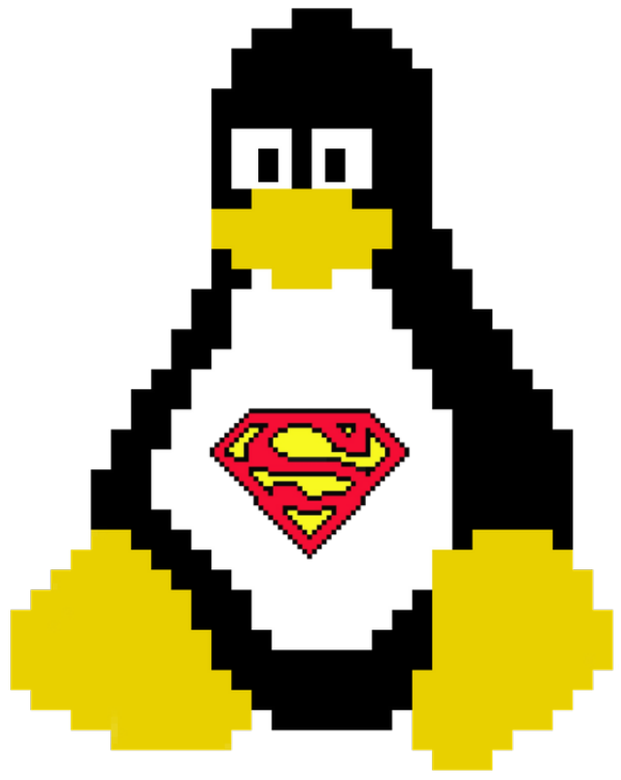
Linux Observability Superpowers

Mary Marchini
@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 fxed 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

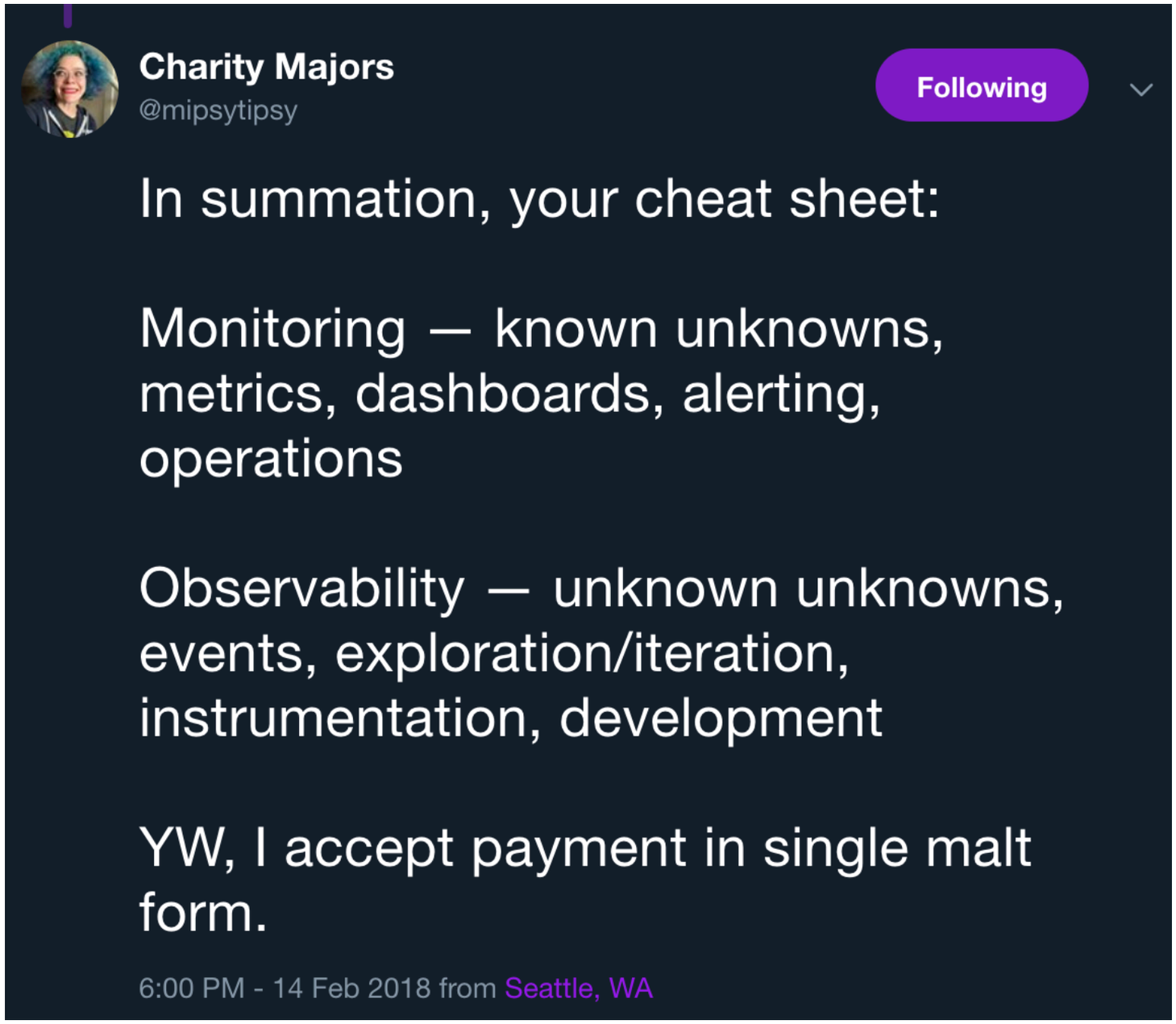
- uptime
- dmesg | tail
- vmstat 1
- mpstat -P ALL 1
- pidstat 1
- iostat -xz 1
- free -m
- sar -n DEV 1
- sar -n TCP,ETCP 1
- top

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/

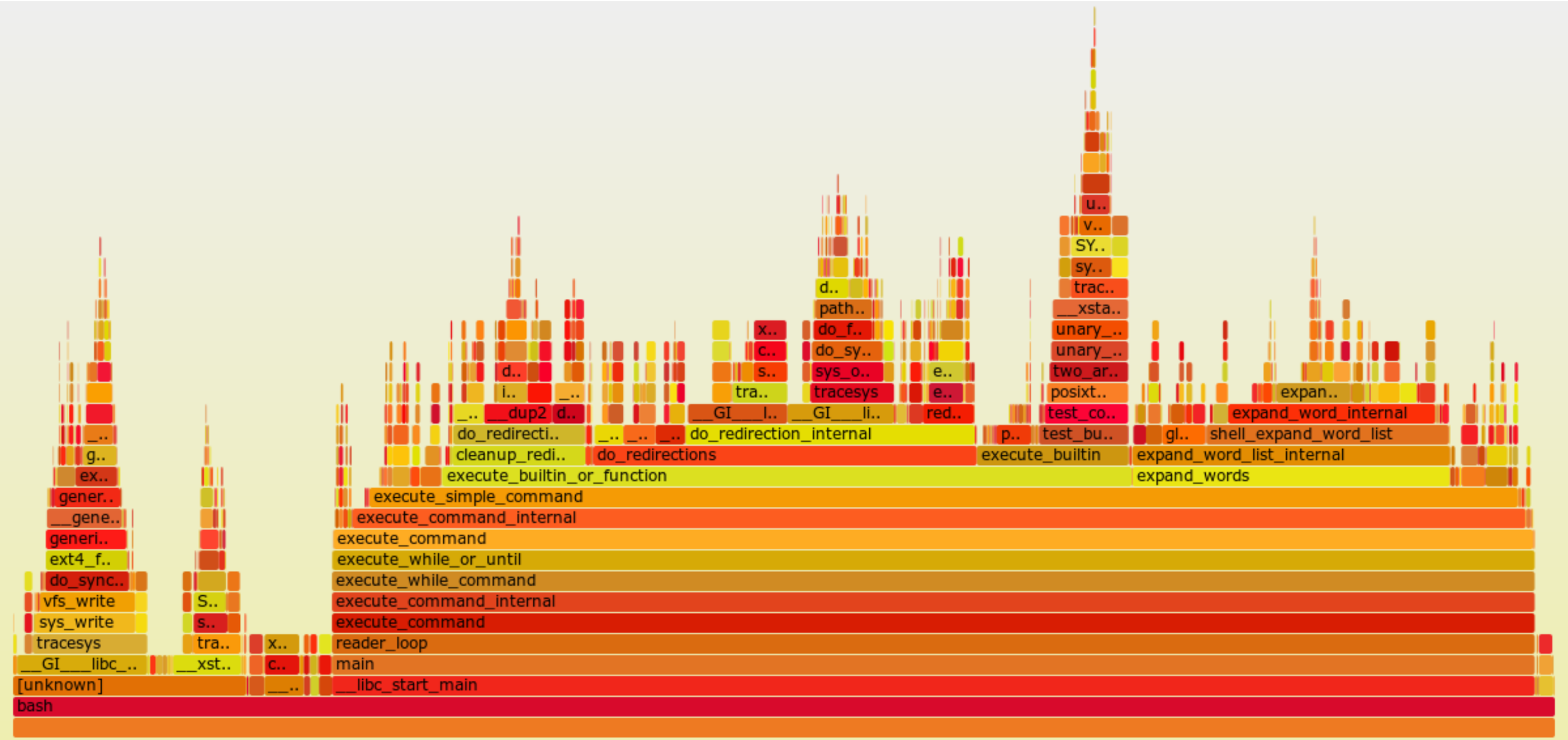

Charity Majors
@mipsytipsy
Following
In summation, your cheat sheet:
Monitoring — known unknowns, metrics, dashboards, alerting, operations
Observability — unknown unknowns, events, exploration/iteration, instrumentation, development
YW, I accept payment in single malt form.
6:00 PM - 14 Feb 2018 from Seattle, WA

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

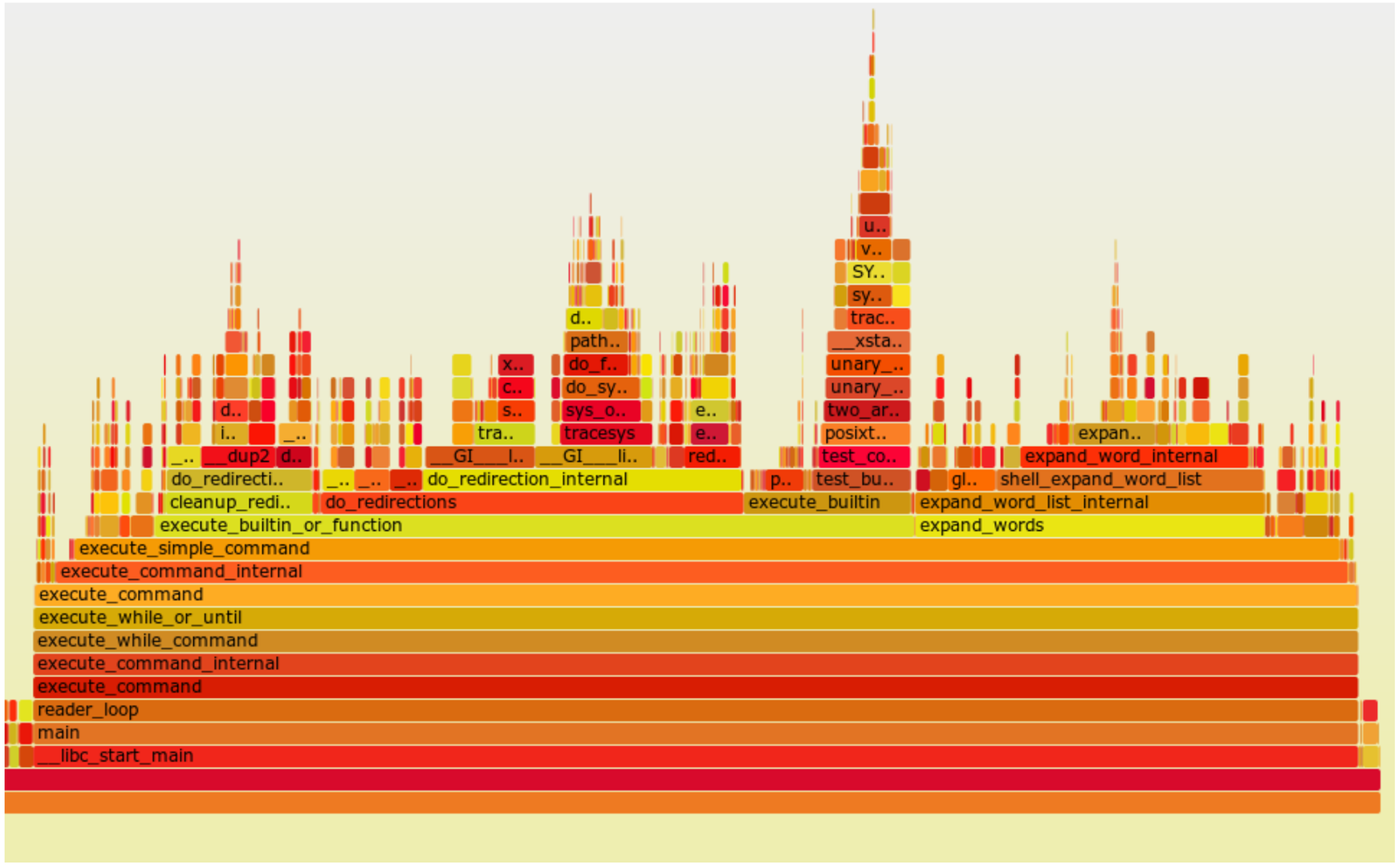
Drill-down analysis

- 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

OBSERVABILITY TOOL

KERNEL

BPF PROGRAM

VERIFIER

EVENT CONFIG

BPF

PER-EVENT DATA

USERLAND ASYNC PROCESSING

ASYNC COPY

MAPS

STATISTICS

STATIC TRACING

TRACEPOINTS

USDT*

DYNAMIC TRACING

KPROBES

UPROBES

SAMPLING, PMC

PERF_EVENTS

* 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
```

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.

BPF Compiler Collection: BCC

https://github.com/iovisor/bcc

BCC Python Example

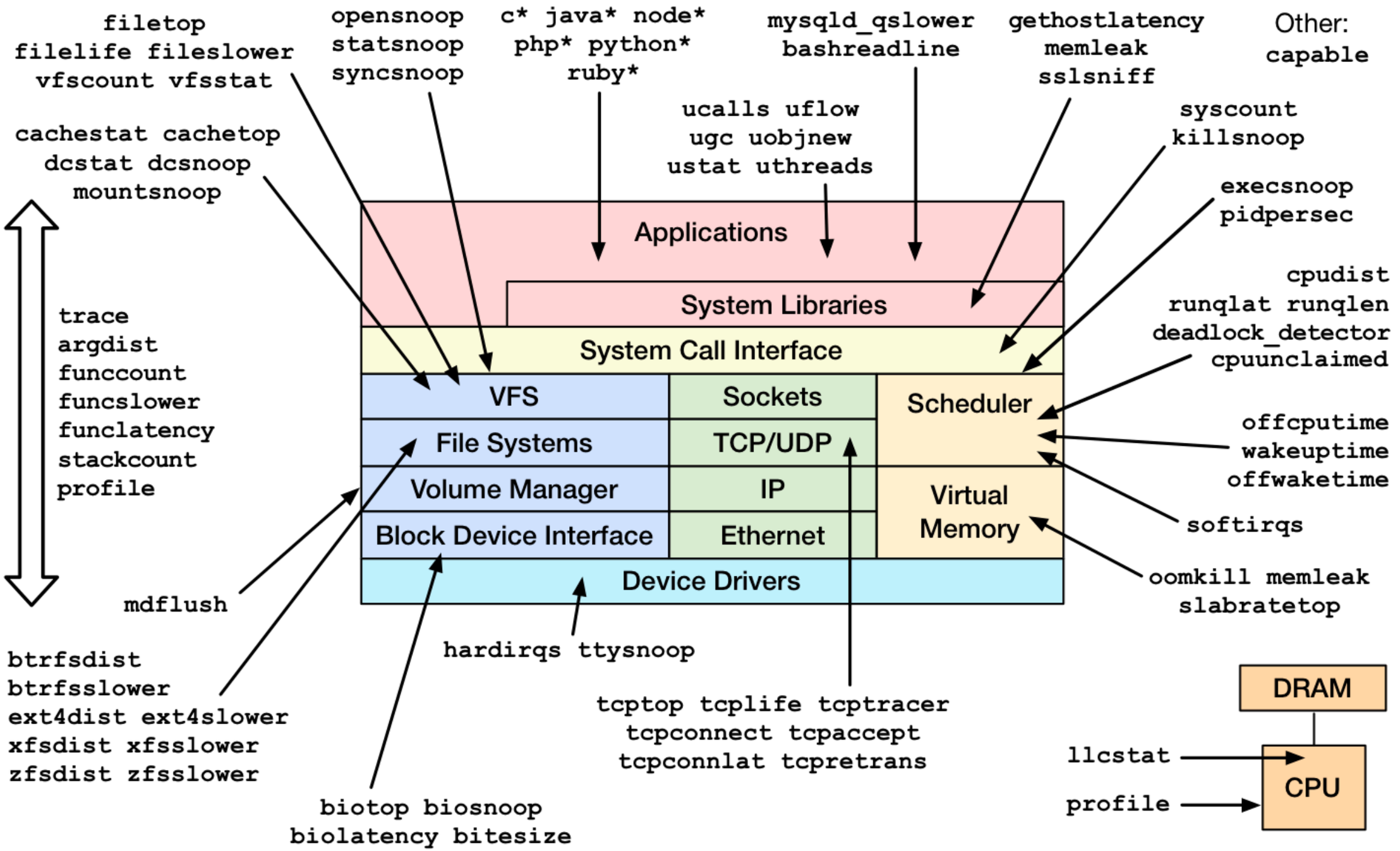
```
# load BPF program
b = BPF(text="""
TRACEPOINT_PROBE(random, urandom_read) {
    bpf_trace_printk("%d\\n", args->got_bits);
    return 0;
}
""")

# 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

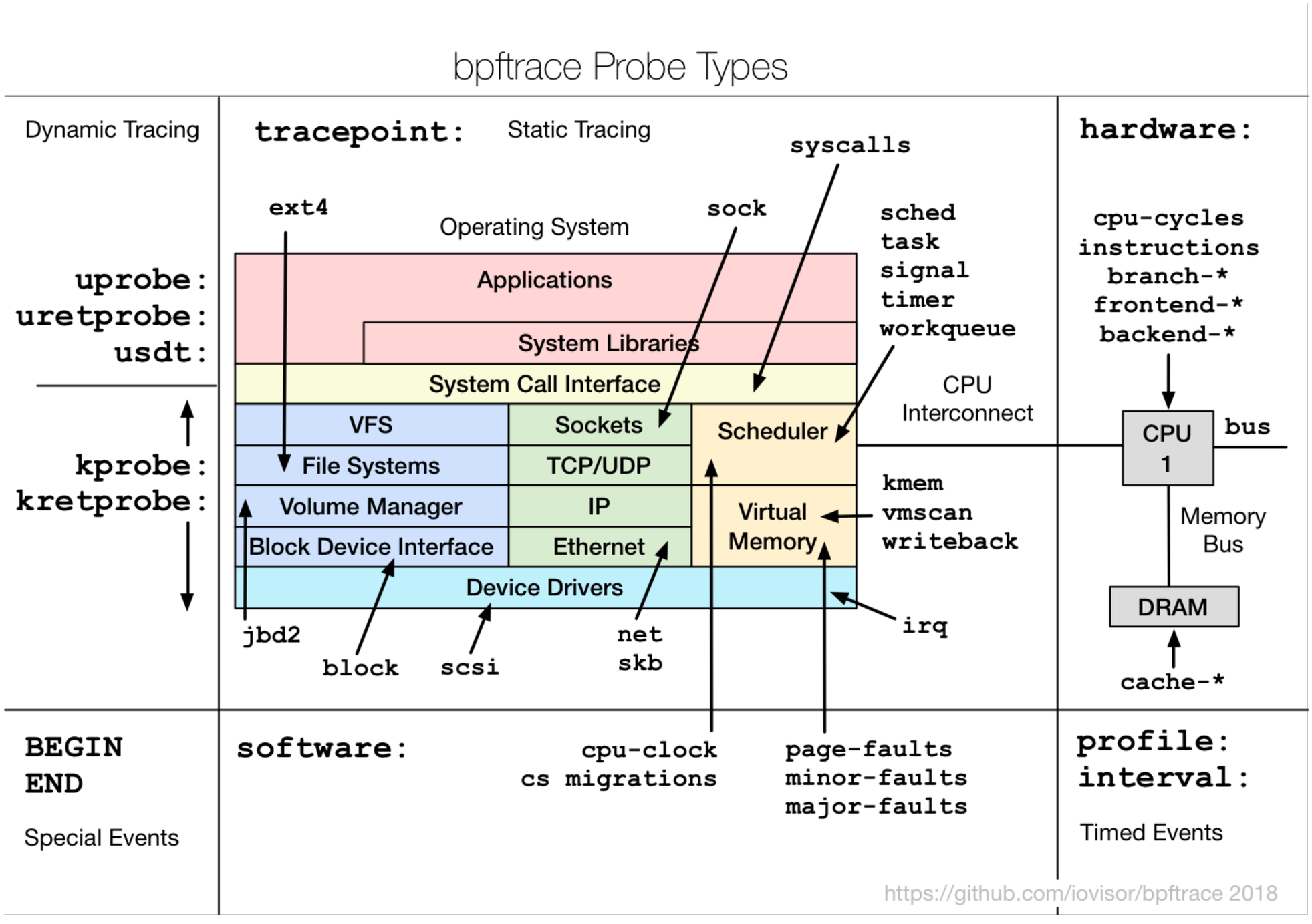


https://github.com/iovisor/bcc#tools 2017

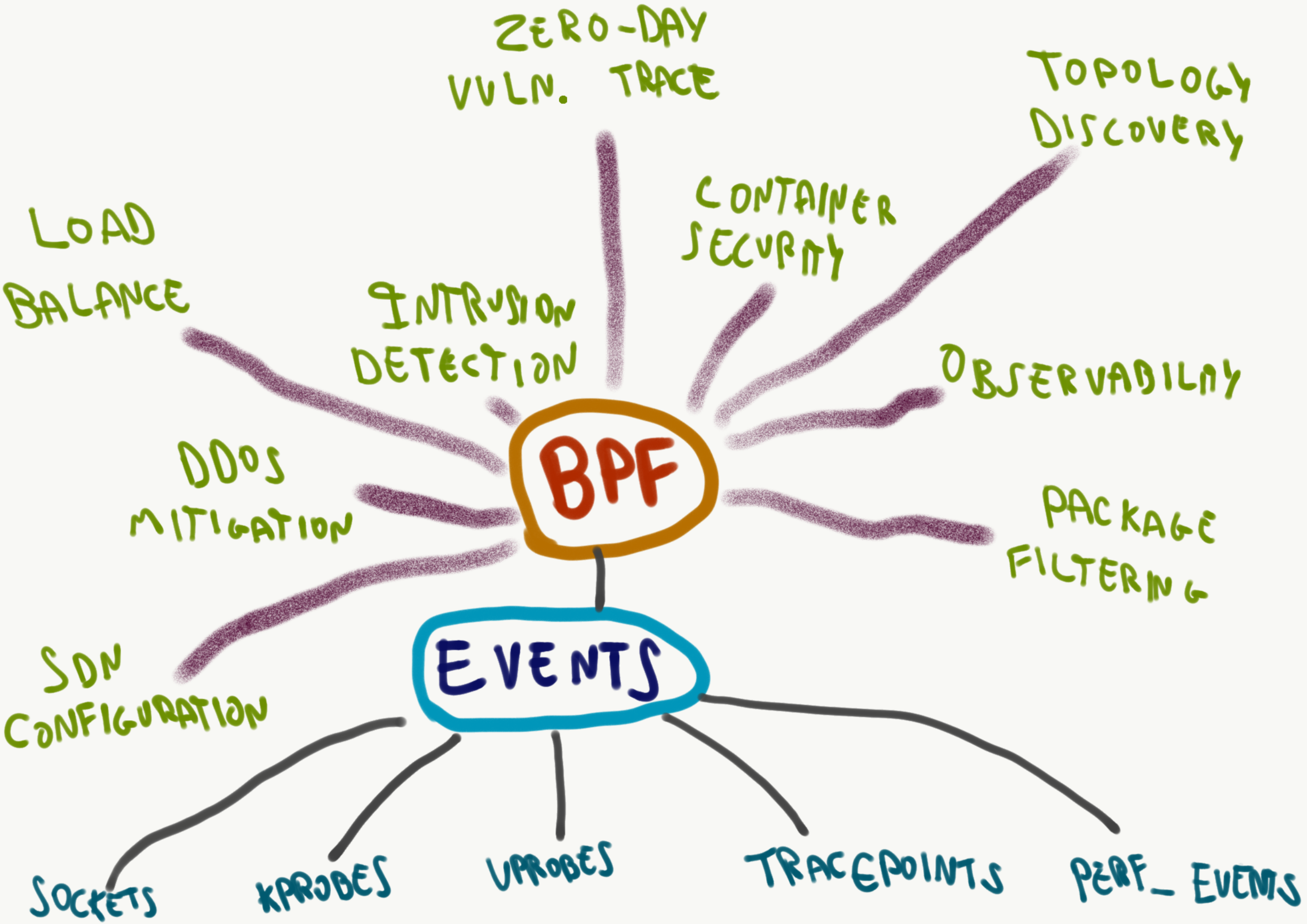
bpftrace: high-level tracing language

```
# 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
tracepoint:
Static Tracing
hardware:
uprobe:
uretprobe:
usdt:
kprobe:
kretprobe:
ext4
Operating System
sock
syscalls
sched
task
signal
timer
workqueue
Applications
System Libraries
System Call Interface
VFS
Sockets
Scheduler
File Systems
TCP/UDP
Volume Manager
IP
Block Device Interface
Ethernet
Virtual Memory
Device Drivers
CPU Interconnect
kmem
vmscan
writeback
irq
jbd2
block
scsi
net
skb
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
LOAD BALANCE
CONTAINER SECURITY
INTRUSION DETECTION
OBSERVABILITY
DDOS MITIGATION
BPF
PACKAGE FILTERING
SDN CONFIGURATION
EVENTS
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?