Linux Observability Superpowers

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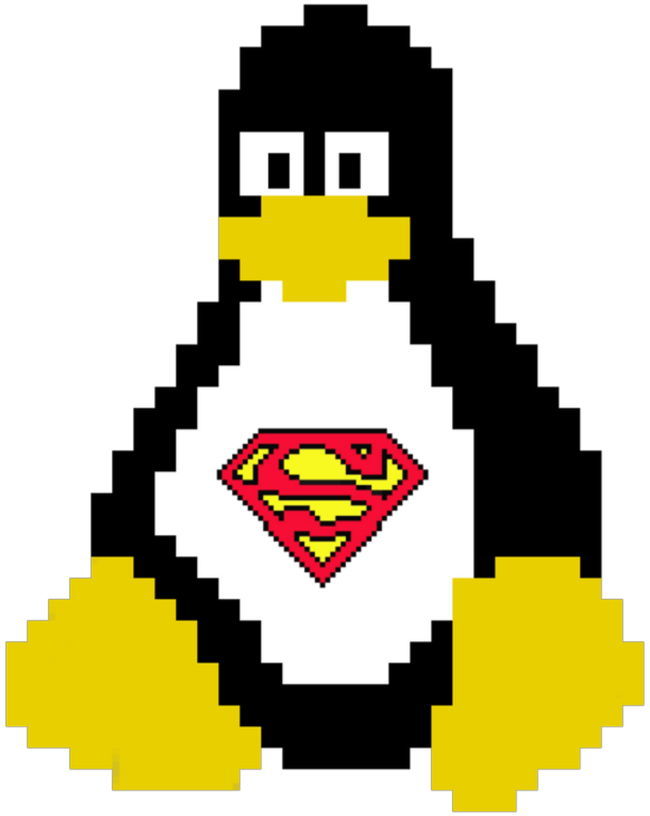
@mmarkini



sthima

Why is my application running so slow?
Customer
You

I don't know. Let me check and get back to you.
Customer
You

Check monitoring

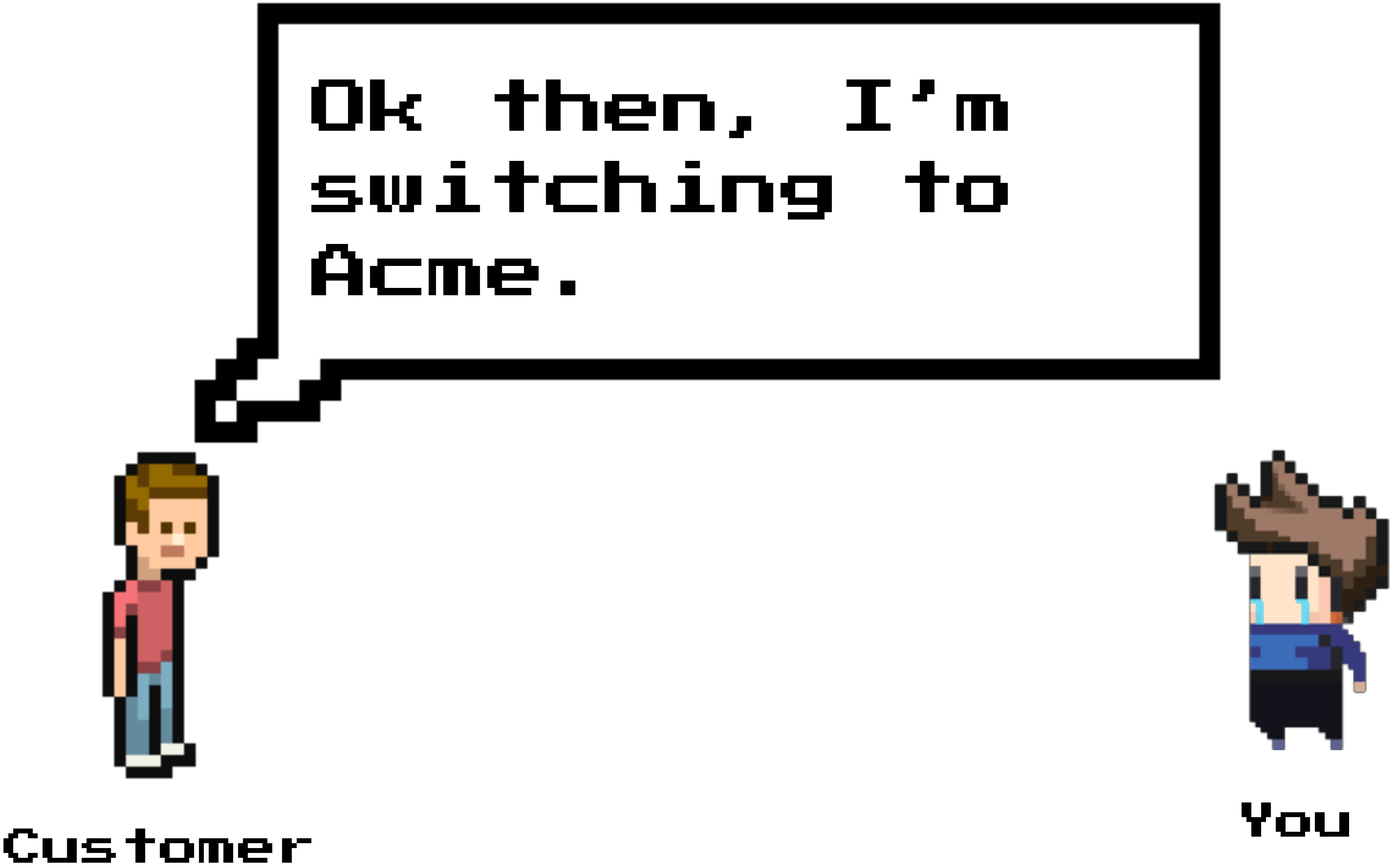
If you find the problem

We found and fixed the problem.
Customer
You

You're the best! Thank you ❤
Customer
You

If you don’t find the problem

I have no idea...
Customer
You


Ok then, I’m switching to Acme.
Customer
You

The Knowns

- Known-knowns
    - things you know exist and you already checked
- Known-unknowns
    - things you know exist but you haven't checked yet
- Unknown-unknowns
    - things you don't know exist or are not aware they are important

The Knowns examples

- Known-knowns
  - CPU usage is 10%
- Known-unknowns
  - Have't checked packages latency yet
- Unknown-unknowns
  - Don't know device interrupts could be heavy CPU consumers, therefore haven't checked it yet

USE Method

- Utilization
- Saturation
- Errors

60 seconds performance analysis

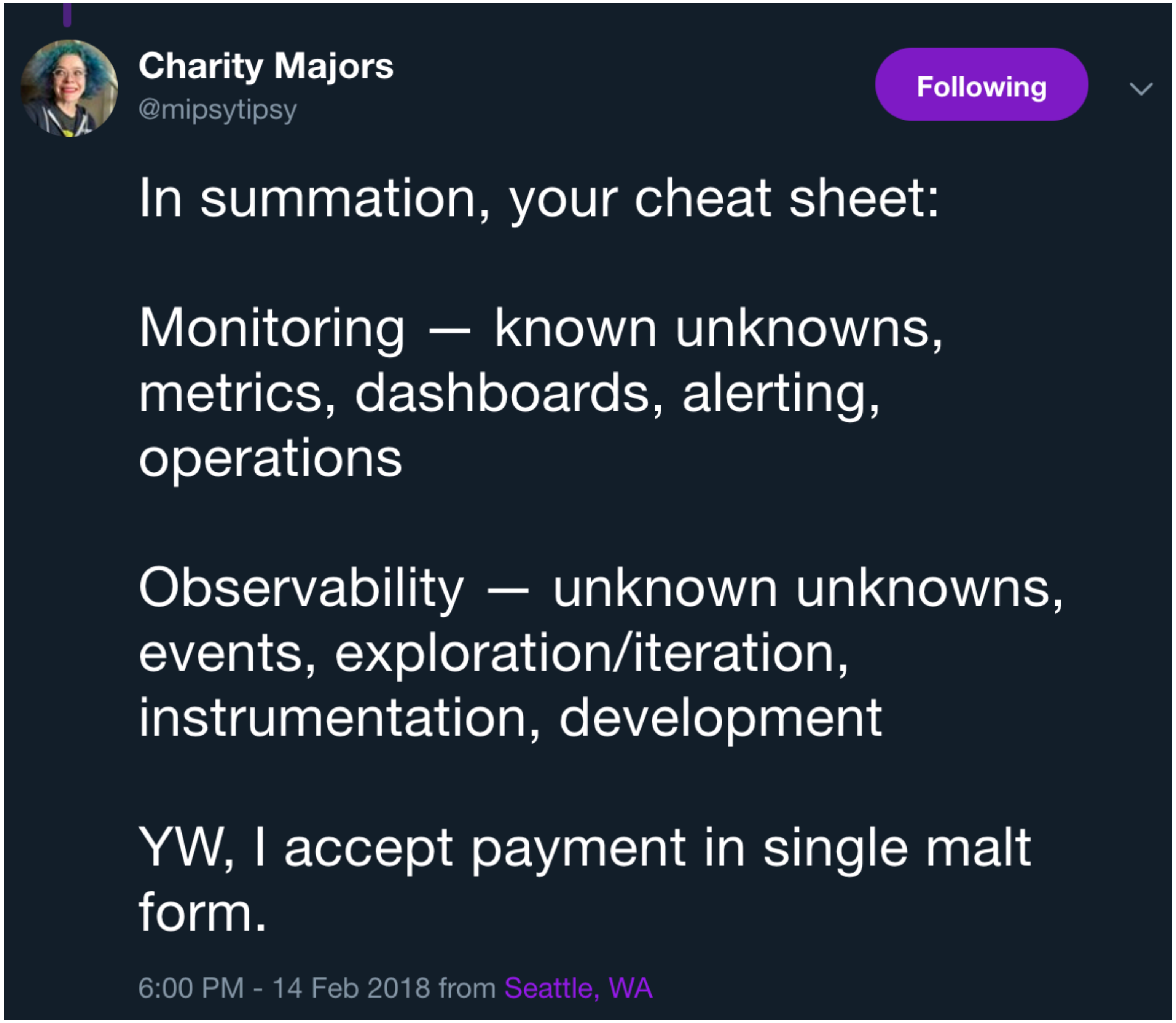
- uptime
- dmesg | tail
- vmstat 1
- mpstat -P ALL 1
- pidstat 1
- iostat -xz 1
- free -m
- sar -n DEV 1
- sar -n TCP,ETCP 1
- top

https://medium.com/netflix-techblog/linux-performance-analysis-in-60-000-milliseconds-accc10403c55

Observability

"it's a measure of how well internal states of a system can be inferred from knowledge of its external outputs. So in contrast to monitoring which is something we actually do, observability (as a noun), is more a property of a system."

https://thenewstack.io/monitoring-and-observability-whats-the-difference-and-why-does-it-matter/



Charity Majors
@mipsytipsy

In summation, your cheat sheet:

Monitoring — known unknowns, metrics, dashboards, alerting, operations

Observability — unknown unknowns, events, exploration/iteration, instrumentation, development

YW, I accept payment in single malt form.

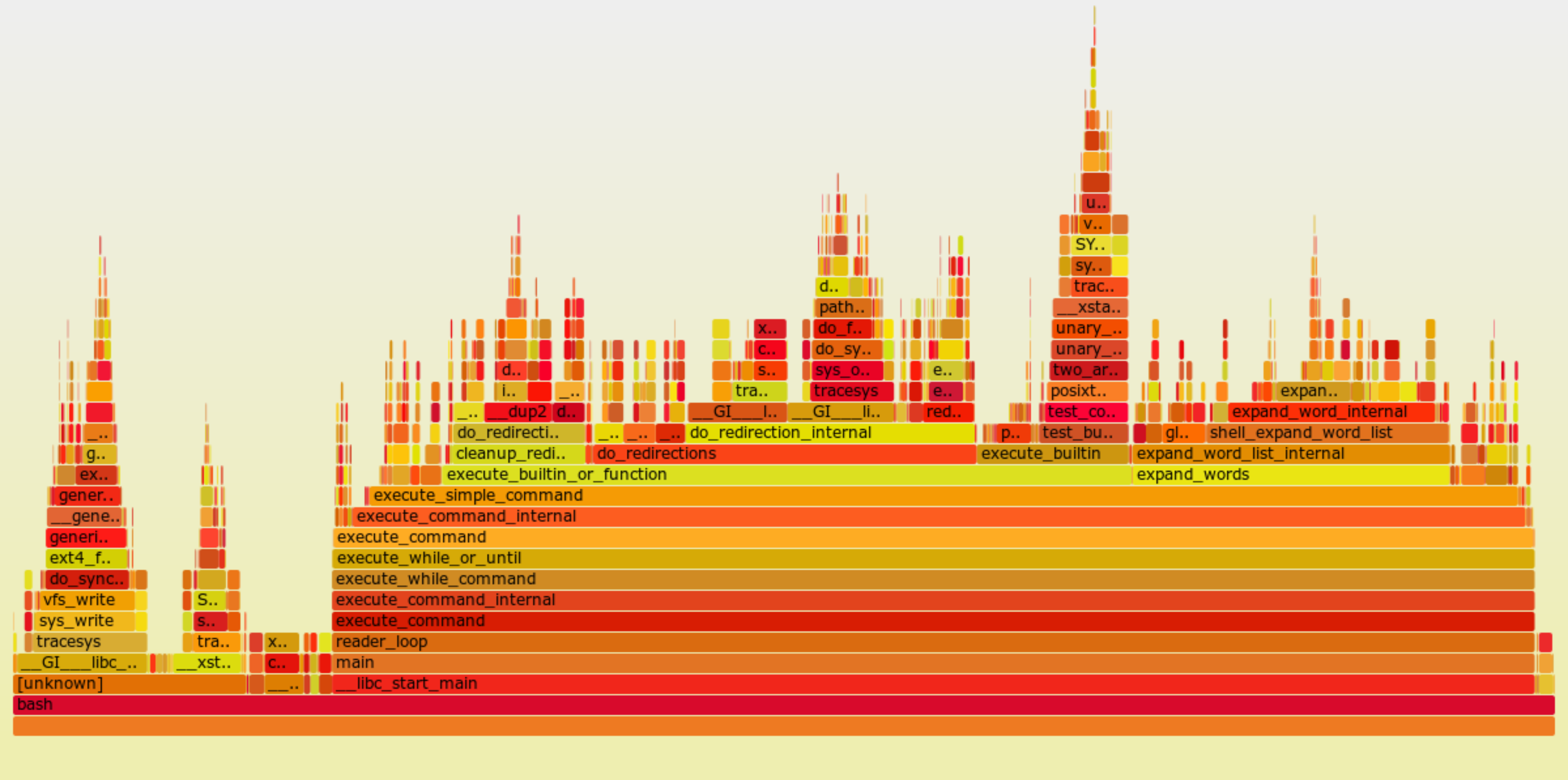
6:00 PM - 14 Feb 2018 from Seattle, WA

If high-level metrics aren’t enough, drill-down the offending resource

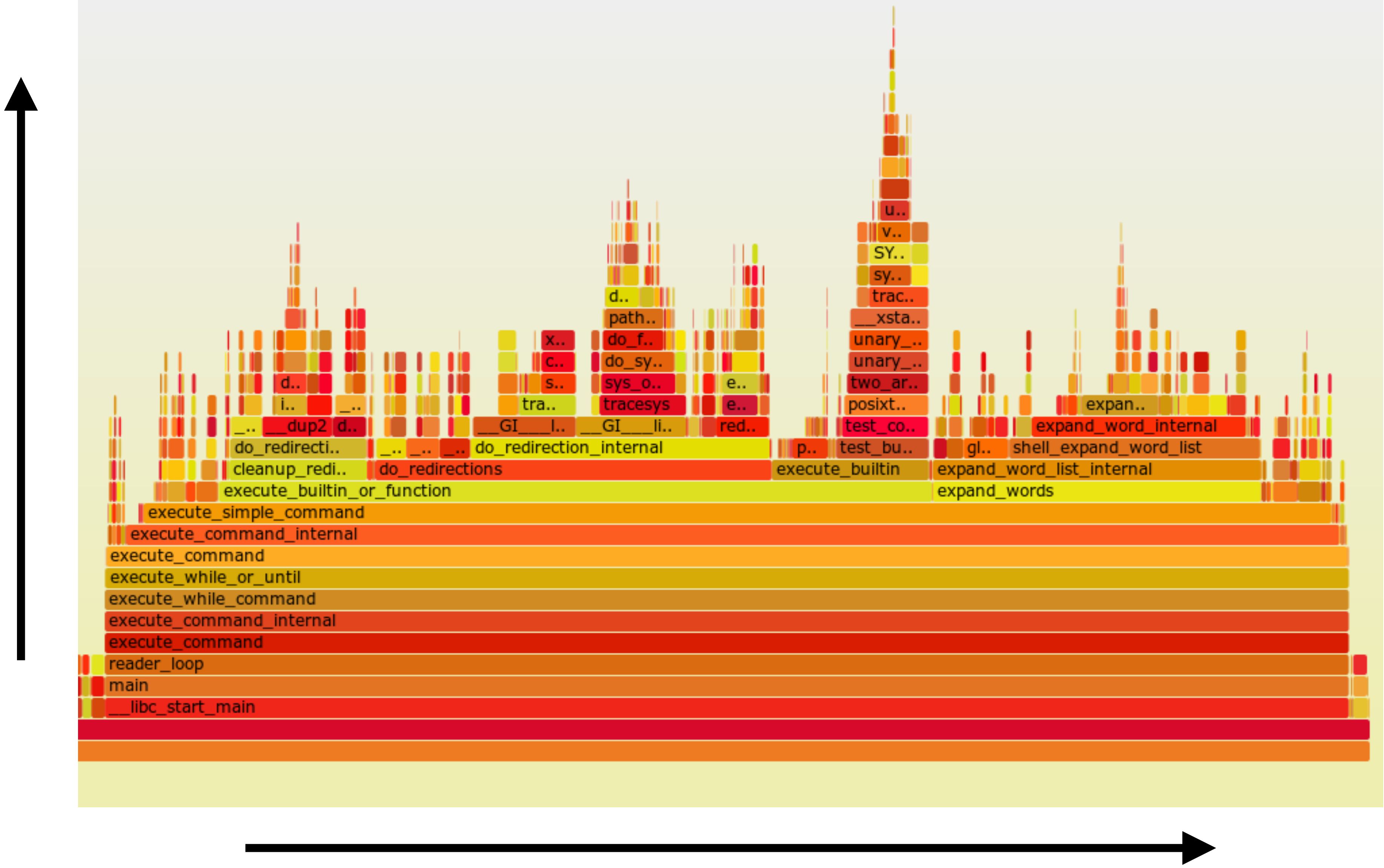
Drill-down analysis

- Generates a lot of data
  - Hard to consume
- Aggregate and/or filter data for better visualization

FlameGraphs



Call Stack



Time on CPU

Colors: arbitrary.
Can be used as third
dimension.

FlameGraphs visualization tools

- brendangregg/FlameGraph
- Netflix/flamescope
- npm install flamegraph
- Chrome DevTools
- etc...

What about sampling?

- Linux perf
- Runtime specific profilers
  - For example: V8 CpuProfiler

FlameGraphs: not only for CPU time

- Cycles per Instruction (CPI)
- Off-CPU time
  - Waiting for I/O, mutex lock, etc.
- Off-Wake time
- Memory usage

FlameGraphs

- CPU time
- CPI
- Off-CPU time
- Wakeup time
- Off-Wake
- Memory usage

Wasn’t possible or practical before

Berkeley Packet Filter

- Kernel-space Virtual Machine
    - Versatile
    - Performant
    - Safe

BPF: what is it used for?

“crazy stuff”

Alexei Starovoitov,
Facebook

BPF: Versatile

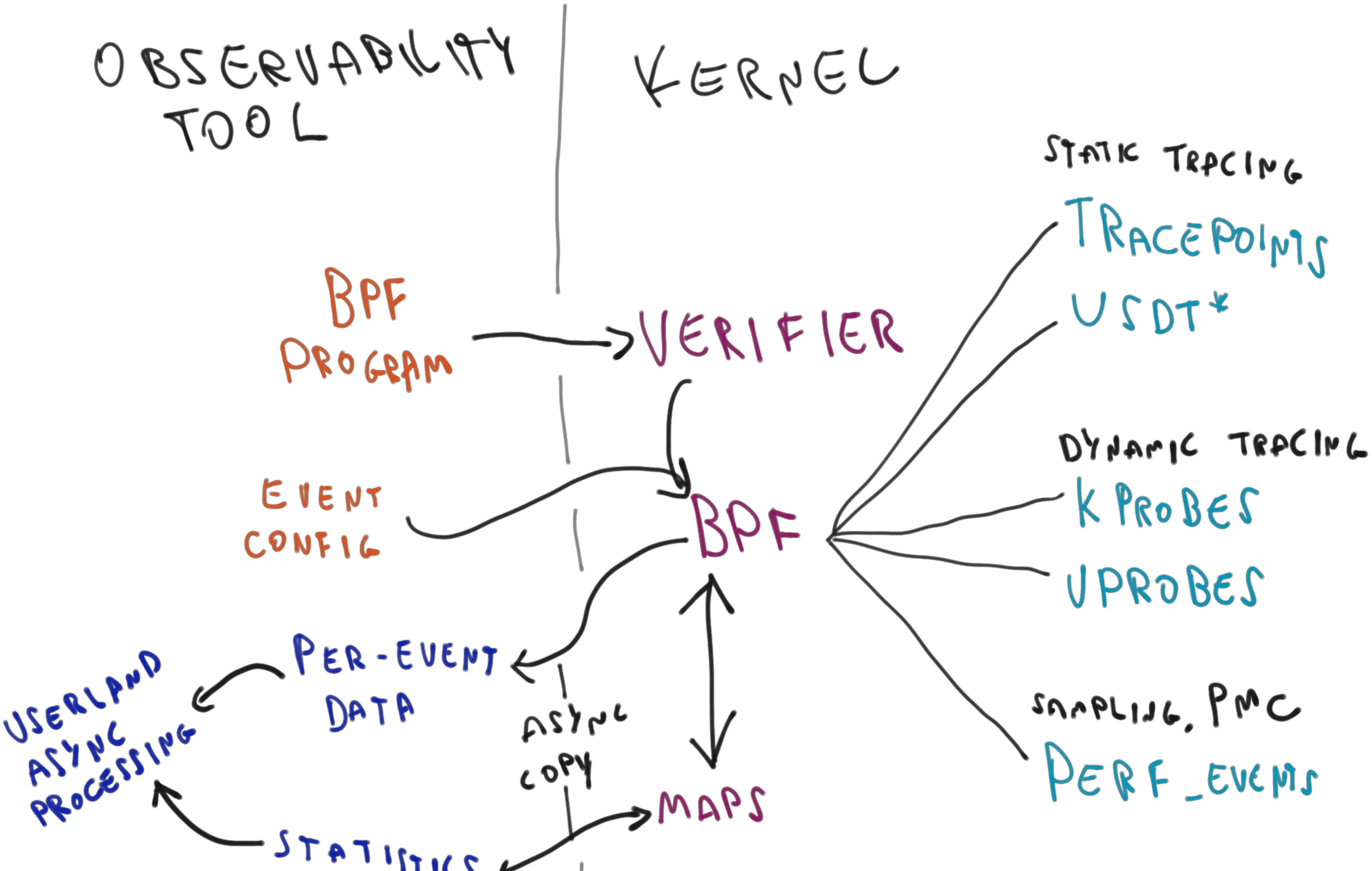
- Write Kernel-space programs without touching Kernel code

BPF: Performance

- Simple assembly instruction set
  - Usually maps 1-1 to x64
- Runs in Kernel-space
- Validator guarantees BPF program simplicity

BPF: Safety

- Validator guarantees:
  - Only read from initialized memory
    - Including offsets in some cases
  - No direct memory access outside the VM
  - No loops, max instructions, etc.
- No destructive operations
  - For example: can't kill a process from a BPF program



* USES UPROBES EVENTS

Writing BPF programs

```
0:   (bf) r6 = r1
1:   (b7) r1 = 0
2:   (7b) *(u64 *)(r10 -32) = r1
3:   (7b) *(u64 *)(r10 -40) = r1
4:   (bf) r3 = r6
5:   (07) r3 += 8
6:   (bf) r1 = r10
7:   (07) r1 += -8
8:   (b7) r2 = 4
9:   (85) call bpf_probe_read#4
10:  (61) r1 = *(u32 *)(r10 -8)
11:  (63) *(u32 *)(r10 -32) = r1
```

iovisor
PROJECT

The IO Visor Project is an open source project and a community of developers to accelerate the innovation, development, and sharing of virtualized in-kernel IO services for tracing, analytics, monitoring, security and networking functions.

facebook

HUAWEI

ubuntu
Supported by Canonical

NETRONOME

SUSE

vmware

BPF Compiler Collection: BCC

https://github.com/iovisor/bcc

BCC Python Example

```python
# load BPF program
b = BPF(text="""
TRACEPOINT_PROBE(random, urandom_read) {
    bpf_trace_printk("%d\\n", args->got_bits);
    return 0;
}
""")

# format output
while 1:
    try:
        (task, pid, cpu, flags, ts, msg) = b.trace_fields()
    except ValueError:
        continue
    print("%-18.9f %-16s %-6d %s" % (ts, task, pid, msg))
```

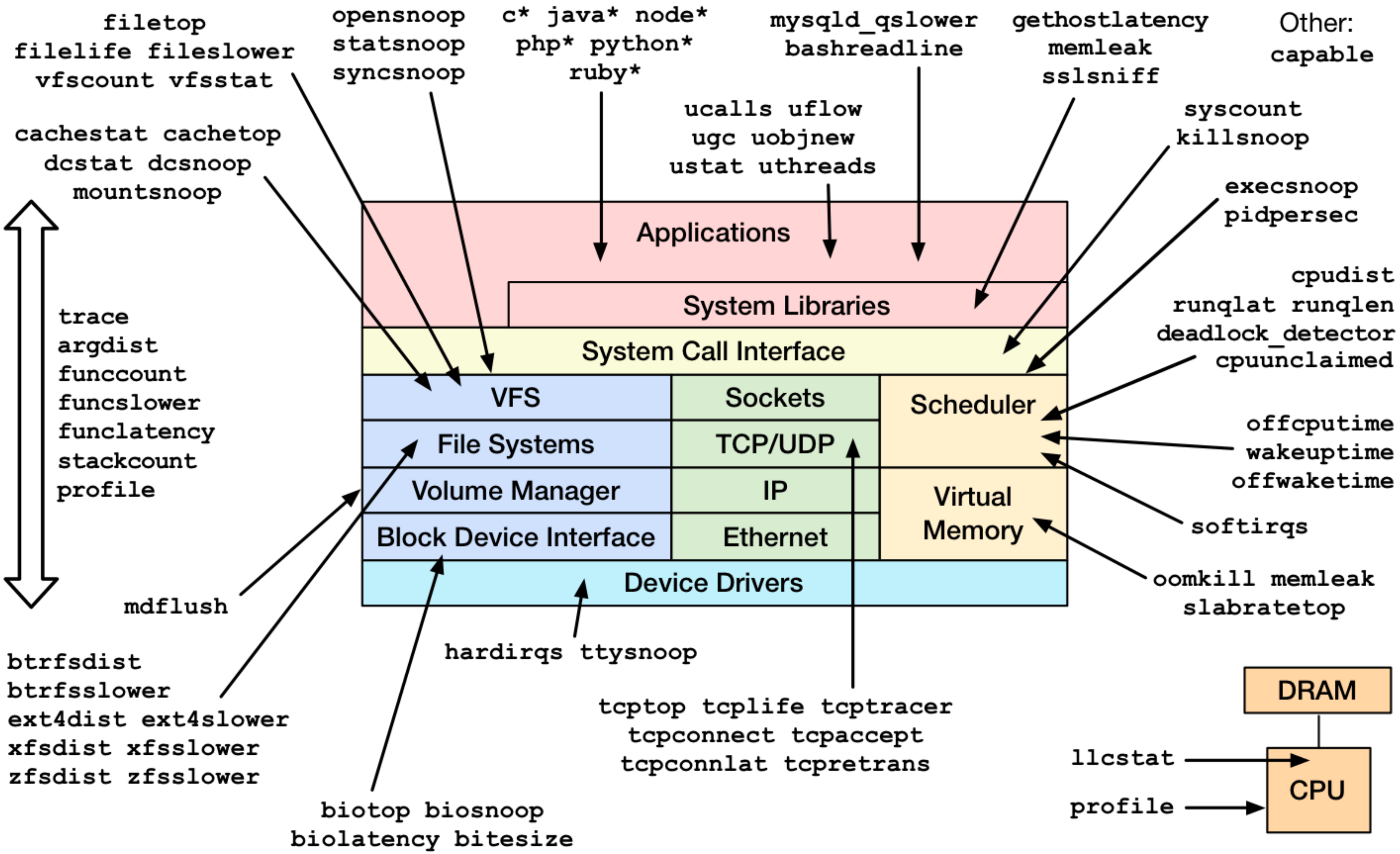
BCC tools

- tools/argdist: Display function parameter values as a histogram or frequency count. Examples.
- tools/bashreadline: Print entered bash commands system wide. Examples.
- tools/biolatency: Summarize block device I/O latency as a histogram. Examples.
- tools/biotop: Top for disks: Summarize block device I/O by process. Examples.
- tools/biosnoop: Trace block device I/O with PID and latency. Examples.
- tools/bitesize: Show per process I/O size histogram. Examples.
- tools/bpflist: Display processes with active BPF programs and maps. Examples.
- tools/btrfsdist: Summarize btrfs operation latency distribution as a histogram. Examples.
- tools/btrfsslower: Trace slow btrfs operations. Examples.
- tools/capable: Trace security capability checks. Examples.
- tools/cachestat: Trace page cache hit/miss ratio. Examples.
- tools/cachetop: Trace page cache hit/miss ratio by processes. Examples.
- tools/cpudist: Summarize on- and off-CPU time per task as a histogram. Examples
- tools/cpuunclaimed: Sample CPU run queues and calculate unclaimed idle CPU. Examples
- tools/criticalstat: Trace and report long atomic critical sections in the kernel. Examples
- tools/dbslower: Trace MySQL/PostgreSQL queries slower than a threshold. Examples.
- tools/dbstat: Summarize MySQL/PostgreSQL query latency as a histogram. Examples.
- tools/dcsnoop: Trace directory entry cache (dcache) lookups. Examples.
- tools/dcstat: Directory entry cache (dcache) stats. Examples.
- tools/deadlock_detector: Detect potential deadlocks on a running process. Examples.
- tools/execsnoop: Trace new processes via exec() syscalls. Examples.
- tools/ext4dist: Summarize ext4 operation latency distribution as a histogram. Examples.
- tools/ext4slower: Trace slow ext4 operations. Examples.
- tools/filelife: Trace the lifespan of short-lived files. Examples.
- tools/fileslower: Trace slow synchronous file reads and writes. Examples.
- tools/filetop: File reads and writes by filename and process. Top for files. Examples.
- tools/funccount: Count kernel function calls. Examples.
- tools/funclatency: Time functions and show their latency distribution. Examples.
- tools/funcslower: Trace slow kernel or user function calls. Examples.
- tools/gethostlatency: Show latency for getaddrinfo/gethostbyname[2] calls. Examples.
- tools/hardirqs: Measure hard IRQ (hard interrupt) event time. Examples.
- tools/inject: Targeted error injection with call chain and predicates Examples.
- tools/killsnoop: Trace signals issued by the kill() syscall. Examples.
- tools/llcstat: Summarize CPU cache references and misses by process. Examples.
- tools/mdflush: Trace md flush events. Examples.
- tools/mysqld_qslower: Trace MySQL server queries slower than a threshold. Examples.
- tools/memleak: Display outstanding memory allocations to find memory leaks. Examples.
- tools/nfsslower: Trace slow NFS operations. Examples.
- tools/nfsdist: Summarize NFS operation latency distribution as a histogram. Examples.
- tools/offcputime: Summarize off-CPU time by kernel stack trace. Examples.
- tools/offwaketime: Summarize blocked time by kernel off-CPU stack and waker stack. Examples.
- tools/oomkill: Trace the out-of-memory (OOM) killer. Examples.

- tools/opensnoop: Trace open() syscalls. Examples.
- tools/pidpersec: Count new processes (via fork). Examples.
- tools/profile: Profile CPU usage by sampling stack traces at a timed interval. Examples.
- tools/reset-trace: Reset the state of tracing. Maintenance tool only. Examples.
- tools/runqlat: Run queue (scheduler) latency as a histogram. Examples.
- tools/runqlen: Run queue length as a histogram. Examples.
- tools/runqslower: Trace long process scheduling delays. Examples.
- tools/shmsnoop: Trace System V shared memory syscalls. Examples.
- tools/sofdsnoop: Trace FDs passed through unix sockets. Examples.
- tools/slabratetop: Kernel SLAB/SLUB memory cache allocation rate top. Examples.
- tools/softirqs: Measure soft IRQ (soft interrupt) event time. Examples.
- tools/solisten: Trace TCP socket listen. Examples.
- tools/sslsniff: Sniff OpenSSL written and readed data. Examples.
- tools/stackcount: Count kernel function calls and their stack traces. Examples.
- tools/syncsnoop: Trace sync() syscall. Examples.
- tools/syscount: Summarize syscall counts and latencies. Examples.
- tools/tcpaccept: Trace TCP passive connections (accept()). Examples.
- tools/tcpconnect: Trace TCP active connections (connect()). Examples.
- tools/tcpconnlat: Trace TCP active connection latency (connect()). Examples.
- tools/tcpdrop: Trace kernel-based TCP packet drops with details. Examples.
- tools/tcplife: Trace TCP sessions and summarize lifespan. Examples.
- tools/tcpretrans: Trace TCP retransmits and TLPs. Examples.
- tools/tcpstates: Trace TCP session state changes with durations. Examples.
- tools/tcpsubnet: Summarize and aggregate TCP send by subnet. Examples.
- tools/tcptop: Summarize TCP send/recv throughput by host. Top for TCP. Examples.
- tools/tcptracer: Trace TCP established connections (connect(), accept(), close()). Examples.
- tools/tplist: Display kernel tracepoints or USDT probes and their formats. Examples.
- tools/trace: Trace arbitrary functions, with filters. Examples.
- tools/ttysnoop: Watch live output from a tty or pts device. Examples.
- tools/ucalls: Summarize method calls or Linux syscalls in high-level languages. Examples.
- tools/uflow: Print a method flow graph in high-level languages. Examples.
- tools/ugc: Trace garbage collection events in high-level languages. Examples.
- tools/uobjnew: Summarize object allocation events by object type and number of bytes allocated.
- tools/ustat: Collect events such as GCs, thread creations, object allocations, exceptions and more
- tools/uthreads: Trace thread creation events in Java and raw pthreads. Examples.
- tools/vfscount tools/vfscount.c: Count VFS calls. Examples.
- tools/vfsstat tools/vfsstat.c: Count some VFS calls, with column output. Examples.
- tools/wakeuptime: Summarize sleep to wakeup time by waker kernel stack. Examples.
- tools/xfsdist: Summarize XFS operation latency distribution as a histogram. Examples.
- tools/xfsslower: Trace slow XFS operations. Examples.
- tools/zfsdist: Summarize ZFS operation latency distribution as a histogram. Examples.
- tools/zfsslower: Trace slow ZFS operations. Examples.

100+ tools

Linux bcc/BPF Tracing Tools



filetop
filelife fileslower
vfscount vfsstat

cachestat cachetop
dcstat dcsnoop
mountsnoop

opensnoop
statsnoop
syncsnoop

c* java* node*
php* python*
ruby*

ucalls uflow
ugc uobjnew
ustat uthreads

mysqld_qslower
bashreadline

gethostlatency
memleak
sslsniff

Other:
capable

syscount
killsnoop

execsnoop
pidpersec

cpudist
runqlat runqlen
deadlock_detector
cpuunclaimed

offcputime
wakeuptime
offwaketime

softirqs

oomkill memleak
slabratetop

trace
argdist
funccount
funcslower
funclatency
stackcount
profile

mdflush

btrfsdist
btrfsslower
ext4dist ext4slower
xfsdist xfsslower
zfsdist zfsslower

biotop biosnoop
biolatency bitesize

hardirqs ttysnoop

tcptop tcplife tcptracer
tcpconnect tcpaccept
tcpconnlat tcpretrans

llcstat

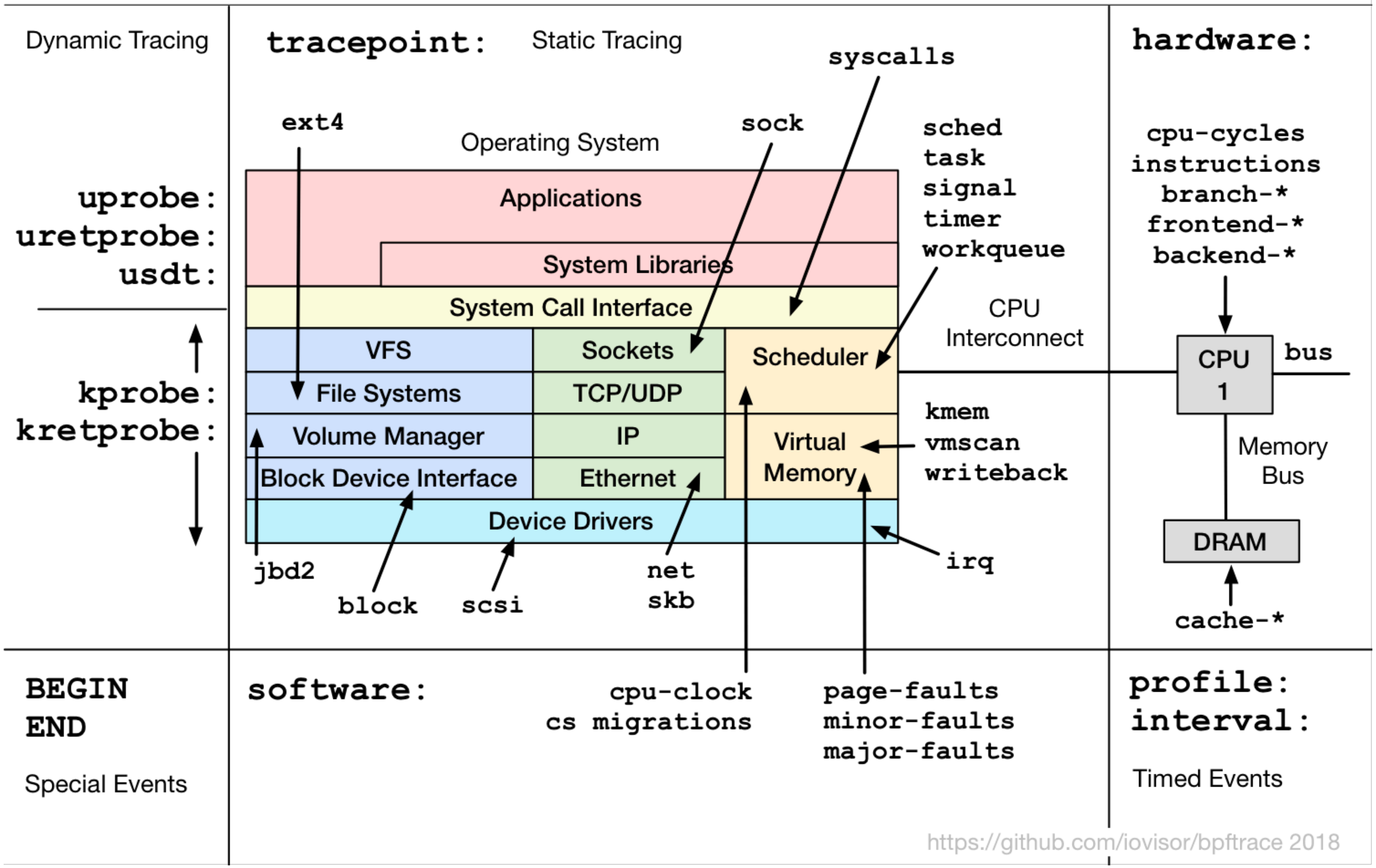
profile

https://github.com/iovisor/bcc#tools 2017

bpftrace: high-level tracing language

```
# Files opened by process
bpftrace -e 'tracepoint:syscalls:sys_enter_open { printf("%s %s\n", comm,
str(args->filename)); }'

# Syscall count by syscall
bpftrace -e 'tracepoint:syscalls:sys_enter_* { @[probe] = count(); }'

# Syscall count by process
bpftrace -e 'tracepoint:raw_syscalls:sys_enter { @[pid, comm] = count(); }'

# Read size distribution by process:
bpftrace -e 'tracepoint:syscalls:sys_exit_read { @[comm] = hist(args->ret); }'

# Disk size by process
bpftrace -e 'tracepoint:block:block_rq_issue { printf("%d %s %d\n", pid, comm,
args->bytes); }'

# Pages paged in by process
bpftrace -e 'software:major-faults:1 { @[comm] = count(); }'

# Page faults by process
bpftrace -e 'software:faults:1 { @[comm] = count(); }'
```

bpftrace Probe Types



Dynamic Tracing

uprobe:
uretprobe:
usdt:

kprobe:
kretprobe:

tracepoint: Static Tracing

syscalls

ext4

Operating System

sock

sched
task
signal
timer
workqueue

Applications

System Libraries

System Call Interface

VFS

Sockets

Scheduler

File Systems

TCP/UDP

Volume Manager

IP

Virtual Memory

Block Device Interface

Ethernet

Device Drivers

CPU Interconnect

kmem
vmscan
writeback

irq

jbd2

block

scsi

net
skb

hardware:

cpu-cycles
instructions
branch-*
frontend-*
backend-*

CPU 1

bus

Memory Bus

DRAM

cache-*

BEGIN
END

Special Events

software:

cpu-clock
cs migrations

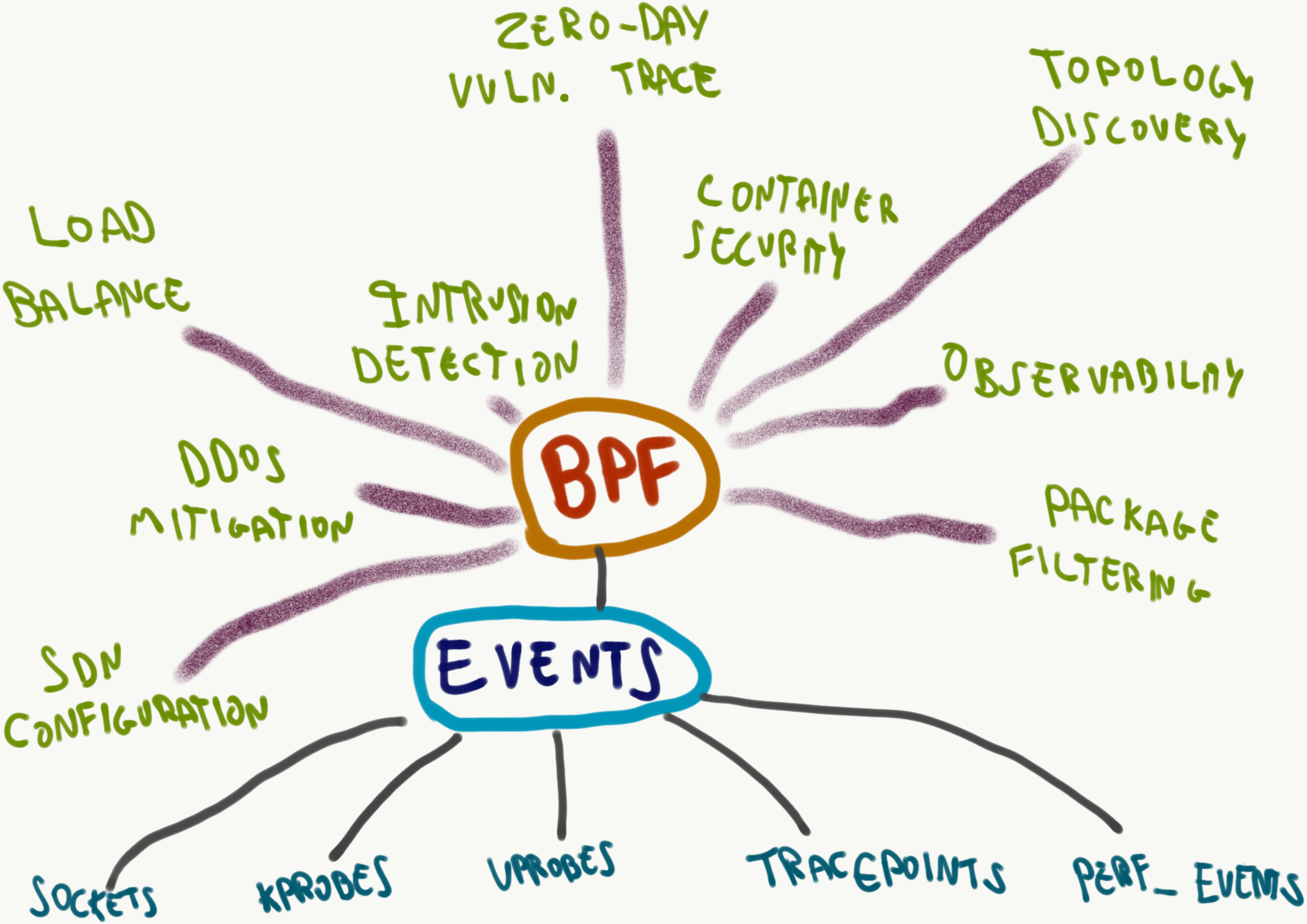
page-faults
minor-faults
major-faults

profile:
interval:

Timed Events

https://github.com/iovisor/bpftrace 2018

What else can we do with BPF?


ZERO-DAY VULN. TRACE
TOPOLOGY DISCOVERY
CONTAINER SECURITY
LOAD BALANCE
INTRUSION DETECTION
OBSERVABILITY
DDOS MITIGATION
BPF
PACKAGE FILTERING
EVENTS
SDN CONFIGURATION
SOCKETS
KPROBES
UPROBES
TRACEPOINTS
PERF_EVENTS

Who is using BPF?

facebook®
NETFLIX
ORACLE®
Google
cilium

Can I run it anywhere?

- Nope
  - Kernel version matters
  - Architecture also matters

How can I leverage BPF?

- Use existing project powered by BPF
  - Observability: bcc tools, bpftrace
  - Load balancer: Katran
- What about GUI?
  - Early stages, no tools available
  - Help us write some :D

Questions?