121015-232120 created.
Traces will be written in /home/root/ltng-traces/auto-20121015-232120
```

Enable the events you want to trace (in this case all kernel events):

```
root@crownbay:~# ltng enable-event --kernel --all
All kernel events are enabled in channel channel0
```

Start the trace:

```
root@crownbay:~# ltng start
Tracing started for session auto-20121015-232120
```

And then stop the trace after awhile or after running a particular workload that you want to trace:

```
root@crownbay:~# ltng stop
Tracing stopped for session auto-20121015-232120
```

You can now view the trace in text form on the target:

```
root@crownbay:~# ltng view
[23:21:56.989270399] (+?.?????????) sys_geteuid: { 1 }, { }
[23:21:56.989278081] (+0.000007682) exit_syscall: { 1 }, { ret = 0 }
[23:21:56.989286043] (+0.000007962) sys_pipe: { 1 }, { fildes = 0xB77B9E8C }
[23:21:56.989321802] (+0.0000035759) exit_syscall: { 1 }, { ret = 0 }
[23:21:56.989329345] (+0.000007543) sys_mmap_pgoff: { 1 }, { addr = 0x0, len = 10485760, prot = 4, flags = 10485760, offset = 0, fd = 1, pgoff = 0 }
[23:21:56.989351694] (+0.0000022349) exit_syscall: { 1 }, { ret = -1247805440 }
[23:21:56.989432989] (+0.0000081295) sys_clone: { 1 }, { clone_flags = 0x411, newsp = 0xB5EFF0, child_tid = 3993865440, parent_tid = 3970832076, newsp2 = 0x0, stack_size = 0 }
[23:21:56.989477129] (+0.0000044140) sched_stat_runtime: { 1 }, { comm = "lttng-consumerd", tid = 3993865440, now = 72156989477129 }
[23:21:56.989486697] (+0.000009568) sched_migrate_task: { 1 }, { comm = "lttng-consumerd", tid = 3993865440, now = 72156989486697 }
[23:21:56.989508418] (+0.0000021721) hrtimer_init: { 1 }, { hrtimer = 3970832076, clockid = 1, now = 72156989508418, function = 0, data = 0 }
[23:21:56.989770462] (+0.000262044) hrtimer_cancel: { 1 }, { hrtimer = 3993865440 }
[23:21:56.989771580] (+0.000001118) hrtimer_cancel: { 0 }, { hrtimer = 3993812192 }
[23:21:56.989776957] (+0.000005377) hrtimer_expire_entry: { 1 }, { hrtimer = 3993865440, now = 72156989776957 }
[23:21:56.989778145] (+0.000001188) hrtimer_expire_entry: { 0 }, { hrtimer = 3993812192, now = 7215698978145 }
[23:21:56.989791695] (+0.000013550) softirq_raise: { 1 }, { vec = 1 }
[23:21:56.989795396] (+0.000003701) softirq_raise: { 0 }, { vec = 1 }
[23:21:56.989800635] (+0.000005239) softirq_raise: { 0 }, { vec = 9 }
[23:21:56.989807130] (+0.000006495) sched_stat_runtime: { 1 }, { comm = "lttng-consumerd", tid = 3993865440, now = 72156989807130 }
[23:21:56.989809993] (+0.000002863) sched_stat_runtime: { 0 }, { comm = "lttng-sessiond", tid = 3993812192, now = 72156989809993 }
[23:21:56.989818514] (+0.000008521) hrtimer_expire_exit: { 0 }, { hrtimer = 3993812192 }
[23:21:56.989819631] (+0.000001117) hrtimer_expire_exit: { 1 }, { hrtimer = 3993865440 }
[23:21:56.989821866] (+0.000002235) hrtimer_start: { 0 }, { hrtimer = 3993812192, function = 0, data = 0 }
[23:21:56.989822984] (+0.000001118) hrtimer_start: { 1 }, { hrtimer = 3993865440, function = 0, data = 0 }
[23:21:56.989832762] (+0.000009778) softirq_entry: { 1 }, { vec = 1 }
[23:21:56.989833879] (+0.000001117) softirq_entry: { 0 }, { vec = 1 }
[23:21:56.989838069] (+0.000004190) timer_cancel: { 1 }, { timer = 3993871956 }
[23:21:56.989839187] (+0.000001118) timer_cancel: { 0 }, { timer = 3993818708 }
[23:21:56.989841492] (+0.000002305) timer_expire_entry: { 1 }, { timer = 3993871956, now = 72156989841492 }
[23:21:56.989842819] (+0.000001327) timer_expire_entry: { 0 }, { timer = 3993818708, now = 72156989842819 }
[23:21:56.989854831] (+0.000012012) sched_stat_runtime: { 1 }, { comm = "lttng-consumerd", tid = 3993865440, now = 72156989854831 }
[23:21:56.989855949] (+0.000001118) sched_stat_runtime: { 0 }, { comm = "lttng-sessiond", tid = 3993812192, now = 72156989855949 }
[23:21:56.989861257] (+0.000005308) sched_stat_sleep: { 1 }, { comm = "kworker/1:1", tid = 21, now = 72156989861257 }
[23:21:56.989862374] (+0.000001117) sched_stat_sleep: { 0 }, { comm = "kworker/0:0", tid = 4, now = 72156989862374 }
[23:21:56.989868241] (+0.000005867) sched_wakeup: { 0 }, { comm = "kworker/0:0", tid = 4, now = 72156989868241 }
[23:21:56.989869358] (+0.000001117) sched_wakeup: { 1 }, { comm = "kworker/1:1", tid = 21, now = 72156989869358 }
[23:21:56.989877460] (+0.000008102) timer_expire_exit: { 1 }, { timer = 3993871956 }
[23:21:56.989878577] (+0.000001117) timer_expire_exit: { 0 }, { timer = 3993818708 }
.
.
.
```

You can now safely destroy the trace session (note that this doesn't delete the trace - it's still there in `~/lttng-traces`):

```
root@crownbay:~# ltng destroy
```

```
Session auto-20121015-232120 destroyed at /home/root
```

Note that the trace is saved in a directory of the same name as returned by 'lttng create', under the `~/lttng-traces` directory (note that you can change this by supplying your own name to 'lttng create'):

```
root@crownbay:~# ls -al ~/lttng-traces
drwxrwx--- 3 root root 1024 Oct 15 23:21 .
drwxr-xr-x 5 root root 1024 Oct 15 23:57 ..
drwxrwx--- 3 root root 1024 Oct 15 23:21 auto-20121015-232120
```

3.6.2.2. Collecting and viewing a userspace trace on the target (inside a shell)

For LTTng userspace tracing, you need to have a properly instrumented userspace program. For this example, we'll use the 'hello' test program generated by the lttng-ust build.

The 'hello' test program isn't installed on the rootfs by the lttng-ust build, so we need to copy it over manually. First cd into the build directory that contains the hello executable:

```
$ cd build/tmp/work/core2_32-poky-linux/lttng-ust/2.0.5-r0/git/tests/hello/.libs
```

Copy that over to the target machine:

```
$ scp hello root@192.168.1.20:
```

You now have the instrumented lttng 'hello world' test program on the target, ready to test.

First, from the host, ssh to the target:

```
$ ssh -l root 192.168.1.47
The authenticity of host '192.168.1.47 (192.168.1.47)' can't be established.
RSA key fingerprint is 23:bd:c8:b1:a8:71:52:00:ee:00:4f:64:9e:10:b9:7e.
Are you sure you want to continue connecting (yes/no)? yes
Warning: Permanently added '192.168.1.47' (RSA) to the list of known hosts.
root@192.168.1.47's password:
```

Once on the target, use these steps to create a trace:

```
root@crownbay:~# lttng create
Session auto-20190303-021943 created.
Traces will be written in /home/root/lttng-traces/auto-20190303-021943
```

Enable the events you want to trace (in this case all userspace events):

```
root@crownbay:~# lttng enable-event --userspace --all
All UST events are enabled in channel channel0
```

Start the trace:

```
root@crownbay:~# lttng start
```

```
Tracing started for session auto-20190303-021943
```

Run the instrumented hello world program:

```
root@crownbay:~# ./hello
Hello, World!
Tracing... done.
```

And then stop the trace after awhile or after running a particular workload that you want to trace:

```
root@crownbay:~# ltng stop
Tracing stopped for session auto-20190303-021943
```

You can now view the trace in text form on the target:

```
root@crownbay:~# ltng view
[02:31:14.906146544] (+?.?????????) hello:1424 ust_tests_hello:tptest: { cpu_id = 1 }, { int
[02:31:14.906170360] (+0.000023816) hello:1424 ust_tests_hello:tptest: { cpu_id = 1 }, { int
[02:31:14.906183140] (+0.000012780) hello:1424 ust_tests_hello:tptest: { cpu_id = 1 }, { int
[02:31:14.906194385] (+0.000011245) hello:1424 ust_tests_hello:tptest: { cpu_id = 1 }, { int
.
.
.
```

You can now safely destroy the trace session (note that this doesn't delete the trace - it's still there in `~/ltng-traces`):

```
root@crownbay:~# ltng destroy
Session auto-20190303-021943 destroyed at /home/root
```

3.6.2.3. Manually copying a trace to the host and viewing it in Eclipse (i.e. using Eclipse without network support)

If you already have an LTTng trace on a remote target and would like to view it in Eclipse on the host, you can easily copy it from the target to the host and import it into Eclipse to view it using the LTTng Eclipse plug-in already bundled in the Eclipse (Juno SR1 or greater).

Using the trace we created in the previous section, archive it and copy it to your host system:

```
root@crownbay:~/ltng-traces# tar zcvf auto-20121015-232120.tar.gz auto-20121015-232120
auto-20121015-232120/
auto-20121015-232120/kernel/
auto-20121015-232120/kernel/metadata
auto-20121015-232120/kernel/channel0_1
auto-20121015-232120/kernel/channel0_0

$ scp root@192.168.1.47:ltng-traces/auto-20121015-232120.tar.gz .
root@192.168.1.47's password:
auto-20121015-232120.tar.gz
100% 1566KB 1.5MB/
```

Unarchive it on the host:

```
$ gunzip -c auto-20121015-232120.tar.gz | tar xvf -
auto-20121015-232120/
auto-20121015-232120/kernel/
auto-20121015-232120/kernel/metadata
auto-20121015-232120/kernel/channel0_1
auto-20121015-232120/kernel/channel0_0
```

We can now import the trace into Eclipse and view it:

1. First, start eclipse and open the 'LTTng Kernel' perspective by selecting the following menu item:

Window | Open Perspective | Other...

2. In the dialog box that opens, select 'LTTng Kernel' from the list.

3. Back at the main menu, select the following menu item:

File | New | Project...

4. In the dialog box that opens, select the 'Tracing | Tracing Project' wizard and press 'Next>'.

5. Give the project a name and press 'Finish'.

6. In the 'Project Explorer' pane under the project you created, right click on the 'Traces' item.

7. Select 'Import...' and in the dialog that's displayed:

8. Browse the filesystem and find the select the 'kernel' directory containing the trace you copied from the target e.g. auto-20121015-232120/kernel

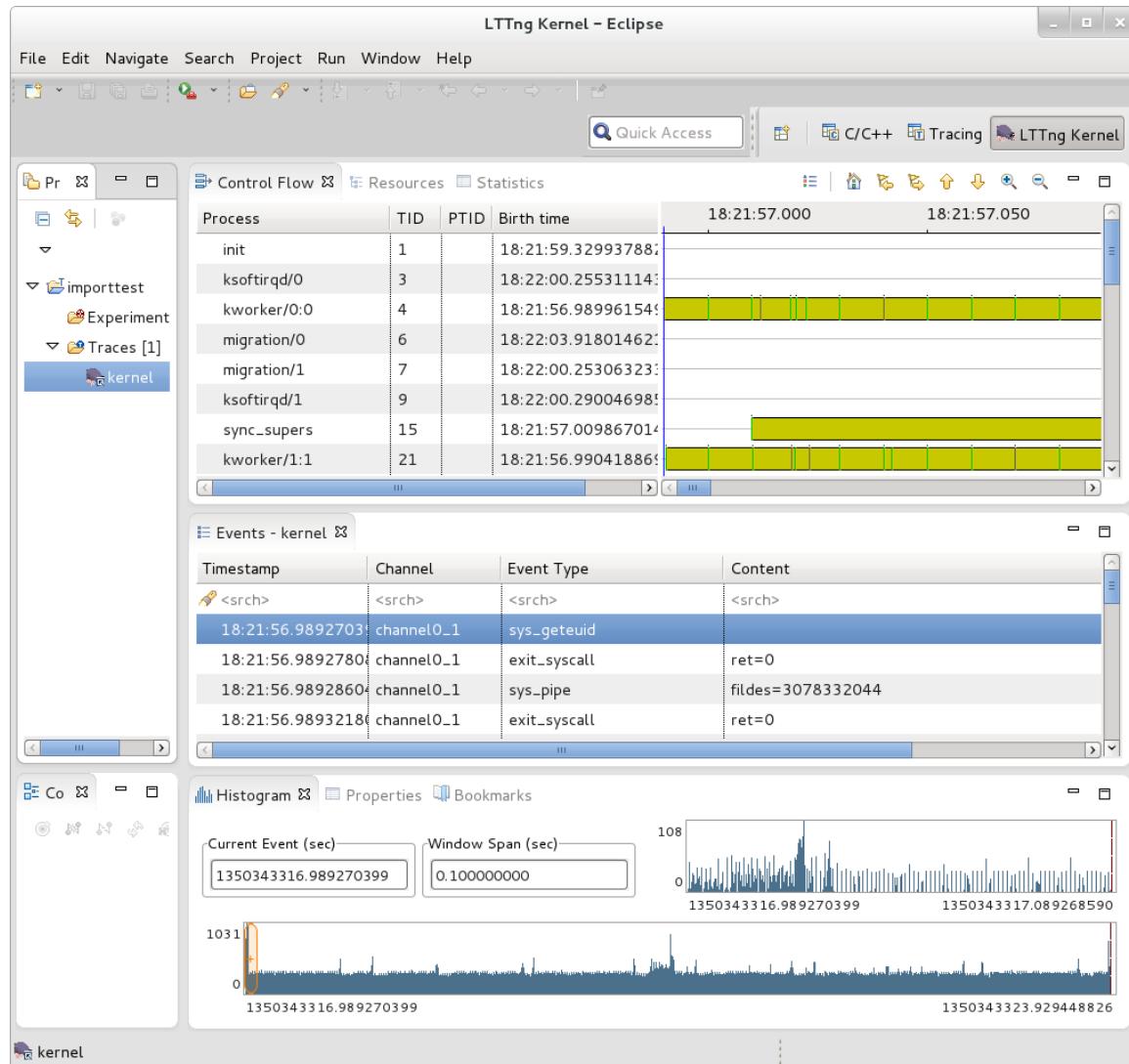
9. 'Checkmark' the directory in the tree that's displayed for the trace

10Below that, select 'Common Trace Format: Kernel Trace' for the 'Trace Type'

11Press 'Finish' to close the dialog

12Back in the 'Project Explorer' pane, double-click on the 'kernel' item for the trace you just imported under 'Traces'

You should now see your trace data displayed graphically in several different views in Eclipse:



You can access extensive help information on how to use the LTTng plug-in to search and analyze captured traces via the Eclipse help system:

[Help](#) | [Help Contents](#) | [LTTng Plug-in User Guide](#)

3.6.2.4. Collecting and viewing a trace in Eclipse

Note

This section on collecting traces remotely doesn't currently work because of Eclipse 'RSE' connectivity problems. Manually tracing on the target, copying the trace files to the host, and viewing the trace in Eclipse on the host as outlined in previous steps does work however - please use the manual steps outlined above to view traces in Eclipse.

In order to trace a remote target, you also need to add a 'tracing' group on the target and connect as a user who's part of that group e.g:

```
# adduser tomz
# groupadd -r tracing
# usermod -a -G tracing tomz
```

1. First, start eclipse and open the 'LTTng Kernel' perspective by selecting the following menu item:

Window | Open Perspective | Other...

2. In the dialog box that opens, select 'LTTng Kernel' from the list.

3. Back at the main menu, select the following menu item:

File | New | Project...

4. In the dialog box that opens, select the 'Tracing | Tracing Project' wizard and press 'Next>'.

5. Give the project a name and press 'Finish'. That should result in an entry in the 'Project' subwindow.

6. In the 'Control' subwindow just below it, press 'New Connection'.

7. Add a new connection, giving it the hostname or IP address of the target system.

8. Provide the username and password of a qualified user (a member of the 'tracing' group) or root account on the target system.

9. Provide appropriate answers to whatever else is asked for e.g. 'secure storage password' can be anything you want. If you get an 'RSE Error' it may be due to proxies. It may be possible to get around the problem by changing the following setting:

Window | Preferences | Network Connections

Switch 'Active Provider' to 'Direct'

3.6.3. Documentation

You can find the primary LTTng Documentation on the LTTng Documentation [<https://lttng.org/docs/>] site. The documentation on this site is appropriate for intermediate to advanced software developers who are working in a Linux environment and are interested in efficient software tracing.

For information on LTTng in general, visit the LTTng Project [<http://lttng.org/lttng2.0>] site. You can find a "Getting Started" link on this site that takes you to an LTTng Quick Start.

Finally, you can access extensive help information on how to use the LTTng plug-in to search and analyze captured traces via the Eclipse help system:

Help | Help Contents | LTTng Plug-in User Guide

3.7. blktrace

blktrace is a tool for tracing and reporting low-level disk I/O. blktrace provides the tracing half of the equation; its output can be piped into the blkparse program, which renders the data in a human-readable form and does some basic analysis:

3.7.1. Setup

For this section, we'll assume you've already performed the basic setup outlined in the "General Setup" section.

blktrace is an application that runs on the target system. You can run the entire blktrace and blkparse pipeline on the target, or you can run blktrace in 'listen' mode on the target and have blktrace and blkparse collect and analyze the data on the host (see the "Using blktrace Remotely" section below). For the rest of this section we assume you've ssh'ed to the host and will be running blktrace on the target.

3.7.2. Basic Usage

To record a trace, simply run the 'blktrace' command, giving it the name of the block device you want to trace activity on:

```
root@crownbay:~# blktrace /dev/sdc
```

In another shell, execute a workload you want to trace.

```
root@crownbay:/media/sdc# rm linux-2.6.19.2.tar.bz2; wget http://downloads.yoctoproject.org/Connecting to downloads.yoctoproject.org (140.211.169.59:80)linux-2.6.19.2.tar.b 100% |*****| 41727k 0:00:00 ETA
```

Press `Ctrl-C` in the `blktrace` shell to stop the trace. It will display how many events were logged, along with the per-cpu file sizes (`blktrace` records traces in per-cpu kernel buffers and simply dumps them to userspace for `blkparse` to merge and sort later).

```
^C== sdc ==
CPU 0:          7082 events,      332 KiB data
CPU 1:          1578 events,      74 KiB data
Total:         8660 events (dropped 0),      406 KiB data
```

If you examine the files saved to disk, you see multiple files, one per CPU and with the device name as the first part of the filename:

```
root@crownbay:~# ls -al
drwxr-xr-x  6 root  root  1024 Oct 27 22:39 .
drwxr-sr-x  4 root  root  1024 Oct 26 18:24 ..
-rw-r--r--  1 root  root 339938 Oct 27 22:40 sdc.blktrace.0
-rw-r--r--  1 root  root  75753 Oct 27 22:40 sdc.blktrace.1
```

To view the trace events, simply invoke 'blkparse' in the directory containing the trace files, giving it the device name that forms the first part of the filenames:

```
root@crownbay:~# blkparse sdc
```

```
8,32 1 1 0.0000000000 1225 Q WS 3417048 + 8 [jbd2/sdc-8]
8,32 1 2 0.000025213 1225 G WS 3417048 + 8 [jbd2/sdc-8]
8,32 1 3 0.000033384 1225 P N [jbd2/sdc-8]
8,32 1 4 0.000043301 1225 I WS 3417048 + 8 [jbd2/sdc-8]
8,32 1 0 0.000057270 0 m N cfq1225 insert_request
8,32 1 0 0.000064813 0 m N cfq1225 add_to_rr
8,32 1 5 0.000076336 1225 U N [jbd2/sdc-8] 1
8,32 1 0 0.000088559 0 m N cfq workload slice:150
8,32 1 0 0.000097359 0 m N cfq1225 set_active wl_prio:0 wl_type:1
8,32 1 0 0.000104063 0 m N cfq1225 Not idling. st->count:1
8,32 1 0 0.000112584 0 m N cfq1225 fifo= (null)
8,32 1 0 0.000118730 0 m N cfq1225 dispatch_insert
8,32 1 0 0.000127390 0 m N cfq1225 dispatched a request
8,32 1 0 0.000133536 0 m N cfq1225 activate rq, drv=1
8,32 1 6 0.000136889 1225 D WS 3417048 + 8 [jbd2/sdc-8]
8,32 1 7 0.000360381 1225 Q WS 3417056 + 8 [jbd2/sdc-8]
8,32 1 8 0.000377422 1225 G WS 3417056 + 8 [jbd2/sdc-8]
8,32 1 9 0.000388876 1225 P N [jbd2/sdc-8]
8,32 1 10 0.000397886 1225 Q WS 3417064 + 8 [jbd2/sdc-8]
8,32 1 11 0.000404800 1225 M WS 3417064 + 8 [jbd2/sdc-8]
8,32 1 12 0.000412343 1225 Q WS 3417072 + 8 [jbd2/sdc-8]
8,32 1 13 0.000416533 1225 M WS 3417072 + 8 [jbd2/sdc-8]
```

```

8,32 1 14 0.000422121 1225 Q WS 3417080 + 8 [jbd2/sdc-8]
8,32 1 15 0.000425194 1225 M WS 3417080 + 8 [jbd2/sdc-8]
8,32 1 16 0.000431968 1225 Q WS 3417088 + 8 [jbd2/sdc-8]
8,32 1 17 0.000435251 1225 M WS 3417088 + 8 [jbd2/sdc-8]
8,32 1 18 0.000440279 1225 Q WS 3417096 + 8 [jbd2/sdc-8]
8,32 1 19 0.000443911 1225 M WS 3417096 + 8 [jbd2/sdc-8]
8,32 1 20 0.000450336 1225 Q WS 3417104 + 8 [jbd2/sdc-8]
8,32 1 21 0.000454038 1225 M WS 3417104 + 8 [jbd2/sdc-8]
8,32 1 22 0.000462070 1225 Q WS 3417112 + 8 [jbd2/sdc-8]
8,32 1 23 0.000465422 1225 M WS 3417112 + 8 [jbd2/sdc-8]
8,32 1 24 0.000474222 1225 I WS 3417056 + 64 [jbd2/sdc-8]
8,32 1 0 0.000483022 0 m N cfq1225 insert_request
8,32 1 25 0.000489727 1225 U N [jbd2/sdc-8] 1
8,32 1 0 0.000498457 0 m N cfq1225 Not idling. st->count:1
8,32 1 0 0.000503765 0 m N cfq1225 dispatch_insert
8,32 1 0 0.000512914 0 m N cfq1225 dispatched a request
8,32 1 0 0.000518851 0 m N cfq1225 activate rq, drv=2
.
.
.
8,32 0 0 58.515006138 0 m N cfq3551 complete rqnoidle 1
8,32 0 2024 58.516603269 3 C WS 3156992 + 16 [0]
8,32 0 0 58.516626736 0 m N cfq3551 complete rqnoidle 1
8,32 0 0 58.516634558 0 m N cfq3551 arm_idle: 8 group_idle: 0
8,32 0 0 58.516636933 0 m N cfq schedule dispatch
8,32 1 0 58.516971613 0 m N cfq3551 slice expired t=0
8,32 1 0 58.516982089 0 m N cfq3551 sl_used=13 disp=6 charge=13 iops=0 s
8,32 1 0 58.516985511 0 m N cfq3551 del_from_rr
8,32 1 0 58.516990819 0 m N cfq3551 put_queue

CPU0 (sdc):
Reads Queued: 0, 0KiB Writes Queued: 331, 26,284KiB
Read Dispatches: 0, 0KiB Write Dispatches: 485, 40,484KiB
Reads Requeued: 0 Writes Requeued: 0
Reads Completed: 0, 0KiB Writes Completed: 511, 41,000KiB
Read Merges: 0, 0KiB Write Merges: 13, 160KiB
Read depth: 0 Write depth: 2
IO unplugs: 23 Timer unplugs: 0

CPU1 (sdc):
Reads Queued: 0, 0KiB Writes Queued: 249, 15,800KiB
Read Dispatches: 0, 0KiB Write Dispatches: 42, 1,600KiB
Reads Requeued: 0 Writes Requeued: 0
Reads Completed: 0, 0KiB Writes Completed: 16, 1,084KiB
Read Merges: 0, 0KiB Write Merges: 40, 276KiB
Read depth: 0 Write depth: 2
IO unplugs: 30 Timer unplugs: 1

Total (sdc):
Reads Queued: 0, 0KiB Writes Queued: 580, 42,084KiB
Read Dispatches: 0, 0KiB Write Dispatches: 527, 42,084KiB
Reads Requeued: 0 Writes Requeued: 0
Reads Completed: 0, 0KiB Writes Completed: 527, 42,084KiB
Read Merges: 0, 0KiB Write Merges: 53, 436KiB
IO unplugs: 53 Timer unplugs: 1

```

Throughput (R/W): 0KiB/s / 719KiB/s
 Events (sdc): 6,592 entries
 Skips: 0 forward (0 - 0.0%)
 Input file sdc.blktrace.0 added
 Input file sdc.blktrace.1 added

The report shows each event that was found in the blktrace data, along with a summary of the overall block I/O traffic during the run. You can look at the blkparse [http://linux.die.net/man/1/blkparse] manpage to learn the meaning of each field displayed in the trace listing.

3.7.2.1. Live Mode

blktrace and blkparse are designed from the ground up to be able to operate together in a 'pipe mode' where the stdout of blktrace can be fed directly into the stdin of blkparse:

```
root@crownbay:~# blktrace /dev/sdc -o - | blkparse -i -
```

This enables long-lived tracing sessions to run without writing anything to disk, and allows the user to look for certain conditions in the trace data in 'real-time' by viewing the trace output as it scrolls by on the screen or by passing it along to yet another program in the pipeline such as grep which can be used to identify and capture conditions of interest.

There's actually another blktrace command that implements the above pipeline as a single command, so the user doesn't have to bother typing in the above command sequence:

```
root@crownbay:~# btrace /dev/sdc
```

3.7.2.2. Using blktrace Remotely

Because blktrace traces block I/O and at the same time normally writes its trace data to a block device, and in general because it's not really a great idea to make the device being traced the same as the device the tracer writes to, blktrace provides a way to trace without perturbing the traced device at all by providing native support for sending all trace data over the network.

To have blktrace operate in this mode, start blktrace on the target system being traced with the -l option, along with the device to trace:

```
root@crownbay:~# blktrace -l /dev/sdc
server: waiting for connections...
```

On the host system, use the -h option to connect to the target system, also passing it the device to trace:

```
$ blktrace -d /dev/sdc -h 192.168.1.43
blktrace: connecting to 192.168.1.43
blktrace: connected!
```

On the target system, you should see this:

```
server: connection from 192.168.1.43
```

In another shell, execute a workload you want to trace.

```
root@crownbay:/media/sdc# rm linux-2.6.19.2.tar.bz2; wget http://downloads.yoctoproject.org/
Connecting to downloads.yoctoproject.org (140.211.169.59:80)
linux-2.6.19.2.tar.b 100% |*****| 41727k 0:00:00 ETA
```

When it's done, do a Ctrl-C on the host system to stop the trace:

```
^C== sdc ==
```

```
CPU 0:          7691 events,      361 KiB data
CPU 1:          4109 events,      193 KiB data
Total:         11800 events (dropped 0),      554 KiB data
```

On the target system, you should also see a trace summary for the trace just ended:

```
server: end of run for 192.168.1.43:sdc
==== sdc ====
CPU 0:          7691 events,      361 KiB data
CPU 1:          4109 events,      193 KiB data
Total:         11800 events (dropped 0),      554 KiB data
```

The blktrace instance on the host will save the target output inside a hostname-timestamp directory:

```
$ ls -al
drwxr-xr-x  10 root      root          1024 Oct 28 02:40 .
drwxr-sr-x   4 root      root          1024 Oct 26 18:24 ..
drwxr-xr-x   2 root      root          1024 Oct 28 02:40 192.168.1.43-2012-10-28-02:40:56
```

cd into that directory to see the output files:

```
$ ls -l
-rw-r--r--  1 root      root      369193 Oct 28 02:44 sdc.blktrace.0
-rw-r--r--  1 root      root      197278 Oct 28 02:44 sdc.blktrace.1
```

And run blkparse on the host system using the device name:

```
$ blkparse sdc
8,32  1      1      0.0000000000  1263  Q  RM 6016 + 8 [ls]
8,32  1      0      0.000036038   0  m  N cfq1263 alloced
8,32  1      2      0.000039390  1263  G  RM 6016 + 8 [ls]
8,32  1      3      0.000049168  1263  I  RM 6016 + 8 [ls]
8,32  1      0      0.000056152   0  m  N cfq1263 insert_request
8,32  1      0      0.000061600   0  m  N cfq1263 add_to_rr
8,32  1      0      0.000075498   0  m  N cfq workload slice:300
.
.
.
8,32  0      0      177.266385696   0  m  N cfq1267 arm_idle: 8 group_idle: 0
8,32  0      0      177.266388140   0  m  N cfq schedule dispatch
8,32  1      0      177.266679239   0  m  N cfq1267 slice expired t=0
8,32  1      0      177.266689297   0  m  N cfq1267 sl_used=9 disp=6 charge=9 iops=0 sec
8,32  1      0      177.266692649   0  m  N cfq1267 del_from_rr
8,32  1      0      177.266696560   0  m  N cfq1267 put_queue

CPU0 (sdc):
Reads Queued:      0,      0KiB  Writes Queued:      270,  21,708KiB
Read Dispatches:  59,  2,628KiB  Write Dispatches:  495, 39,964KiB
Reads Requeued:      0  Writes Requeued:      0
Reads Completed:  90,  2,752KiB  Writes Completed:  543, 41,596KiB
Read Merges:        0,      0KiB  Write Merges:        9,   344KiB
Read depth:          2      Write depth:          2
IO unplugs:        20      Timer unplugs:        1

CPU1 (sdc):
Reads Queued:  688,  2,752KiB  Writes Queued:  381, 20,652KiB
Read Dispatches: 31,  124KiB  Write Dispatches:  59,  2,396KiB
Reads Requeued:      0  Writes Requeued:      0
```

```

Reads Completed:      0,      0KiB  Writes Completed:      11,      764KiB
Read Merges:          598,    2,392KiB  Write Merges:          88,      448KiB
Read depth:           2       Write depth:           2
IO unplugs:          52       Timer unplugs:         0

Total (sdc):
Reads Queued:        688,    2,752KiB  Writes Queued:        651,    42,360KiB
Read Dispatches:      90,     2,752KiB  Write Dispatches:      554,    42,360KiB
Reads Requeued:       0       Writes Requeued:       0
Reads Completed:      90,     2,752KiB  Writes Completed:      554,    42,360KiB
Read Merges:          598,    2,392KiB  Write Merges:          97,      792KiB
IO unplugs:          72       Timer unplugs:         1

Throughput (R/W): 15KiB/s / 238KiB/s
Events (sdc): 9,301 entries
Skips: 0 forward (0 - 0.0%)

```

You should see the trace events and summary just as you would have if you'd run the same command on the target.

3.7.2.3. Tracing Block I/O via 'ftrace'

It's also possible to trace block I/O using only trace events subsystem, which can be useful for casual tracing if you don't want to bother dealing with the userspace tools.

To enable tracing for a given device, use `/sys/block/xxx/trace/enable`, where `xxx` is the device name. This for example enables tracing for `/dev/sdc`:

```
root@crownbay:/sys/kernel/debug/tracing# echo 1 > /sys/block/sdc/trace/enable
```

Once you've selected the device(s) you want to trace, selecting the 'blk' tracer will turn the blk tracer on:

```
root@crownbay:/sys/kernel/debug/tracing# cat available_tracers
blk function_graph function nop

root@crownbay:/sys/kernel/debug/tracing# echo blk > current_tracer
```

Execute the workload you're interested in:

```
root@crownbay:/sys/kernel/debug/tracing# cat /media/sdc/testfile.txt
```

And look at the output (note here that we're using 'trace_pipe' instead of trace to capture this trace - this allows us to wait around on the pipe for data to appear):

```
root@crownbay:/sys/kernel/debug/tracing# cat trace_pipe
cat-3587 [001] d..1 3023.276361: 8,32 Q  R 1699848 + 8 [cat]
cat-3587 [001] d..1 3023.276410: 8,32 m  N cfq3587 alloco
cat-3587 [001] d..1 3023.276415: 8,32 G  R 1699848 + 8 [cat]
cat-3587 [001] d..1 3023.276424: 8,32 P  N [cat]
cat-3587 [001] d..2 3023.276432: 8,32 I  R 1699848 + 8 [cat]
cat-3587 [001] d..1 3023.276439: 8,32 m  N cfq3587 insert_request
cat-3587 [001] d..1 3023.276445: 8,32 m  N cfq3587 add_to_rr
cat-3587 [001] d..2 3023.276454: 8,32 U  N [cat] 1
cat-3587 [001] d..1 3023.276464: 8,32 m  N cfq workload slice:150
cat-3587 [001] d..1 3023.276471: 8,32 m  N cfq3587 set_active wl_prio:0 w
cat-3587 [001] d..1 3023.276478: 8,32 m  N cfq3587 fifo= (null)
cat-3587 [001] d..1 3023.276483: 8,32 m  N cfq3587 dispatch_insert
```

```
cat-3587 [001] d..1 3023.276490: 8,32 m N cfq3587 dispatched a request
cat-3587 [001] d..1 3023.276497: 8,32 m N cfq3587 activate rq, drv=1
cat-3587 [001] d..2 3023.276500: 8,32 D R 1699848 + 8 [cat]
```

And this turns off tracing for the specified device:

```
root@crownbay:/sys/kernel/debug/tracing# echo 0 > /sys/block/sdc/trace/enable
```

3.7.3. Documentation

Online versions of the man pages for the commands discussed in this section can be found here:

- <http://linux.die.net/man/8/blktrace>
- <http://linux.die.net/man/1/blkparse>
- <http://linux.die.net/man/8/btracing>

The above manpages, along with manpages for the other blktrace utilities (btt, blkiomon, etc) can be found in the /doc directory of the blktrace tools git repo:

```
$ git clone git://git.kernel.dk/blktrace.git
```

Chapter 4. Real-World Examples

This chapter contains real-world examples.

4.1. Slow Write Speed on Live Images

In one of our previous releases (denzil), users noticed that booting off of a live image and writing to disk was noticeably slower. This included the boot itself, especially the first one, since first boots tend to do a significant amount of writing due to certain post-install scripts.

The problem (and solution) was discovered by using the Yocto tracing tools, in this case 'perf stat', 'perf script', 'perf record' and 'perf report'.

See all the unvarnished details of how this bug was diagnosed and solved here: [Yocto Bug #3049](#)