Performance Wins with BPF Getting Started

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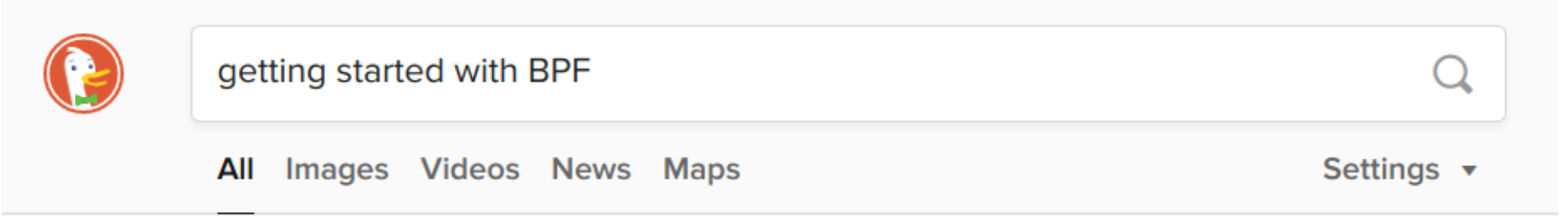
SYSTEMS @ SCALE

Jun 2021

NETFLIX



This article is not for beginners

Getting started with BPF on Ubuntu 20.04 Focal · Amédée d ...
https://amedee.me/2020/06/17/bpf-on-ubuntu-20/
Getting started with BPF on Ubuntu 20.04 Focal. June 17, 2020 · 6 minute read · Tags: **bpf**, debugging, ubuntu I believe that reasoning about a program, and knowing where to insert "probes", is a key part of development that can make the difference between "stuck all afternoon" and finishing a task on time.

... not the best start

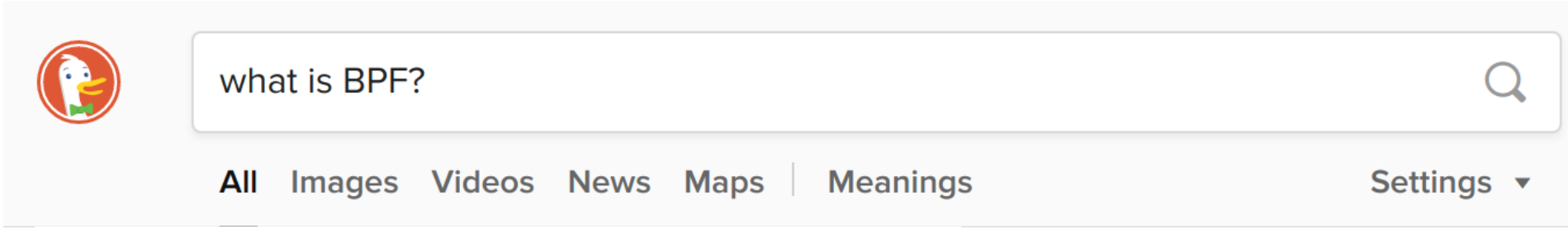
... out of date

BPF has evolved

Many docs were true in 2015 but not today

Newcomers keep re-posting old info as new

This talk is Jun 2021



[redacted]

[redacted] - Wikipedia

https://en.wikipedia.org/wiki/[redacted]

[redacted] (BPF) is a technology[redacted]

[redacted]

[redacted]

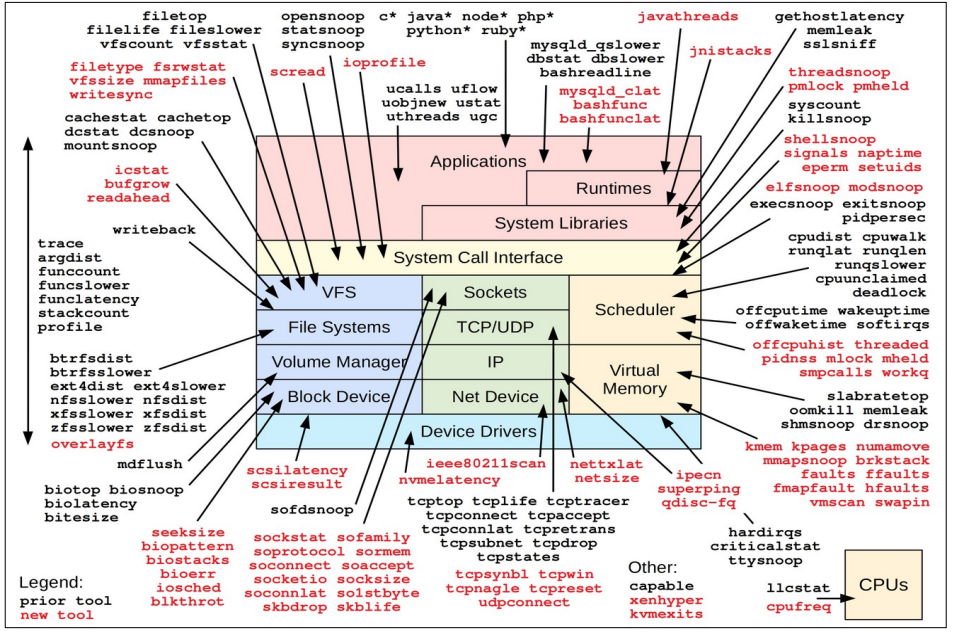
BPF is no longer an acronym

BPF is a bytecode and execution environment

How to get quick and easy BPF performance wins

Think like a sysadmin

Not like a programmer




```
# define BPF program
prog = """
int hello(void *ctx) {
    bpf_trace_printk("Hello, World!\\n");
    return 0;
}
"""

# load BPF program
b = BPF(text=prog)
b.attach_kprobe(event=b.get_syscall_fnname("clone"), fn_nam
```

Think like a sysadmin

Get it installed everywhere and use it.

```
# apt-get install bcc-tools
# PATH=$PATH:/usr/share/bcc/tools
# execsnoop
# opensnoop
# tcplife
# ext4slower
# biosnoop
[...]
```

Think like a sysadmin

Get it installed everywhere and use it.

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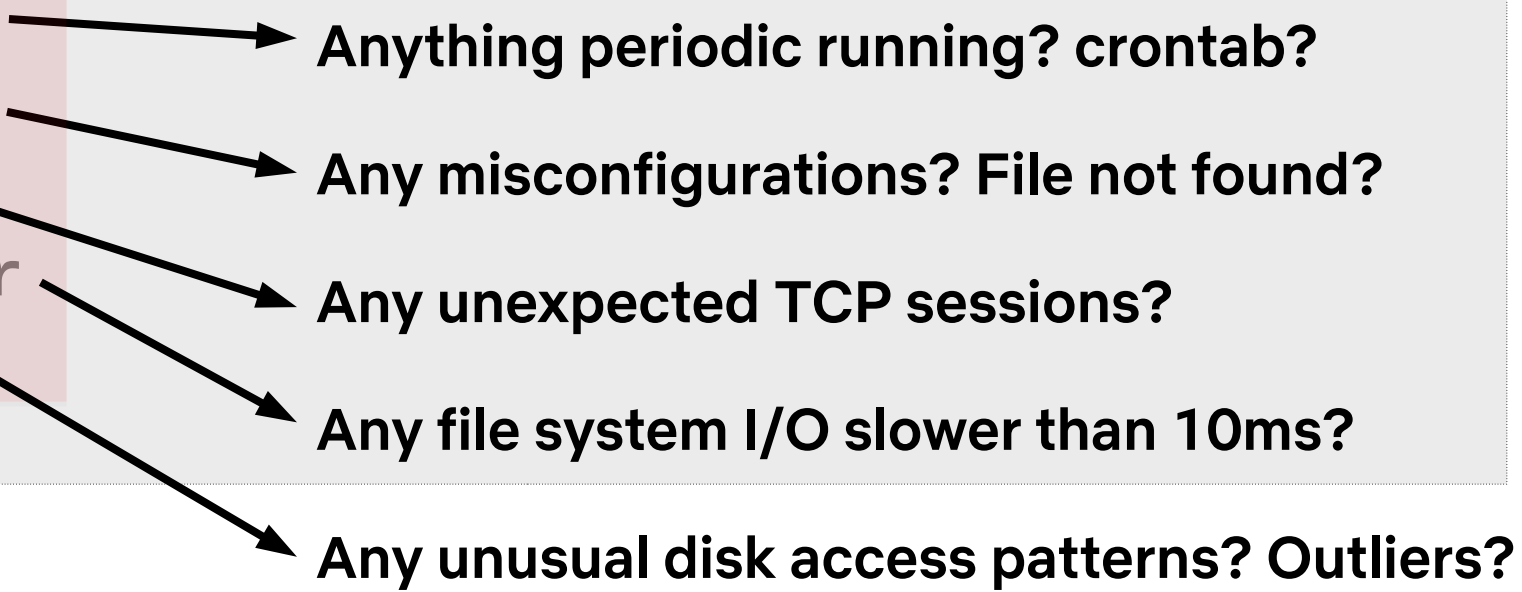


Case Study: BCC biosnoop

```
# iostat -xz 1
Linux 4.15.0-1052-aws (cass-xxx)   12/04/2019  _x86_64_    (8 CPU)
[…]

avg-cpu:  %user   %nice %system %iowait  %steal   %idle
           4.67    0.13    0.25    0.00    0.00   94.95


Device: rrqm/s   wrqm/s     r/s     w/s    rkB/s    wkB/s avgrq-sz avgqu-sz   await r_await w_await  svctm  %util
xvda      0.00     0.00    1.00    0.00     8.00     0.00    16.00     0.00    0.00    0.00    0.00   0.00   0.00
xvdb      0.00     0.00   32.00    0.00   152.00     0.00     9.50     0.16    5.00    5.00    0.00   5.00  16.00
xvdc      0.00     0.00   36.00    1.00   192.00     4.00    10.59     0.19    5.19    5.33    0.00   5.19  19.20
xvdd      4.00     0.00   37.00    0.00   181.00     0.00     9.78     0.18    4.97    4.97    0.00   4.54  16.80
xvde      0.00     0.00   27.00    0.00   156.00     0.00    11.56     0.18    6.67    6.67    0.00   6.67  18.00
xvdf      0.00     0.00   35.00    0.00   164.00     0.00     9.37     0.19    5.37    5.37    0.00   5.37  18.80
xvdg      0.00     0.00   25.00    1.00   136.00     4.00    10.77     0.14    5.23    5.44    0.00   5.23  13.60
md0       0.00     0.00  195.00    2.00   965.00     8.00     9.88     0.00    0.00    0.00    0.00   0.00   0.00

[…]
```

Case Study: BCC biosnoop, cont.

```
# /usr/share/bcc/tools/biosnoop
TIME(s)     COMM           PID    DISK    T SECTOR     BYTES  LAT(ms)
0.000000    perl           7755   xvdc    R 610822184  4096      8.57
0.000812    biosnoop       32196  xvda    R 269480     4096      0.43
0.006197    perl           3285   xvde    R 610737856  4096      6.10
0.006390    perl           23937  xvde    R 377704624  4096      0.10
0.015040    perl           7755   xvdb    R 732825200  4096      8.51
0.022842    perl           3285   xvdc    R 732953880  4096      7.72
0.023019    perl           23937  xvdb    R 377707064  4096      0.09
0.034443    perl           7755   xvdg    R 732998328  4096     11.28
0.039648    perl           23937  xvdd    R 733127392  4096      5.08
0.039863    perl           31913  xvdg    R 732868048  4096      0.10
0.049431    perl           3285   xvdg    R 732906896  4096      9.45
0.058521    perl           27565  xvdg    R 610744920  4096      8.99
0.070843    perl           27565  xvdg    R 377706520  4096     12.26
0.080564    perl           31913  xvdc    R 610951744  4096      9.62
0.080804    perl           7755   xvdc    R 732858664  4096      0.14
0.086932    perl           27565  xvdg    R 732937416  4096      6.01
0.087093    perl           27565  xvde    R 610853240  4096      0.09
[…]
```

Case Study: BCC biosnoop, cont.

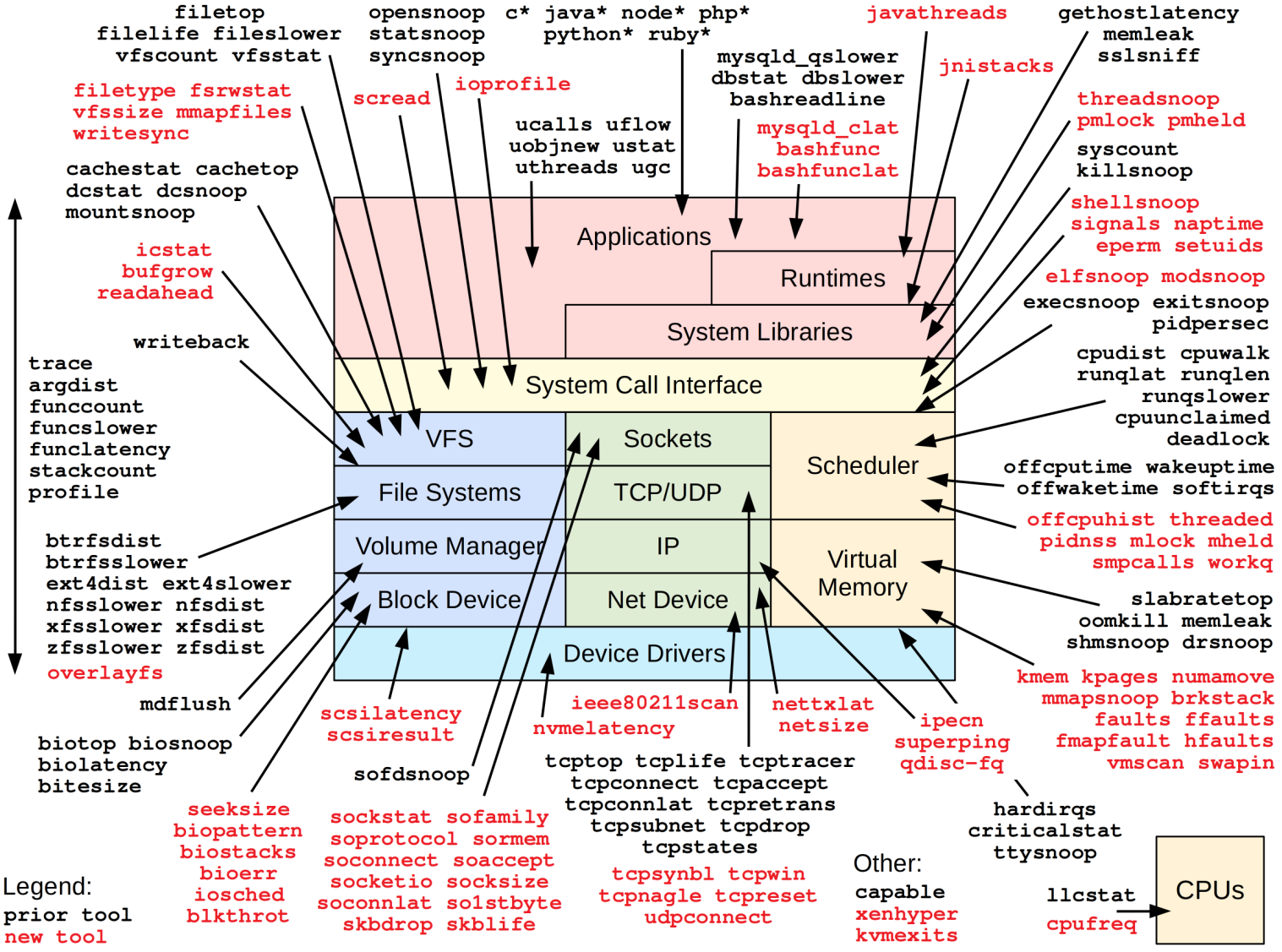
```
# ps -ef | grep perl
root      3285  3274  1 14:16 ?        00:04:24 /usr/bin/perl /apps/…ec2rotatelogs.pl
root      7755  7748  1 04:16 ?        00:10:20 /usr/bin/perl /apps/…ec2rotatelogs.pl
root     11366 11359  1 10:16 ?        00:06:39 /usr/bin/perl /apps/…ec2rotatelogs.pl
root     15054 15049  2 16:16 ?        00:03:07 /usr/bin/perl /apps/…ec2rotatelogs.pl
root     19675 19670  1 06:16 ?        00:08:53 /usr/bin/perl /apps/…ec2rotatelogs.pl
root     23937 23930  1 12:16 ?        00:05:30 /usr/bin/perl /apps/…ec2rotatelogs.pl
root     27565 27561  2 18:16 ?        00:00:28 /usr/bin/perl /apps/…ec2rotatelogs.pl
root     28232 28223  1 02:16 ?        00:11:43 /usr/bin/perl /apps/…ec2rotatelogs.pl
root     31913 31907  1 08:15 ?        00:07:40 /usr/bin/perl /apps/…ec2rotatelogs.pl
[…]
```

Many more tools to try!

bcc tools
bpftrace tools
(from my book, open source)

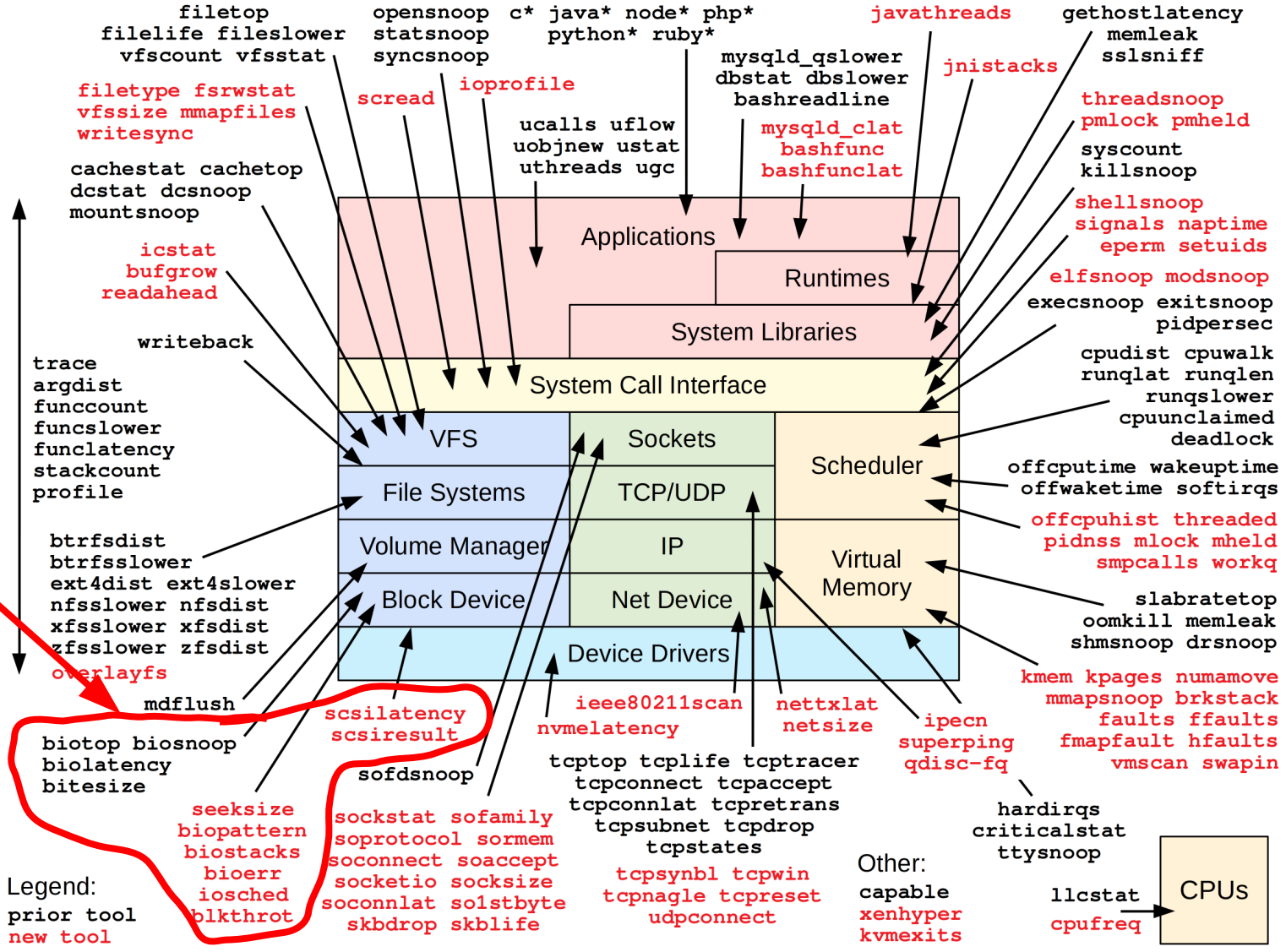
Solve >90% of perf issues with canned observability (tracing) tools

This is BPF observability in one pic



Print on your office/home wall, use as a checklist

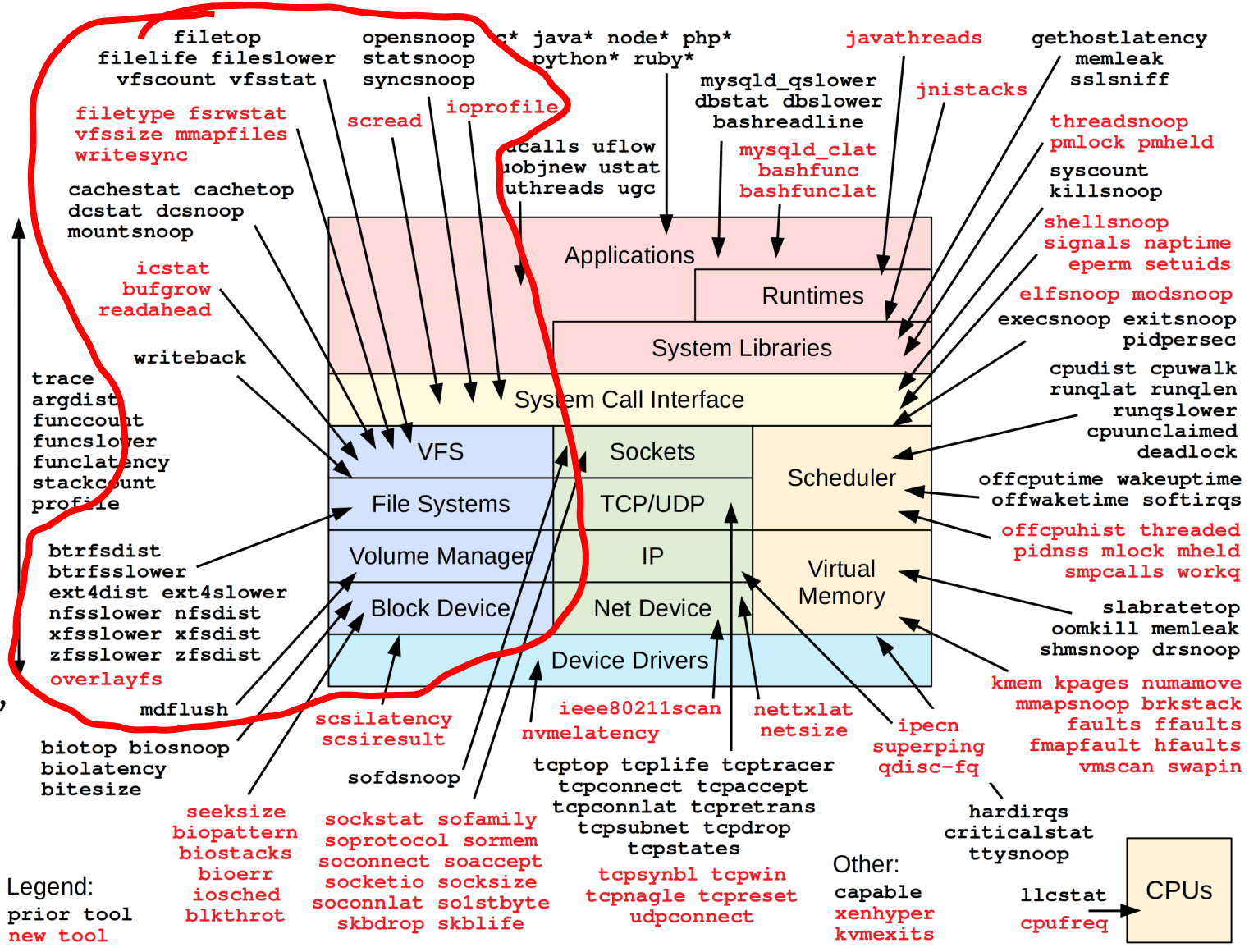
Suspected disk issue?
Try these first:



Print on your office/home wall, use as a checklist

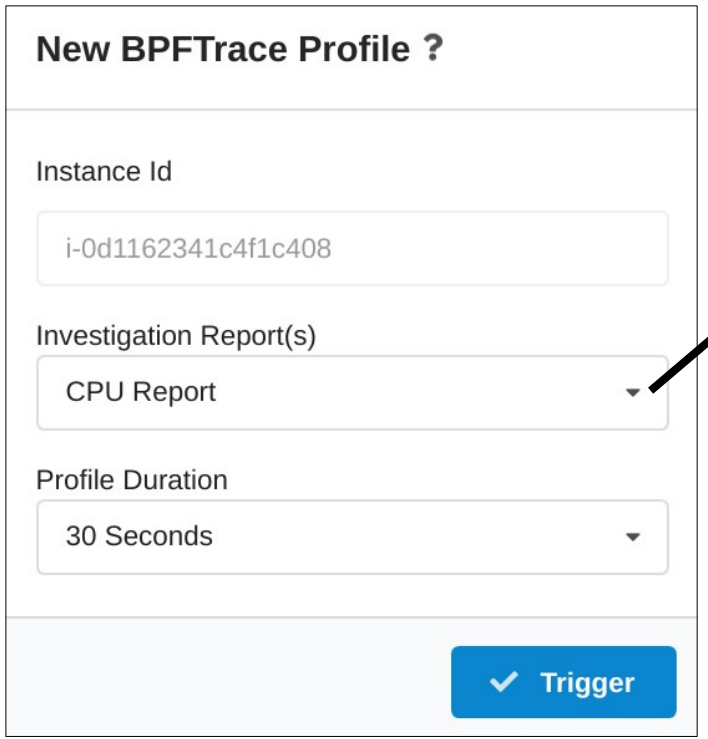
Suspected disk issue? Try these first:

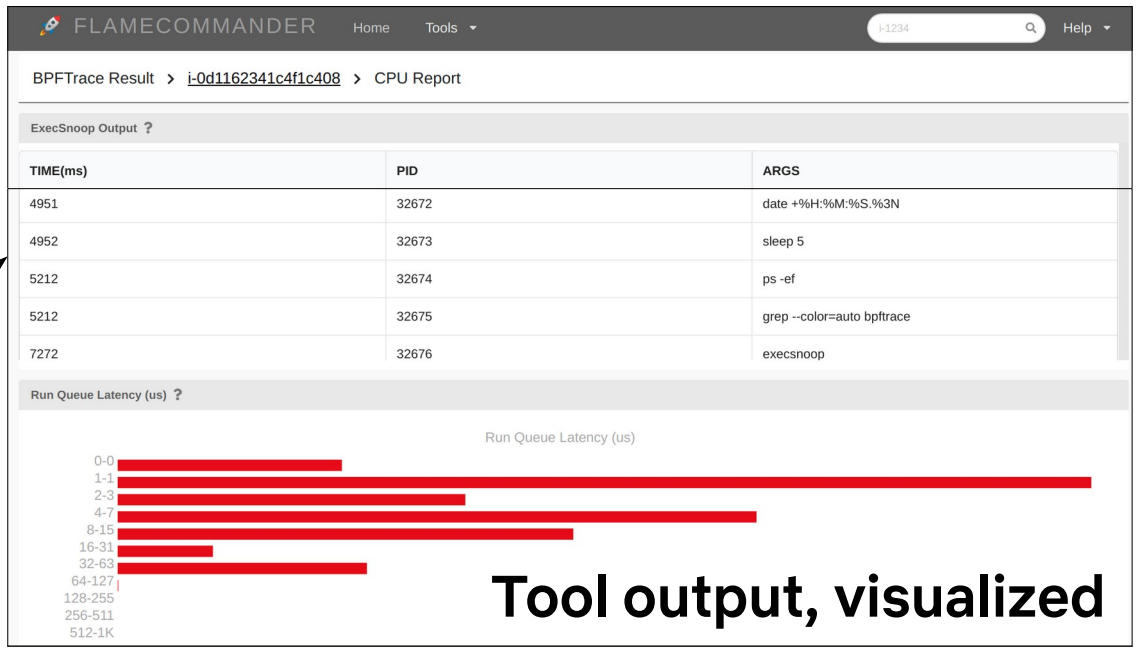
Then walk up the stack: file system tools, VFS tools, syscall tools, etc.



The future of BPF perf observability

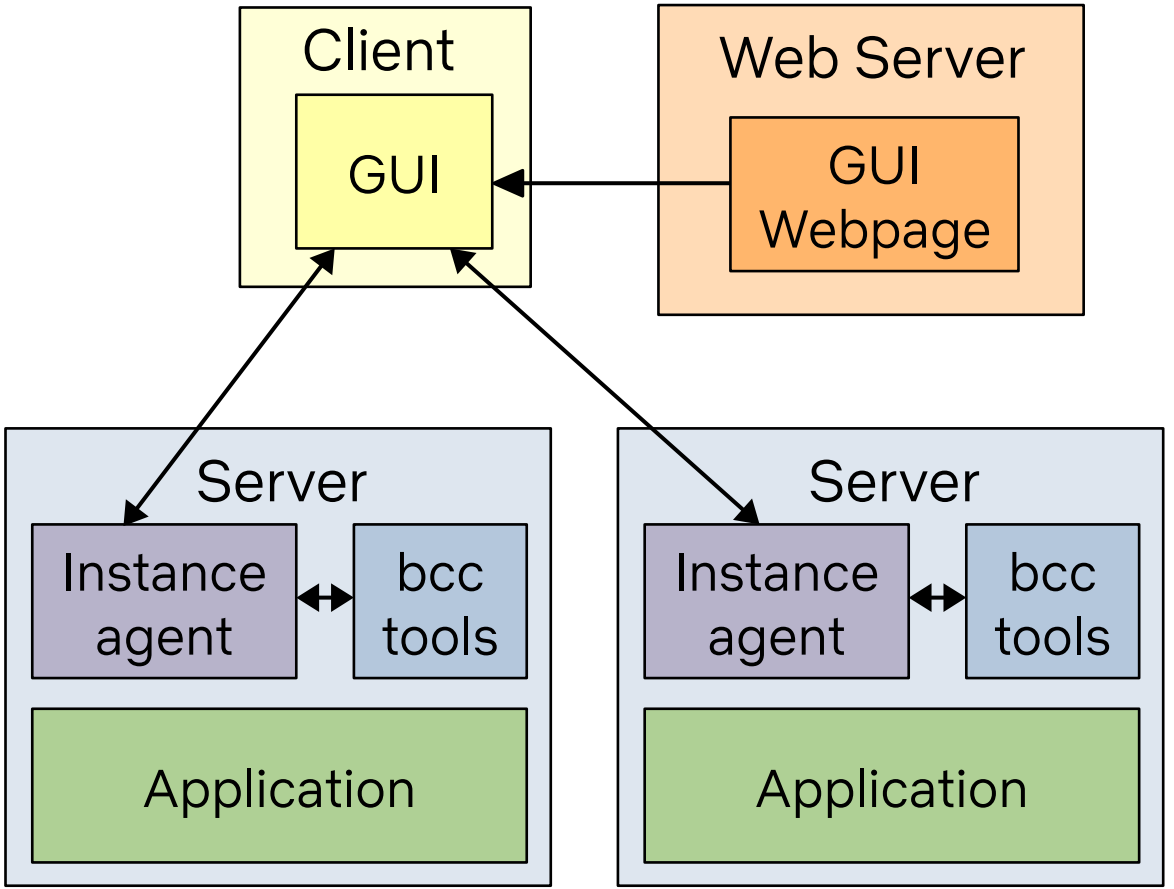
… is GUIs. The end user may not even know it's BPF.





This GUI is in development by Susie Xia, Netflix

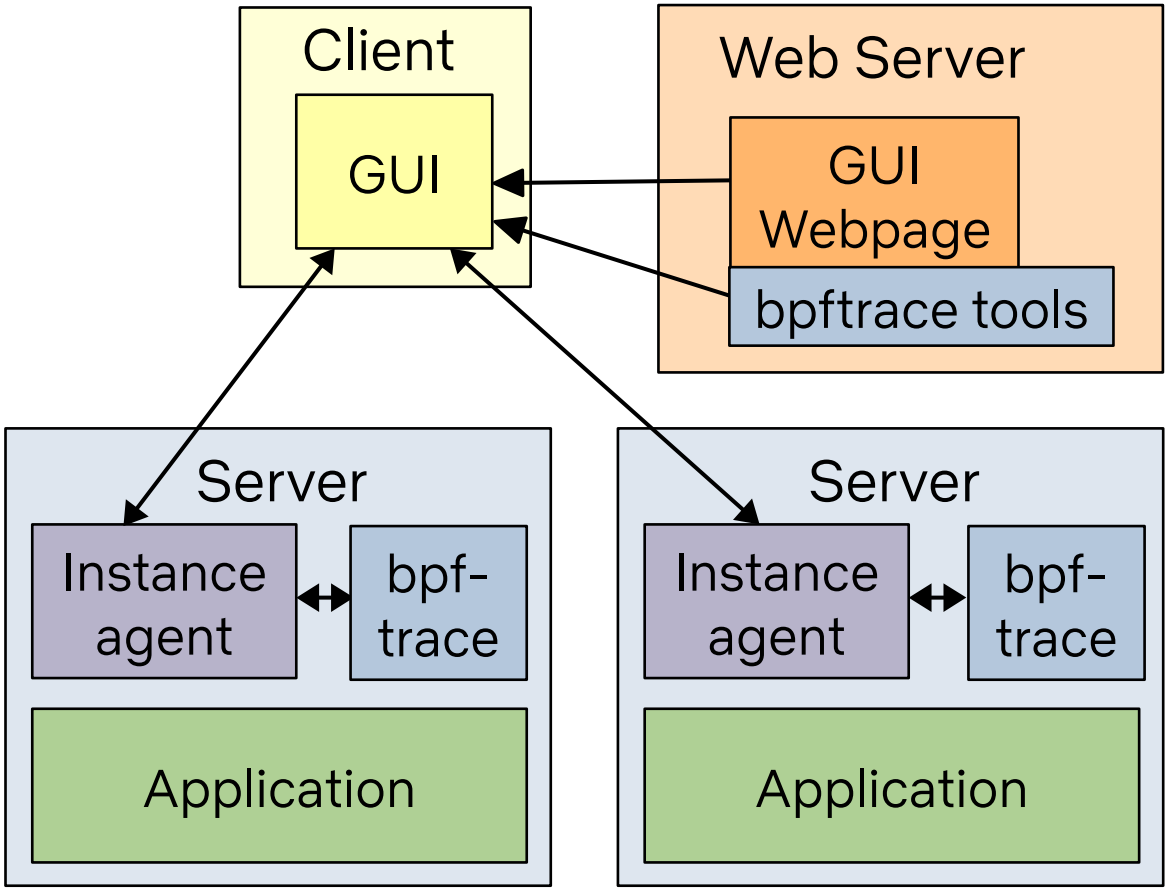
Example real-time BPF observability UI



Netflix Vector (now retired)
uses this model

- Instance agent pcp pmdabcc
- https://github.com/Netflix/vector

Example real-time BPF observability UI #2



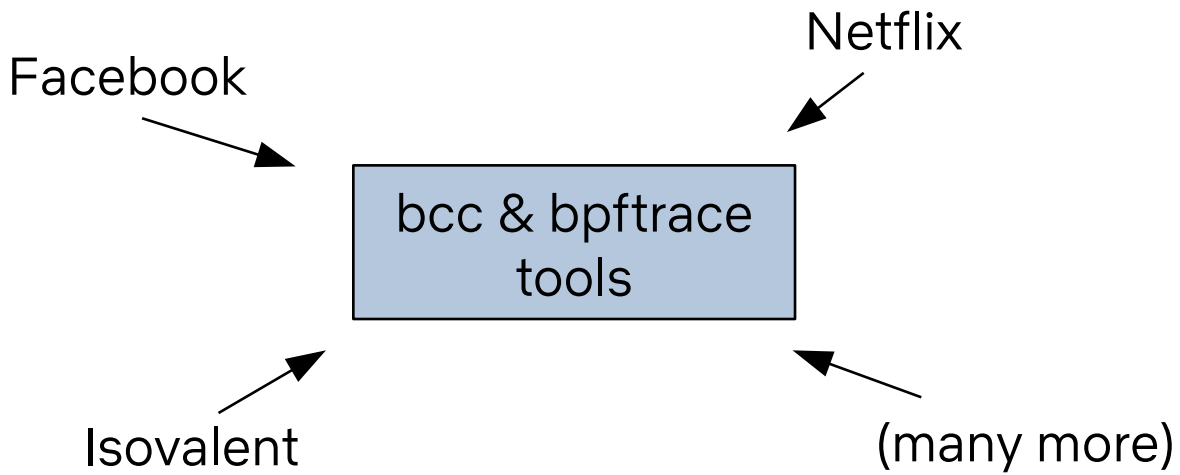
Netflix FlameCommander UI

- (not yet open source)

Think like a sysadmin

Please try to use bcc/bpftrace tools as-is and fetch regular updates

Many tools are sandcastles, and require frequent rebuilding to match kernel changes
Fortunately many companies and engineers maintain these versions

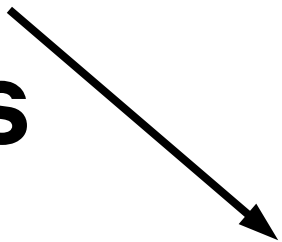


Sysadmins sometimes program

shell scripting

awk

sed one-liners



bpftrace tools

bpftrace one-liners

Think like a programmer if

You have a real-world problem that tools don’t solve

You’re a BPF-based startup

You’re debugging your own code*

You’re doing networking/security/etc.

You really want to learn BPF internals

* JIT-ed runtimes like Java are currently complex to trace

Recommended tracing front-ends

I want to run some tools

- **bcc, bpftrace**

I want to hack up some *new* tools

- **bpftrace**

I want to spend weeks developing a BPF product

- **bcc libbpf C, bcc Python (maybe), gobpf, libbbpf-rs**

New, lightweight,
CO-RE & BTF based

Requires LLVM; becoming
obsolete / special-use only

Recommended tracing front-ends

I want to run some tools — Unix analogies

- **bcc, bpftrace** — /usr/bin/*

I want to hack up some *new* tools

- **bpftrace** — bash, awk

I want to spend weeks developing a BPF product

- **bcc libbpf C, bcc Python (maybe), gobpf, libbbpf-rs** — C, C++

New, lightweight, CO-RE & BTF based

Requires LLVM; becoming obsolete / special-use only

bpftrace example

```
# readahead.bt
Attaching 5 probes...
^C
Readahead unused pages: 128

Readahead used page age (ms):
@age_ms:
[1]                 2455 |@@@@@@@@@@@@@@@                                     |
[2, 4)              8424 |@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@|
[4, 8)              4417 |@@@@@@@@@@@@@@@@@@@@@@@@@@@                         |
[8, 16)             7680 |@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@     |
[16, 32)            4352 |@@@@@@@@@@@@@@@@@@@@@@@@@@                          |
[32, 64)               0 |                                                    |
[64, 128)              0 |                                                    |
[128, 256)           384 |@@                                                  |
```

bpftrace example

```
#!/usr/local/bin/bpftrace

kprobe:__do_page_cache_readahead    { @in_readahead[tid] = 1; }
kretprobe:__do_page_cache_readahead { @in_readahead[tid] = 0; }

kretprobe:__page_cache_alloc
/@in_readahead[tid]/
{
     @birth[retval] = nsecs;
     @rapages++;
}

kprobe:mark_page_accessed
/@birth[arg0]/
{
     @age_ms = hist((nsecs - @birth[arg0]) / 1000000);
     delete(@birth[arg0]);
     @rapages--;
}

END
{
     printf("\nReadahead unused pages: %d\n", @rapages);
     printf("\nReadahead used page age (ms):\n");
     print(@age_ms); clear(@age_ms);
     clear(@birth); clear(@in_readahead); clear(@rapages);
}
```

Fits on one slide!

BCC libbpf tool example

```
# ./opensnoop
PID    COMM               FD ERR PATH
27974  opensnoop          28   0 /etc/localtime
1482   redis-server        7   0 /proc/1482/stat
[…]

# ldd opensnoop
    linux-vdso.so.1 (0x00007ffddf3f1000)
    libelf.so.1 => /usr/lib/x86_64-linux-gnu/libelf.so.1 (0x00007f9fb7836000)
    libz.so.1 => /lib/x86_64-linux-gnu/libz.so.1 (0x00007f9fb7619000)
    libc.so.6 => /lib/x86_64-linux-gnu/libc.so.6 (0x00007f9fb7228000)
    /lib64/ld-linux-x86-64.so.2 (0x00007f9fb7c76000)

# ls -lh opensnoop opensnoop.stripped
-rwxr-xr-x 1 root root 645K Feb 28 23:18 opensnoop
-rwxr-xr-x 1 root root 151K Feb 28 23:33 opensnoop.stripped
```

151 Kbytes for a stand-alone BPF program!

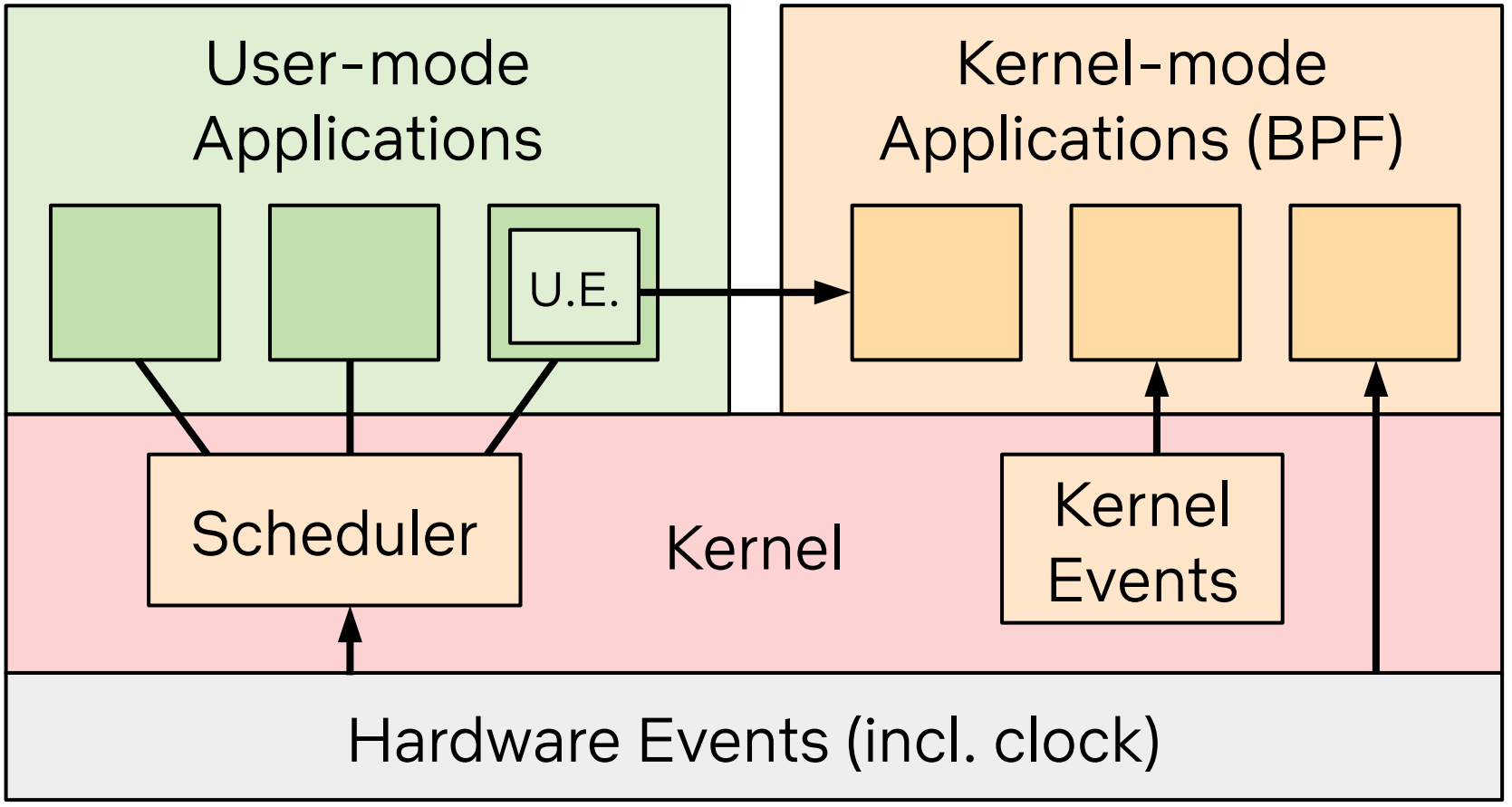
(Note: A static bpftrace/BTF + scripts will also have a small average tool size)

PSA

CONFIG_DEBUG_INFO_BTF=y

E.g., Ubuntu 20.10, Fedora 30, and RHEL 8.2 have it

BPF Future: Event-based Applications



A New Type of Software

	Execution model	User defined	Compil-ation	Security	Failure mode	Resource access
User	task	yes	any	user based	abort	syscall, fault
Kernel	task	no	static	none	panic	direct
BPF	event	yes	JIT, CO-RE	verified, JIT	error message	restricted helpers

Take Away

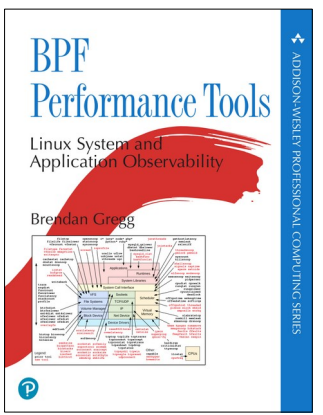
To get started with **BPF performance wins**,
think like a **sysadmin**:

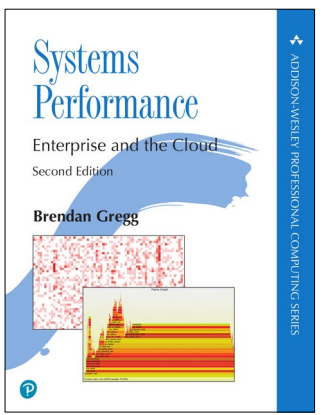
1. Install BCC & bpftrace tools
2. Run them
3. Get some wins

References

This is also where I recommend you go to learn more:

- https://github.com/iovisor/bcc/blob/master/docs/tutorial.md
- https://github.com/iovisor/bpftrace/blob/master/docs/tutorial_one_liners.md
- BPF Performance Tools, Addison Wesley 2020
- Systems Performance 2nd Edition, Addison Wesley 2021
- http://www.brendangregg.com/blog/2019-01-01/learn-ebpf-tracing.html
- http://www.brendangregg.com/ebpf.html
- https://ebpf.io/what-is-ebpf





Thanks

BPF: Alexei Starovoitov (Facebook), Daniel Borkmann (Isovalent), David S. Miller (Red Hat), Jakub Kicinski (Facebook), Yonghong Song (Facebook), Martin KaFai Lau (Facebook), John Fastabend (Isovalent), Quentin Monnet (Isovalent), Jesper Dangaard Brouer (Red Hat), Andrey Ignatov (Facebook), and Stanislav Fomichev (Google), Linus Torvalds, and many more in the BPF community

BCC: Brenden Blanco (VMware), Yonghong Song, Sasha Goldsthein (Google), Teng Qin (Facebook), Paul Chaignon (Isovalent), Vicent Martí (PlanetScale), and many more in the BCC community

bpftrace: Alastair Robertson (Yellowbrick Data), Dan Xu (Facebook), Bas Smit, Mary Marchini (Netflix), Masanori Misono, Jiri Olsa, Viktor Malík, Dale Hamel, Willian Gaspar, Augusto Mecking Caringi, and many more in the bpftrace community

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