What's More in Tracing with LTTng

The next big step is to trace userspace applications and understand how to view the overwhelming trace information easily using some GUI tools. Read on to dive deeper into tracing.

In the article that appeared in the March 2014 issue of *OSFY*, I introduced tracing and, more specifically, LTTng. I included a small section towards the end in which you could generate a small kernel trace. Now, it's time to have a look at more advanced use cases. In this article, I will introduce LTTng for tracing applications in userspace. Eventually, we'll discuss how to use the power of the Eclipse Tracing and Monitoring Framework (TMF) and other tools to gather information from combined userspace and kernel traces, using a real life example.

Userspace tracing with LTTng

If you remember, we enabled tracepoint in the kernel the last time, and gathered data and information about this. What if you wanted to trace specific 'points' in your application at the userspace level, at the same blazingly fast speed! As an example, consider that you want to know how much time a *handle_newconnect()* call takes in your Web server and how it interacts with the system. Or maybe you wish to know why the APT (package manager for Debian/Ubuntu) takes so much time installing your package? (*Hint:* It blocks for about 37 per cent of total elapsed time. But why, and where?)

Before we find the answers to all those questions, let us look at the *thttpd* Web server. Let us first make it ready for LTTng/UST-the userspace tracing library of LTTng. The first step is inserting a tracepoint function call in a specific function in the *thttpd* source. This is known as *instrumenting* the application. For that we need something called the *tracepoint provider*.

Let's start by adding the tracepoint call in our target function-*handle_newconnect()*. I have created my own repos of clean and instrumented versions with minor edits (which allow it to get compiled properly), but original versions can be found on *http://www.acme.com* (Jef Poskanzer).

```
wget http://step.polymtl.ca/~suchakra/osfy/thttpd-clean.tar.gz
tar -xvf thttpd-clean.tar.gz && cd  thttpd-clean
```

For instrumenting the function, there are three basic steps. These are given below.

Tracepoint declaration

First, prepare the *tracepoint provider* header: This provides a tracepoint declaration in which you can specify the tracepoint provider (TP) name, arguments, payload variable types, fields and expressions. Refer to the *lttng-ust man* page for detailed field types that you can use. Some examples are *ctf_integer, ctf_float* and *ctf_string*. The *TRACEPOINT_EVENT* macro sets everything up for you once you specify the arguments. We can create this header for our tracepoint and name it as *thttpd_tp_provider.h*

```
/*
 *  thttpd_tp_provider.h
 */

#undef TRACEPOINT_PROVIDER
#define TRACEPOINT_PROVIDER thttpd

#undef TRACEPOINT_INCLUDE_FILE
#define TRACEPOINT_INCLUDE_FILE ./thttpd_tp_provider.h

#ifdef __cplusplus
#extern "C"{
#endif /*__cplusplus */

#if !defined(_THTTPD_PROVIDER_H) || defined(TRACEPOINT_HEADER_
MULTI_READ)
#define _THTTPD_PROVIDER_H
#include <lttng/tracepoint.h>
TRACEPOINT_EVENT(
     thttpd,                         /* tracepoint provider
name */
     count,                          /* tracepoint name */
     TP_ARGS(int, var),
     TP_FIELDS( ctf_integer(int, count, var))
)
#endif /* _THTTPD_PROVIDER_H */

#include <lttng/tracepoint-event.h>

#ifdef __cplusplus
}
#endif /*__cplusplus */
```

We also need to create a C file in which *TRACEPOINT_CREATE_PROBES* is defined. This will get the trace probes ready.

```
/*
 *  thttpd_tp.c
 */
#define TRACEPOINT_CREATE_PROBES
#include "thttpd_tp_provider.h"
```

Tracepoint call

The next step is to add the tracepoint to the target function. Insert the following lines in *thttpd.c* above the *main()*:

```
#define TRACEPOINT_DEFINE
#include "thttpd_tp_provider.h"
```

Insert the tracepoint functions inside the *handle_newconnect()* body. I choose to put it in such a way as to keep track of the *http_conn_count* while I trace.

```
handle_newconnect(struct timeval *tvP, int listen_fd)
{
.
.
.
       }
       c->hc->initialized = 0;
       ++httpd_conn_count;

       /* tracepoint with a payload as the connection count
*/
       tracepoint(thttpd, count, httpd_conn_count);
     }
     /* Get the connection. */
     switch (httpd_get_conn(hs, listen_fd, c->hc)) {
.
.
.
}
```

Building it all

Once this is done, add the *thttpd_tp.c* file to the SRC variable in *Makefile.in*, and add *lttng-ust* library and *libdl* to the linking process while building the source.

```
export LDFLAGS="-ldl -llttng-ust"
./configure
make
```

Now you have completed the instrumentation phase of the application. Whenever this instrumented *thttpd* starts, it will register itself to *lttng-sessiond* so that traces can be seamlessly written to the tracebuffer.

To make *thttpd* run, we will need a *config* file (which *thttpd* does not provide by default). Here is *config* from the official *thttpd* Fedora package:

```
# Save this as thttpd.conf
dir=/var/www/thttpd
chroot
user=thttpd         # default = nobody
logfile=/var/log/thttpd.log
pidfile=/var/run/thttpd.pid
```

I have prepared a version of *thttpd* for you that contains the above instrumentation as well as the *thttpd.conf*. You will need the *conf* file to start *thttpd* successfully in the next section. Get it from *http://step.polymtl.ca/~suchakra/osfy/thttpd-instrumented.tar.gz*

Start tracing

So now you are all set! Let's start our usual tracing routine. It's similar to kernel tracing.

```
$ lttng create osfy-thttpd
$ lttng enable-event -a -u        # enable all userspace
events
$ lttng start
$ sudo ./thttpd -C ./thttpd.conf      # start instrumented
thttpd
```

Now you can start loading your server-maybe by just opening a browser, pointing to *http://localhost* and simulating a load on the server by Apache Bench. I just tried connections from my browser for now.

```
$ lttng stop
$ lttng view

Trace directory: /home/suchakra/lttng-traces/osfy-
thttpd-20140120-172551

[17:26:24.474009892] (+?.?????????) isengard.localdomain
thttpd:count: { cpu_id = 2 }, { count = 1 }
[17:26:24.474044119] (+0.000034227) isengard.localdomain
thttpd:count: { cpu_id = 2 }, { count = 2 }
[17:26:38.936110649] (+14.462066530) isengard.localdomain
thttpd:count: { cpu_id = 3 }, { count = 3 }
[17:26:38.936246752] (+0.000136103) isengard.localdomain
thttpd:count: { cpu_id = 3 }, { count = 4 }
[17
```

You can observe that the five events were recorded and the connection count (our payload) is increasing. The delta time shows how much I waited between the requests and how many total requests I made while tracing. It's now time to finally end this tracing session.

```
$ lttng destroy
```

You can also record kernel as well as userspace traces at the same time for a more comprehensive view of the complete system with *thttpd*. Just enable the kernel and userspace events before starting a trace:

```
$ lttng enable-event -a -k
$ lttng enable-event -a -u
```

You can also add more information to the events or the trace channels by using *contexts*. For example, if you wish to add a Perf 'cache misses' counter value to all events recorded in the trace, you can use *add-context* before starting a trace:

```
$ lttng add context -k -t perf:cache-misses
```

There are many other cool things that you can do, such as filtering the traces, etc. Just browse through the man pages for *lttng* and *lttng-ust* to get more ideas.

Trace viewing and analysis

As I mentioned the last time, we can use various tools other than the command line based *babeltrace* to help us view and analyse Common Trace Format (CTF) traces. There are a couple of graphical tools available, but I will only cover the most comprehensive one-TMF. In order to maintain the continuity of our *thttpd* experiment, let's trace it again while enabling the userspace events (*-a -u* options, as mentioned above) in addition to kernel events. Run the trace for some time while making some HTTP requests and generate the traces. I have already generated some traces if you need those. Get them from *http://step.polymtl.ca/~suchakra/osfy/osfy-thttpd-20140127-194024.tar.gz*. We will need it later.

Setting up TMF

There are two ways to use TMF. One is the standalone Rich Client Platform (RCP) version. You can grab the latest Trace Viewer RCP from *http://secretaire.dorsal.polymtl.ca/~alexmont/tracing-rcp/* . Otherwise, if you are a regular Eclipse user and prefer to install TMF as an Eclipse plugin, download the latest version of the Eclipse IDE for C/C++ developers, which already includes Linux Tools and the LTTng plugins. On other versions, you can add the plugin using the *'Help→Install New Software...'* option. TMF is under the'Linux Tools' section of the main Eclipse repository.

Now you are all set and ready to roll! I will be using the Eclipse plugin to explain how to use TMF. The RCP version is no different as it is the plugin; it's just without the whole Eclipse framework.

Loading your first CTF trace

Fire up Eclipse and switch the perspective to ‘LTTng Kernel’. By default, you will see some views. The important ones for now are Control Flow, Resource, Statistics Histogram and the Project Explorer. You can always add views using *‘Window → Show View → Other'*.

Let's load up the combined kernel and *thttpd* trace first. Right click on *Project Explorer → New → Tracing Project*. Give it a new project name (such as OSFYTraces). Once it's created, go to ‘Traces' under *OSFYTraces tree → right click → ‘Batch Import...'* Check the ‘Common Trace Format' and in the next window, click on‘Add Directory' and browse to your trace directory. You can use the traces from *osfy-thttpd-20140127-194024.tar.gz* which you just downloaded or your own traces (created by default in */home/username/lttng-traces)*. Now select the desired traces the wizard has found for you. Under Generic CTF Trace, select ‘64-bit’ (that’s our UST trace) and under LTTng Kernel Trace, select ‘kernel’. Before importing them, you can rename them by clicking on their names. I renamed the ‘64-bit' trace to ‘ust’.

So two traces will appear under ‘Traces’ in the project explorer. Double click on the kernel trace and wait for it to load. You will observe the histogram and control flow view being populated. The kernel events will start showing up too. At this point, you have successfully loaded the kernel trace and are ready for analysis.

So let's first get familiar with the interface now. We will go through a small example to get familiar with the usage. On your right, you will see multiple ‘views’. In Figure 1, you can see the top section shows ‘Control Flow’, ‘Resources' and ‘Statistics’ views in the tabs. The second section shows the event views. As you open a trace named ‘kernel’, it will show all the kernel events recorded. There will be lots of events listed in it. Click on ‘*<srch>*’ under the ‘Event Type’ section and type *sys_execve*. Under ‘Content’, type *‘thttpd’*. This will take you to an event that is an *execv syscall* and contains *thttpd* as the string in the trace content. Have a look at Figure 2(a).

You can also observe that in the *Control Flow* view, the corresponding process is highlighted and the graph on the right now points to the exact time of the recorded event. You can move around and see other events on the graph by just clicking on *events*. A mouse-over gives some more information. You can zoom using the mouse wheel or more fine grained timing on events. You can also move to the next events in the same selected process using the right and left arrow keys. Colours are the next important thing and you can click on the small ‘Legend’ icon to understand what they mean. Blue is a *SYSCALL*, green shows that process was in *USERMODE*, yellow is *WAIT_BLOCKED* and so on.

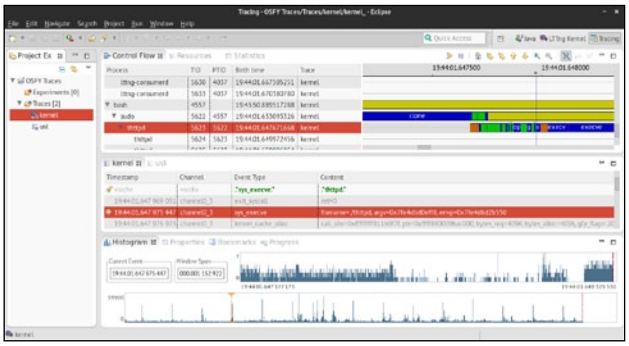
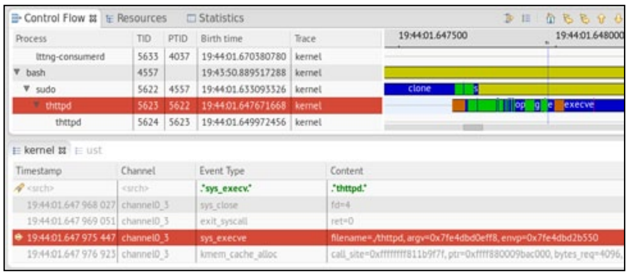


Figure 1: TMF ‘Tracing' perspective



Process	TID	PTID	Birth time	Trace
lttng-consumerd	5633	4037	19:44:01.670380780	kernel
bash	4557		19:43:50.889517288	kernel
sudo	5622	4557	19:44:01.633093326	kernel
thttpd	5623	5622	19:44:01.647671668	kernel
thttpd	5624	5623	19:44:01.649972456	kernel

Timestamp	Channel	Event Type	Content
<srch>	<srch>	.*sys_execv.*	.*thttpd.*
19:44:01.647 968 027	channel0_3	sys_close	fd=4
19:44:01.647 969 051	channel0_3	exit_syscall	ret=0
19:44:01.647 975 447	channel0_3	sys_execve	filename=./thttpd, argv=0x7fe4dbd0eff8, envp=0x7fe4dbd2b550
19:44:01.647 976 923	channel0_3	kmem_cache_alloc	call_site=0xffffffff811b9f7f, ptr=0xffff880009bac000, bytes_req=4096,

Figure 2(a): The *sys_execve* event in the kernel trace

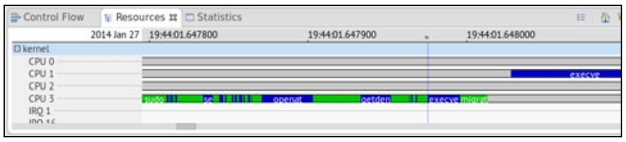


Figure 2(b): Resources view showing the event on CPU3

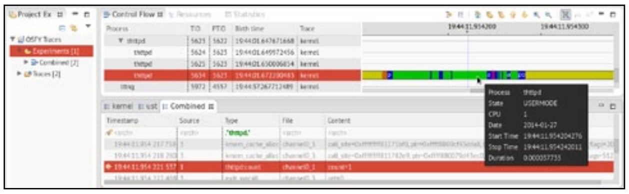
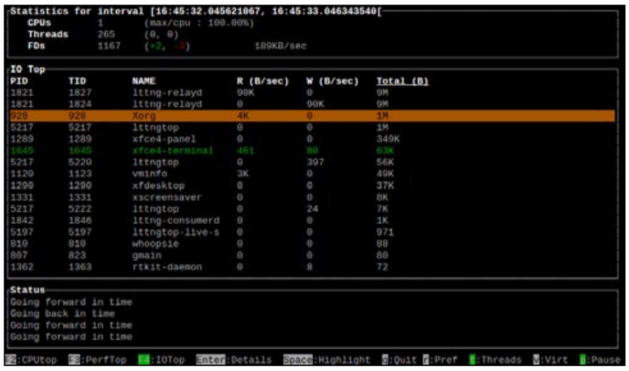


Figure 3: Trace experiment showing combined kernel and UST trace



```
Statistics for interval [16:45:32.045621067, 16:45:33.046343540[
    CPUs          1         (max/cpu : 100.00%)
    Threads       265       (0, 0)
    FDs           1167      (+2, -1)           109KB/sec

IO Top
PID        TID         NAME              R (B/sec)    W (B/sec)    Total (B)
1821       1827        lttng-relayd      90K          0            9M
1821       1824        lttng-relayd      0            90K          9M
928        928         Xorg              4K           0            1M
5217       5217        lttngtop          0            0            1M
1289       1289        xfce4-panel       0            0            349K
1645       1645        xfce4-terminal    461          80           63K
5217       5220        lttngtop          0            397          56K
1120       1123        vminfo            3K           0            49K
1290       1290        xfdesktop         0            0            37K
1331       1331        xscreensaver      0            0            8K
5217       5222        lttngtop          0            24           7K
1842       1846        lttng-consumerd   0            0            1K
5197       5197        lttngtop-live-s   0            0            971
810        810         whoopsie          0            0            88
807        823         gmain             0            0            80
1362       1363        rtkit-daemon      0            8            72

Status
Going forward in time
Going back in time
Going forward in time
Going forward in time
F2:CPUtop  F3:PerfTop  F4:IOTop  Enter:Details  Space:Highlight  q:Quit  r:Pref  t:Threads  V:Virt  p:Pause
```

Figure 4: LTTngTop

The interface is quite intuitive, and the event and the control flow views are synchronised. Next, click on the'Resources' tab and you will see all the system resources and their consumption during the trace. See Figure 2(b). Of course, it's a lot better this way rather than looking at *cpu_id* each time in the *babeltrace* output. You can also have a look at the 'Statistics' and 'Histogram' tab, which gives you a more comprehensive view of the system's functioning so that you can observe trends statistically too.

Now that you are familiar with the interface, do a small activity by which you try to see what happens in the system when the userspace tracepoint was hit and recorded the *count* data from *handle_newconnect()* in *thttpd*. You can create a *trace experiment* for this. Go to *Project explorer → Right click Experiments → New (name it 'Combined') → Select kernel and ust traces.* Now double click on 'Combined' and there you go. You have combined UST and kernel traces now. Interesting! Now you can know exactly how the system behaved while the userspace tracepoint was hit. Under the *<srch>* in *Type*, write *'thttpd:count'* and your first UST tracepoint that was hit shall be displayed. Above and below that, the system activity in kernel trace will be shown too. See Figure 3.

There are other CTF trace viewers out there too. Another graphical one is the Linux Trace Tookit Viewer (LTTV), which you can install by using the following command:

```
$ sudo yum install lttv
```

Being a precursor to TMF, it was one of the original graphical trace viewers and inspired a lot of techniques and methods that were used in TMF. LTTV is quite fast but may not be as versatile and comprehensive as TMF.

Looking ahead

LTTng 2.4 'Époque Opaque' is around the corner (RC5 is available at the time of writing) and will have some new and awesome features:

1. *Live trace viewing:* Yes, you heard that right. You can now view and analyse your traces while they are being created. You can view the live streaming data on any remote machine too. There is another tool, LTTngTop (it's an *ncurses*-based *top* like viewer), for live as well as already recorded traces which you can use with this feature. See Figure 4 and check it out at *http://git.lttng.org/?p=lttngtop.git*. Live trace reading will soon come to Eclipse TMF also (maybe not in the next release). This is a feature that sysadmins would really love!
2. *Snapshots:* Soon you will also be able to take a 'snapshot' of the trace buffers at a given time and observe the traced data. It's a pretty cool feature for scenarios in which you may want to trigger a snapshot record at some coredump, for example. Snapshot trace data can also be used with flight-recorder mode (the trace data snapshot gets overwritten in the buffer as in a flight recorder). Long term system monitoring is also a good use-case for snapshots.

The fancy control flow view is fine, but you may wonder what the actual path a process takes through the system during execution is. Can you show that? Indeed, it may soon be a reality. As for the question we discussed earlier about APT taking up your valuable time while installing packages, *Critical Flow View* answers that. Refer to this awesome post at *http://multivax.blogspot.ca/2013/12/system-level-profiling-of-apt.html.*

I would also recommend that you check out Workload Kit *(https://github.com/giraldeau/workload-kit)*. It is a way to quickly generate repeatable workloads for tracing on your machines. It contains *lttng-simple*, which is a command line tool to quickly start with LTTng on your system and do some experimentation.

This concludes the series on tracing using the LTTng tools. In case you have any questions, do contact me. Happy tracing!

References

[1] *http://lttng.org/files/doc/man-pages/man3/lttng-ust.3.html*
[2] *http://secretaire.dorsal.polymtl.ca/~alexmont/tracing-rcp/*
[3] *http://git.lttng.org/?p=lttngtop.git*
[4] *http://multivax.blogspot.ca/2013/12/system-level-profiling-of-apt.html*
[5] *https://github.com/giraldeau/workload-kit*

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By: Suchakrapani Sharma

The author is a PhD student at École Polytechnique de Montréal. He is currently doing research on dynamic tracing tools. He has varied interests, from performance analysis tools to Embedded Linux and UX/graphics design. He can be contacted at *suchakra@fedoraproject.org*