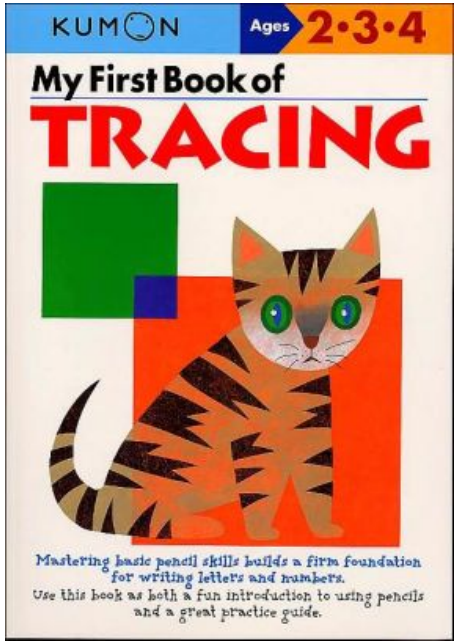
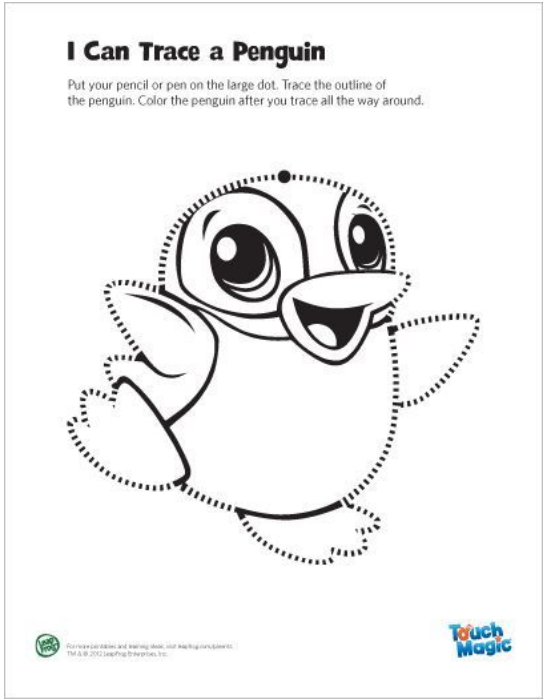


Linux Tracing

Anthony Critelli



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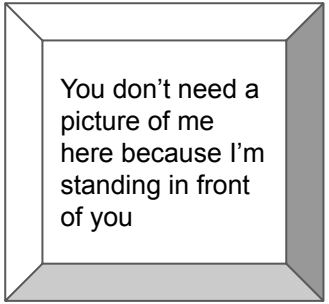
About me



- Linux systems engineer
- Dislike colorful slides
- Started career as a network engineer
  - Not much interesting going on in networking (other than marketing buzzwords)
  - Lots interesting going on in Linux
- Interests
  - Automation
  - Occasionally blog (both on my personal site and for RedHat Enable SysAdmin)
- “Hey, you look familiar”
  - Former IST (the school formerly known as NSSA now known as iSchool) sysadmin
  - Former CCDC coach (0-1 record, they fired me. JK, I stopped working at RIT)

What do I mean by tracing?

- Observing the execution of an arbitrary program, including the kernel itself, as its running
- In particular, I'd like to:
  - Attach to a live program
  - Have low overhead
- There are *a lot* of tracers for Linux
  - **http://www.brendangregg.com/blog/2015-07-08/choosing-a-linux-tracer.html**
- We'll focus on two tracing tools today, just because:
  - Ftrace
  - eBPF, specifically the BCC project

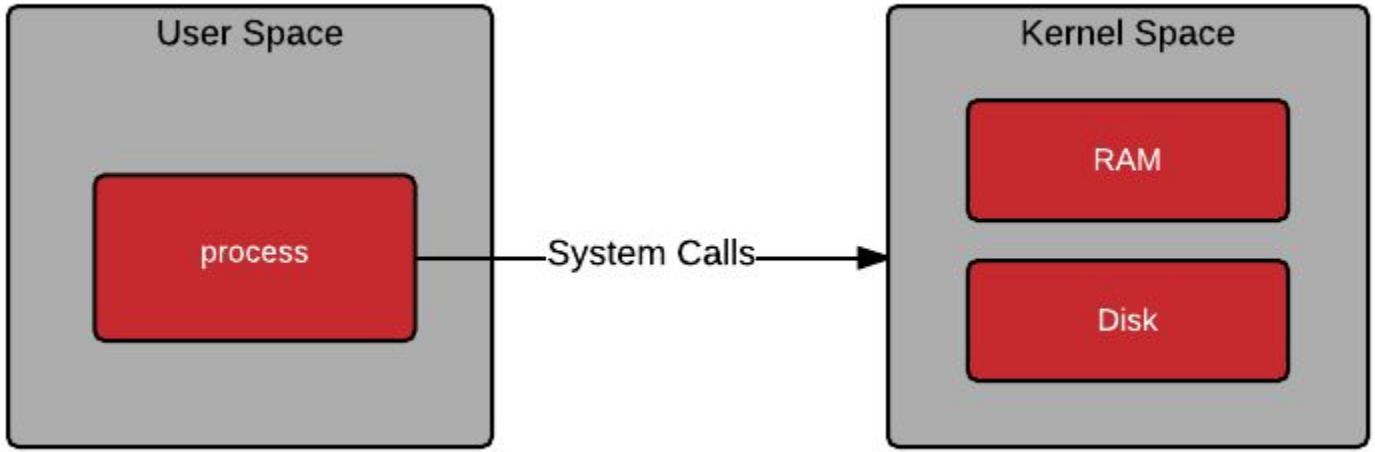
Why might you trace?

- Troubleshooting - many userland programs have trace probes (or can be compiled with them).
  - Example: MySQL
- Performance analysis - understand what your code is doing and where it might be bottlenecking, among other things
- For the learning opportunity - start tracing a user or kernel function, and you'll find yourself down the rabbit hole of trying to better understand the codebase
- Demystify the black box. Computers really aren't magic.
  - Except they kind of are. I mean, this is all a bunch of sand doing math real quick so that you can shitpost on Workplace

What do I need before I start?

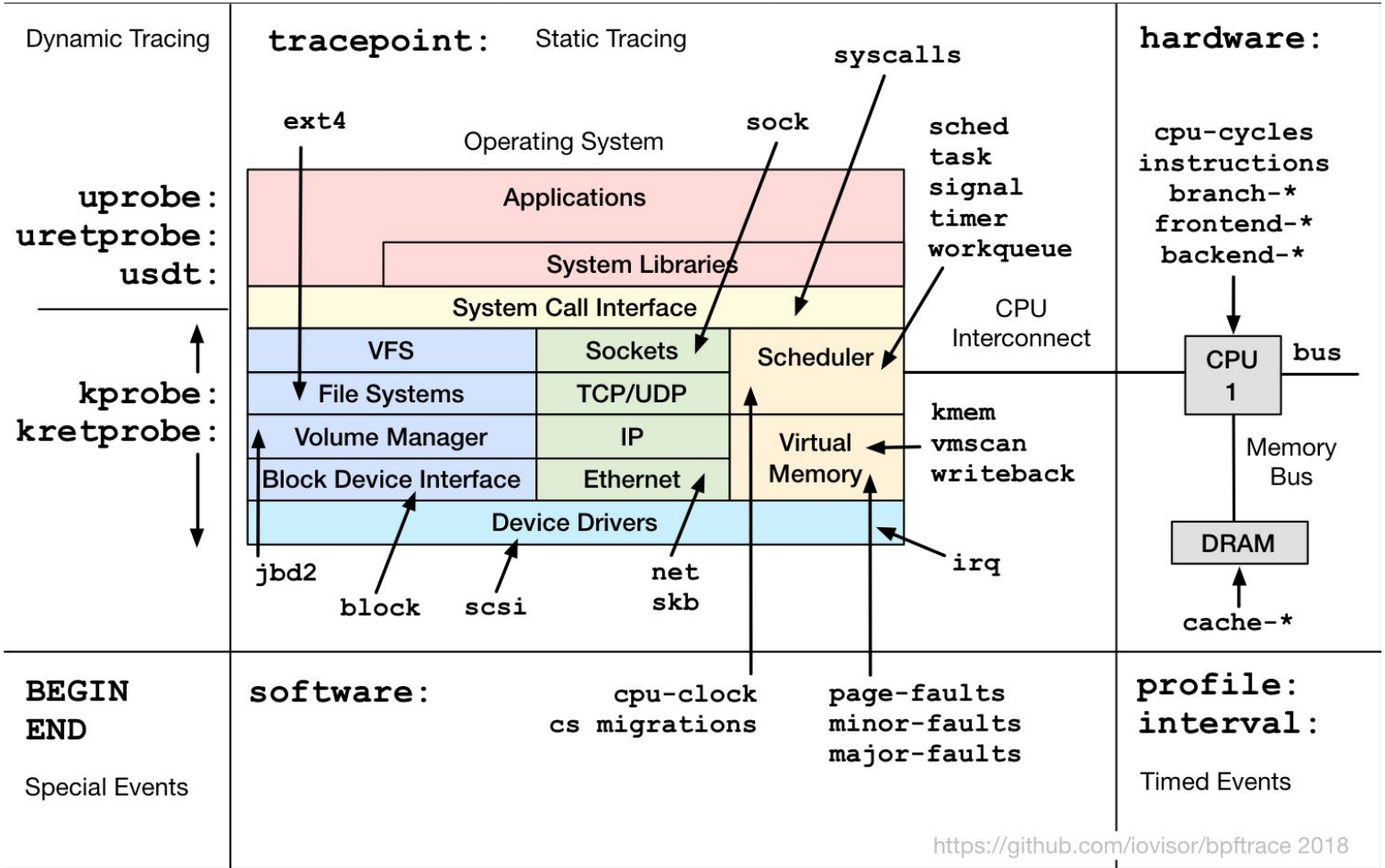
- A basic knowledge of C, especially a basic knowledge of pointers
  - You can start playing around without this, but it helps *a lot*
  - Trust me: just take the 15 minutes needed to refresh your knowledge of pointers
- A basic understanding of how Linux works
  - User vs. kernel space, etc.
- Willingness to be very out of your element, unless you do a lot of programming in C, or kernel development
  - There are a lot of rabbit holes to follow

User Space vs. Kernel Space



https://www.redhat.com/en/blog/architecting-containers-part-1-why-understanding-user-space-vs-kernel-space-matters

bpftrace Probe Types



Tools

- Many tools, but we'll look at Ftrace and eBPF (specifically, the BCC tools)
- Why?
  - It's what I'm personally "comfortable" with, and I'm the one talking at you
- Ftrace has a low barrier to entry, you can immediately start looking at what your kernel is doing
- eBPF is really gaining popularity
  - Highly espoused by our lord and savior Brendan Gregg
- I've found that using a combination of Ftrace (for initially looking at things) and eBPF/BCC have allowed me to start tracing interesting things

Terminology: Static vs. Dynamic? User vs. Kernel?

- Static tracing - the program’s source code must be instrumented to expose a probe
  - Requires modifying the code
  - Many programs do expose some static trace probes
- Dynamic tracing - source code modification isn’t necessary
  - Often just requires installing debugging symbols
- User tracing - tracing of code that executed in userspace
- Kernel tracing - tracing of code (the kernel and its functions) that run in kernel space

Ftrace

https://www.kernel.org/doc/Documentation/trace/ftrace.txt

- Kernel **f**unction **tracer** (actually a collection/framework of tracing tools)
- Has many useful built-in tracers: hardware latency, function graphing, interrupt requests, block I/O, etc.
- You can interact with it like a file system at /sys/kernel/tracing or /sys/kernel/debug/tracing
    - There’s also a front-end called trace-cmd

eBPF

- Grew out of BPF (Berkeley packet filters)
  - Wait what? Packets?
  - Yeah: turns out it's useful to run some user code inside the kernel
- eBPF is an in-kernel "virtual machine"
  - That is: the eBPF code compiles down to its own bytecode that the kernel executes
  - No, it's not a Windows XP VM running in your kernel
- It's fast: Netflix runs some of their instrumentation in production
- Writing eBPF bytecode is miserable (like, you know: writing any kind of bytecode)
  - I've never done this
  - Tools have been developed to provide front-ends

The eBPF Compiler collection (BCC)

https://github.com/iovisor/bcc

- A set of tools to make writing and interacting with eBPF easier
  - Write the kernel instrumentation in C
  - Write frontends in Python
- Why is this neat?
  - You can do kernel eBPF things in C, as you would expect
  - You can then send this data to userspace Python scripts
  - It's *much* easier to work with data in Python
    - Still be considerate of how often things are getting sent to userspace (expensive)

BCC Continued

- BCC has some nice things to make your life easier
- Functions for writing to shared tracing pipe (same one used by ftrace)
- Macros and functions for things like:
  - Maintaining hashes that can later be accessed by userspace
  - Building histograms, also accessible in userspace later
- The repository also has a wealth of existing, pre-written tools
  - These can probably do most things you'd be interested in
  - Great examples of how to write your own programs

BPF Trace

https://github.com/iovisor/bpftrace/

- A higher level tracing language on top of eBPF and BCC
- Great for writing one-liners
  - Lots of examples on their GitHub
- Won’t be discussing it further here

(some) Things that you can do with eBPF and these tools

- Dynamically trace kernel functions (entry and return) and get their arguments
  - Remember, dynamically just means that the kernel doesn't need any special trace points to support this
- Do the same thing for userspace applications
  - Typically, you'd install the debugging symbols/recompile a package with debugging enabled for the binary that you're interested in playing with
- Do the same thing for syscalls
- Perform these same operations with static trace points
  - Many applications expose this kind of instrumentation

Front end	Difficulty	Pros	Cons	References
BPF bytecode	Brutal	Precise control	Insanely difficult	Kernel source: struct bpf_insn prog in samples/bpf/sock_example.c
C	Hard	Build stand-alone binaries	Difficult	Kernel source: samples/bpf/tracex1_kern.c and samples/bpf/tracex1_user.c
perf	Hard	Use perf's capabilities: custom events, stack walking	Difficult, not yet well documented	Section below: 7. perf.
bcc	Moderate	Custom output, Python libraries, large community, production use (e.g., Facebook, Netflix)	Verbose	Section below: 5. bcc.
bpftrace	Easy	Powerful one-liners, many capabilities, growing community, production use (e.g., Netflix, Facebook)	Limited control of code and output	Section below: 6. bpftrace.
ply	Easy	Powerful one-liners, small binary, for embedded	Limited control of code and output	github: github.com/iovisor/ply.

http://www.brendangregg.com/ebpf.html

So, where do I start?

- Learning where to start can be daunting, especially if you just want to learn and don’t have a defined use case
- What I found useful:
  - Pick some arbitrary thing, like doing a DNS lookup with nslookup
  - Observe it using ftrace.
  - See what kernel functions are called
  - Pick some of the more obvious ones (e.g. network, I/O, filesystem, etc.)
  - See if you can write a BCC program to collect some data (how many times the function is called, its arguments, etc.)
- Hopefully, this presentation will give you some ideas in practice
- Everyone learns differently: honestly, it’s probably better to read the example code first, then dive in

Live Demo

Tips and Tricks for Learning

- All of these tools have lots of examples
  - The eBPF ecosystem, in particular, has tons of pre-written tools and examples
- I found the BCC developer tutorial to be helpful (check the BCC docs folder)
- While the eBPF tools provide a lot of features, none of this is really “batteries included”
  - Expect to try and fail a lot
  - Be aware of differences between eBPF versions (e.g. you might be reading docs for a newer version)
- Just get started: find something that sounds neat, and learn to explore it

A few resources

- Review the tools and examples in the previously repositories
- Brendan Gregg's blog http://www.brendangregg.com
- Bootlin's Elixir tool for browsing kernel source: https://elixir.bootlin.com/linux/latest/source
- A packet's journey through the kernel: https://blog.packagecloud.io/eng/2017/02/06/monitoring-tuning-linux-networking-stack-sending-data/
- Julia Evan's blog: https://jvns.ca
- A bunch of eBPF resources: https://qmonnet.github.io/whirl-offload/2016/09/01/dive-into-bpf/

Thanks! Questions?

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