Linux tracing systems & how they fit together

Data sources:

- kprobes (kernel functions)
- kernel tracepoints
- uprobes (userspace C functions)
- USDT / dtrace probes
- LTTng userspace tracing

Ways to extract data:

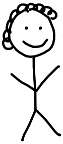
- perf
- ftrace
- LTTng
- SystemTap
- eBPF
- sysdig

frontends:

- perf
- ftrace
- trace-cmd
- catapult
- kernelshark
- trace compass
- bcc
- sysdig
- LTTng
- SystemTap

by Julia Evans

what's this?



I've been confused about the Linux tracing ecosystem for a long time. I finally figured out the basics so this zine is a quick high-level overview

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Tracing

Let's say you want to

- see every time a certain function is called (and its arguments)
- see every time an 'event' happens (like the CPU switching which process it's running - that event is called sched-switch)
- define your own tracing events
- aggregate (to see exactly how much time was spent in a function)

to do this, we need to:

- define tracing events (either at compile time or at runtime). aka **data sources**
- a way to collect delicious tracing data and send it to userspace. Usually something in the kernel collects tracing data.
- a frontend to use !

let's go see what the options are ⟶

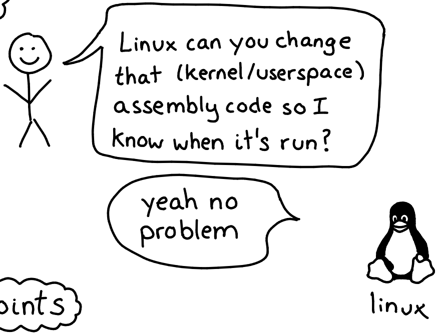
(the ecosystem is a little fragmented ☺)

data sources

There are 2 basic kinds of data sources:
(not quite the right terminology but I'm not sure what is)

- 'dynamic probes': change your assembly code at runtime to instrument it
- 'tracepoints': choose at compile time (or in advance anyway) which events can be traced.

dynamic probes


Linux can you change that (kernel/userspace) assembly code so I know when it's run?
yeah no problem
linux

Tracepoints

① Compile a tracepoint into your program
(you can also often define them at runtime)

② as long as nobody activates it,
~ no overhead!

③ Your users can activate the tracepoint (with tools like ftrace/dtrace + friends) to get info about what your program is doing.

Here are the 5 data sources the tools in this zine use:

kprobes
kernel

let you trace any instruction / function call / function return in the kernel. kprobe.txt in the kernel docs says more.

uprobes
userspace

like kprobes, but for userspace programs!

tracepoints:

kernel tracepoints
kernel

these are defined by a TRACE_EVENT macro. For example there are 2 tracepoints (enter/exit) for every syscall

dtrace probes aka USDT probes
userspace

dtrace isn't a Linux program, but lots of programs (like python/mysql) can be compiled with dtrace probes. And there are Linux tracing tools that can use those probes!

lttng-ust
userspace

lttng-ust is a tracing format (works with LTTng) that works entirely in userspace.

Ways to get (delicious delicious) tracing data

There are a bunch of ways to collect tracing data. These 3 are the ones that are built into the Linux kernel.

ftrace

uprobes

kprobes

kernel tracepoints

magical filesystem at /sys/kernel/debug/tracing. Super powerful, you interact with it by reading from / writing to files.

perf_events

kernel tracepoints

① call the perf_event_open syscall

② the kernel writes data to a ring buffer ("perf buffer")

eBPF

uprobes

kprobes

dtrace probes

kernel tracepoints

The newest and most powerful

① Write a small eBPF program

② Ask Linux to attach it to a kprobe/uprobe/tracepoint

③ The eBPF program sends data to userspace with ftrace/perf/BPF maps

more ways

These are all developed outside the kernel
(though they all ultimately insert kernel modules)

SystemTap

uprobes

kprobes

dtrace probes

kernel tracepoints

① Write some C code

② Compile it into a custom kernel module

③ Insert that module into the kernel

LTTng

uprobes

kprobes

kernel tracepoints

lttng-ust

① Insert the LTTng kernel module

② Use the LTTng tools to get it to collect data for you

Sysdig

just traces system calls
I think

Frontends

tools to help you:

- tell the kernel what data to collect / programs to run
- display the data in a useful way

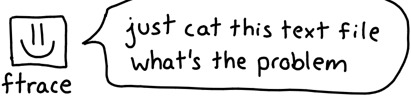
perf trace

for perf + ftrace

'perf' can use perf_event_open (surprise) and also ftrace to record tracing data. I use 'perf trace' to trace syscalls.

ftrace

ftrace by itself doesn't really have a frontend.



trace-cmd

for ftrace

A command line frontend to ftrace, a lot easier to use.

perf-tools

for perf / ftrace

A collection of scripts by Brendan Gregg. The kprobe / uprobe scripts are fun to play with!

more frontends

bcc

for eBPF

Python framework to help you write eBPF programs. Also tons of examples!

https://github.com/iovisor/bcc

catapult

for ftrace

Can draw graphs of sched_switch events recorded by ftrace.

(and maybe more things? unsure.)

kernelshark

for ftrace

graphical trace-cmd frontend

haven't tried it yet

LTTng / sysdig / SystemTap

all frontends for their respective data collectors

why eBPF is exciting

→ it supports a ton of data sources (kprobes/uprobes/ USDT probes/tracepoints

→ you can write your own programs and insert them into the kernel so it's high performance and flexible

→ it's pretty safe: what eBPF programs can do is strictly limited by the kernel (no loops! no arbitrary memory access). Every program runs through a verifier before it can run.

→ people are building cool easy to use tools with it (strace built with eBPF? yes please!)

Brendan Gregg's blog has a TON of posts about eBPF, and

https://github.com/iovisor/bcc

has lots of tools written using it, and makes it easier to write your own

thanks for reading

To learn more:

- brendan gregg's blog
- the kernel docs on kprobes / ftrace, in the Documentation folder
- LWN has a bunch of useful articles on ftrace

♡

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Julia Evans, wizard wow fun industries 2017