eBPF 101

“eBPF does to Linux what JavaScript does to HTML”

Brendan Gregg

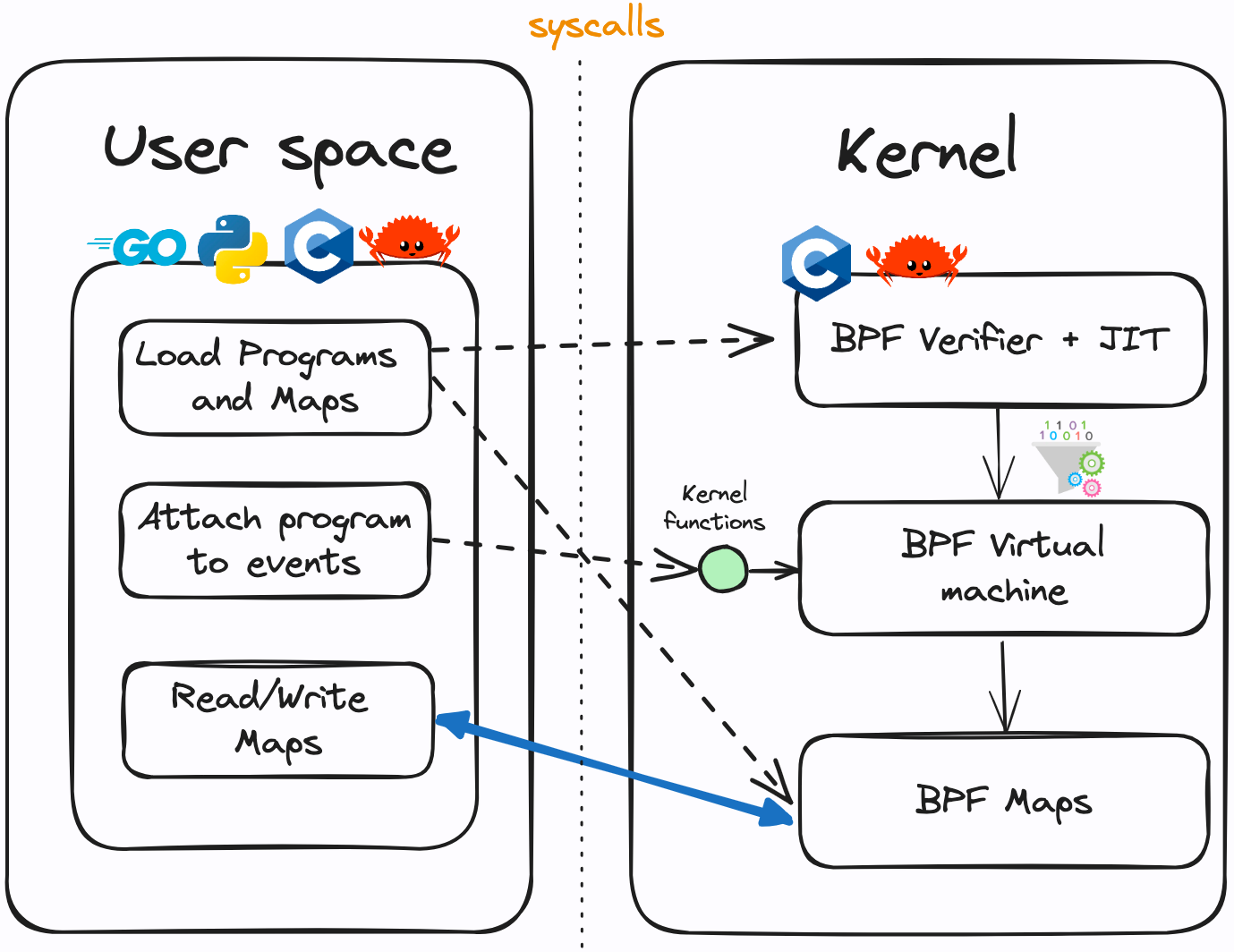
Agenda

- What is eBPF?
- Why do we need eBPF?
- Examples
  - The EASY way
  - The HARD way
- Takeaways

What is eBPF?

- BPF, **Berkeley Packet Filter**, was introduced to Linux in 1997, kernel version 2.1.75
- It has been used in the tcpdump utility to capture packets
- In 2012 `seccomp-bpf` was added to kernel version 3.5, allowed to take decisions about user apps making system calls
- eBPF, **extended BPF**, started in 2014 with new features...

The eBPF basics



Why do we need eBPF?

- To add new functionalities to the Kernel without the overhead of creating Kernel Modules, and with **dynamic loading**
- **Better performance** skipping the cost of transitioning between kernel and user space (for each event)
- It's a great match for **cloud native** environments, no more need for sidecar pattern

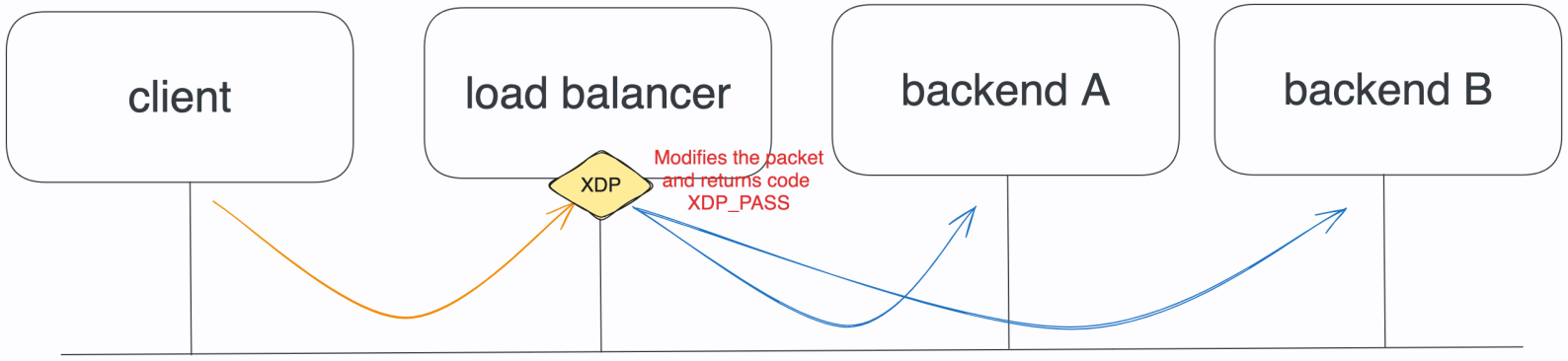
Where to use eBPF?

Observability, Networking & Security

- App observability (Beyla, Tetragon)
- Profile & Tracing (bpftrace, sysdig)
- Load-balancing (Katran)
- Network monitoring (Netobserv, pwru)
- Kubernetes (Cilium, Calico)
- Firewalls (Bpfilter)
- DDoS mitigation (Cloudflare, Meta)

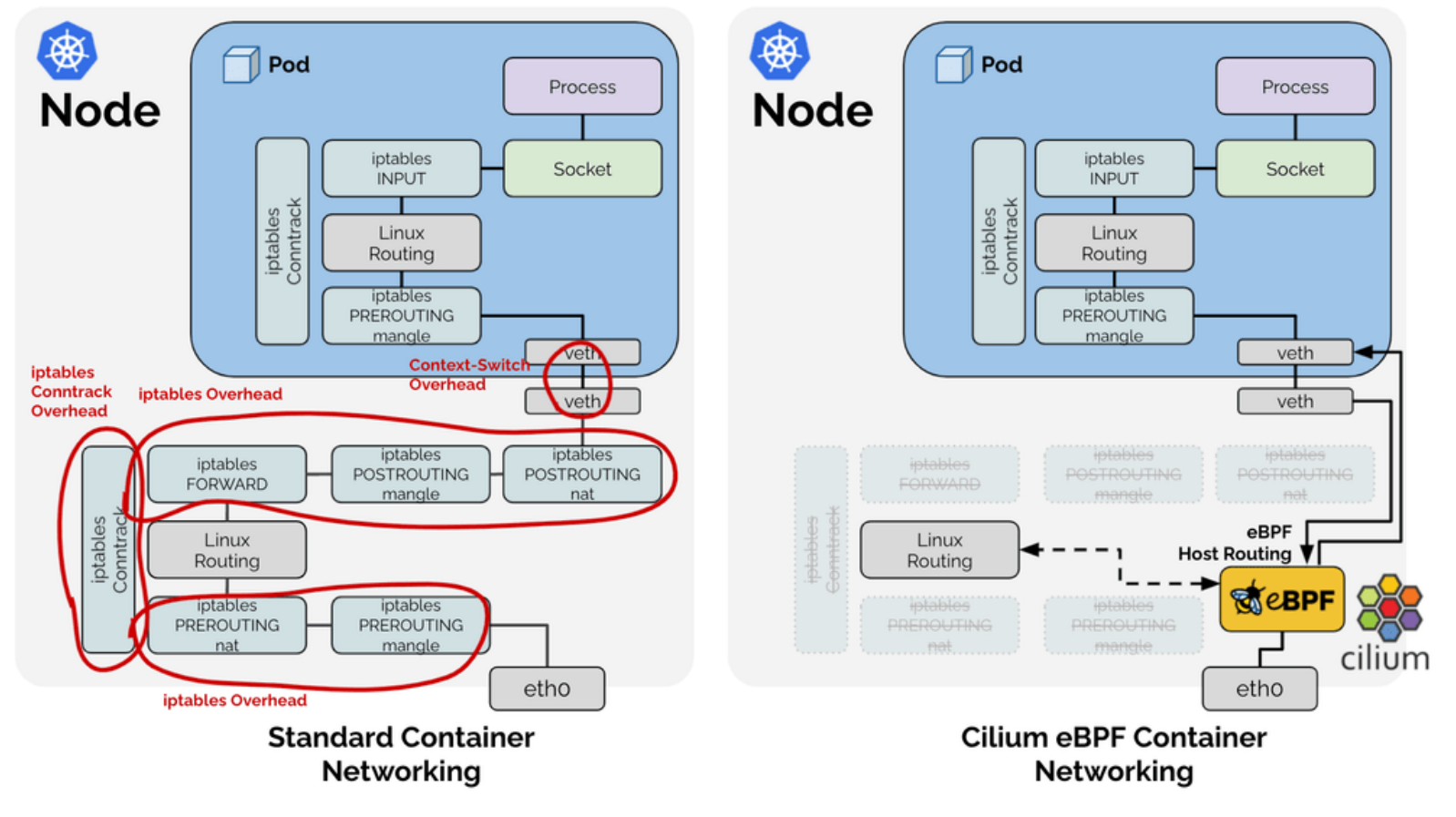
Tools available: https://ebpf.io/applications/

A Load Balancer from scratch



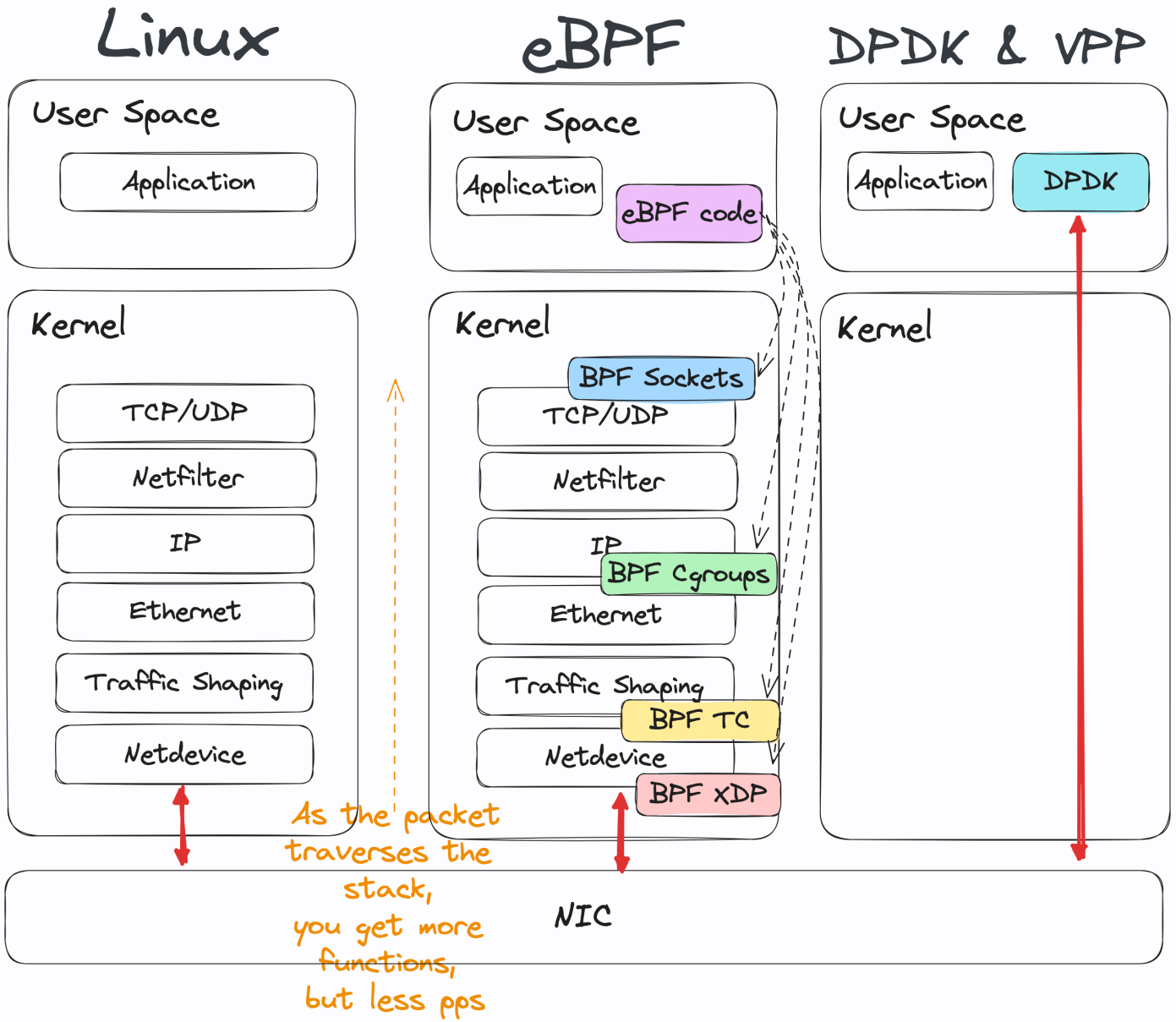
https://www.youtube.com/watch?v=L3_AOFSNKK8

eBPF in Kubernetes



https://cilium.io/blog/2021/05/11/cni-benchmark/

Comparing Linux, VPP, and eBPF

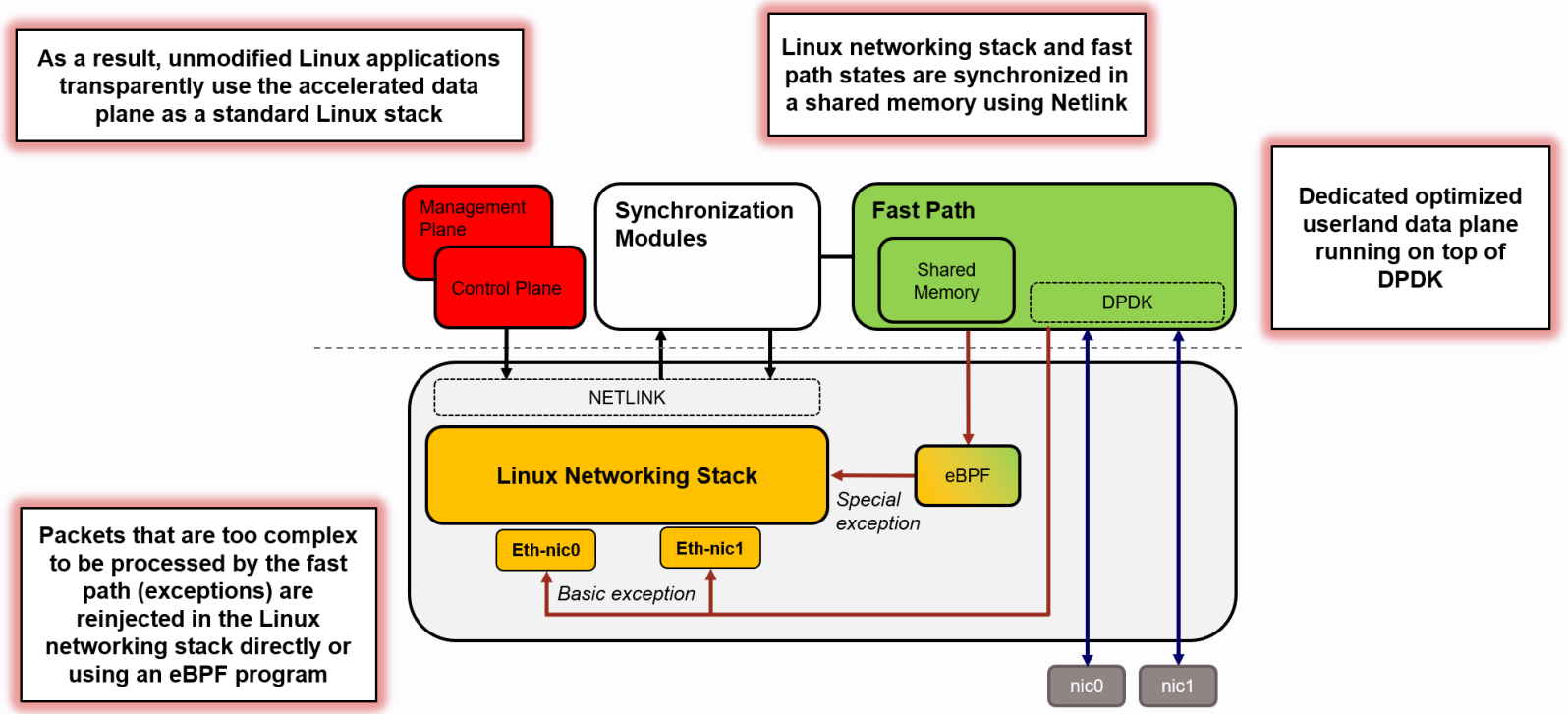

Linux
User Space
Application
Kernel
TCP/UDP
Netfilter
IP
Ethernet
Traffic Shaping
Netdevice
eBPF
User Space
Application
eBPF code
Kernel
BPF Sockets
TCP/UDP
Netfilter
IP
BPF Cgroups
Ethernet
Traffic Shaping
BPF TC
Netdevice
BPF XDP
DPDK & VPP
User Space
Application
DPDK
Kernel
As the packet traverses the stack, you get more functions, but less pps
NIC

Some numbers

Linux	DPDK & VPP	XDP and eBPF
~30 cores for 28Mpps forwarding	**~3 cores** for 28Mpps forwarding	**~5 cores** for 28Mpps forwarding
Rich feature set. Socket programming as usual (IPtables)	Amazing performance!, but you lose the NIC from the Kernel and need to reimplement everything	Excellent performance with early packet processing and fallback to Kernel. Access to FIB table (`bpf_fib_lookup`)
Optimized for general purpose	Great for forwarding plane, with networking features	Optimized for best of both worlds

https://virtualnog.net/posts/2020-12-11-linux-networking/

Both can cooperate



https://www.6wind.com/6windgate-5-0-versus-vpp-fast-path-benefits-from-linux-integration-and-ebpf/

Examples

Check the main README.md for details to setup the environment and run the examples

The EASY way

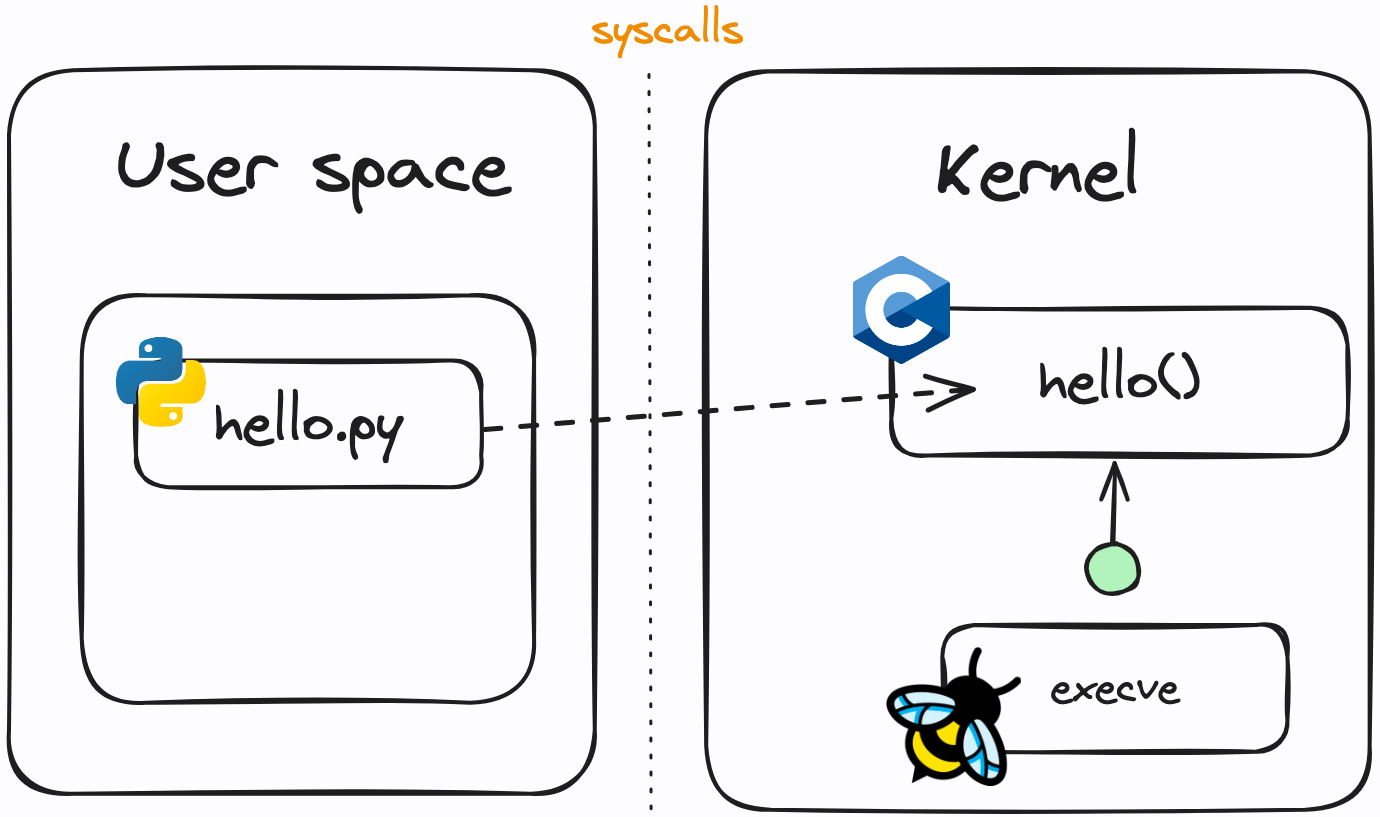
The BCC library, BPF Compiler Collection (BCC)

> BCC is a toolkit for creating efficient kernel tracing and manipulation programs with eBPF, and includes several useful tools and examples.

- kernel instrumentation in C (and includes a C wrapper around LLVM)
- front-ends in Python and lua
- takes care of a lot of low-level details

There are frameworks for other languages (`ebpf-go`)

Hello World

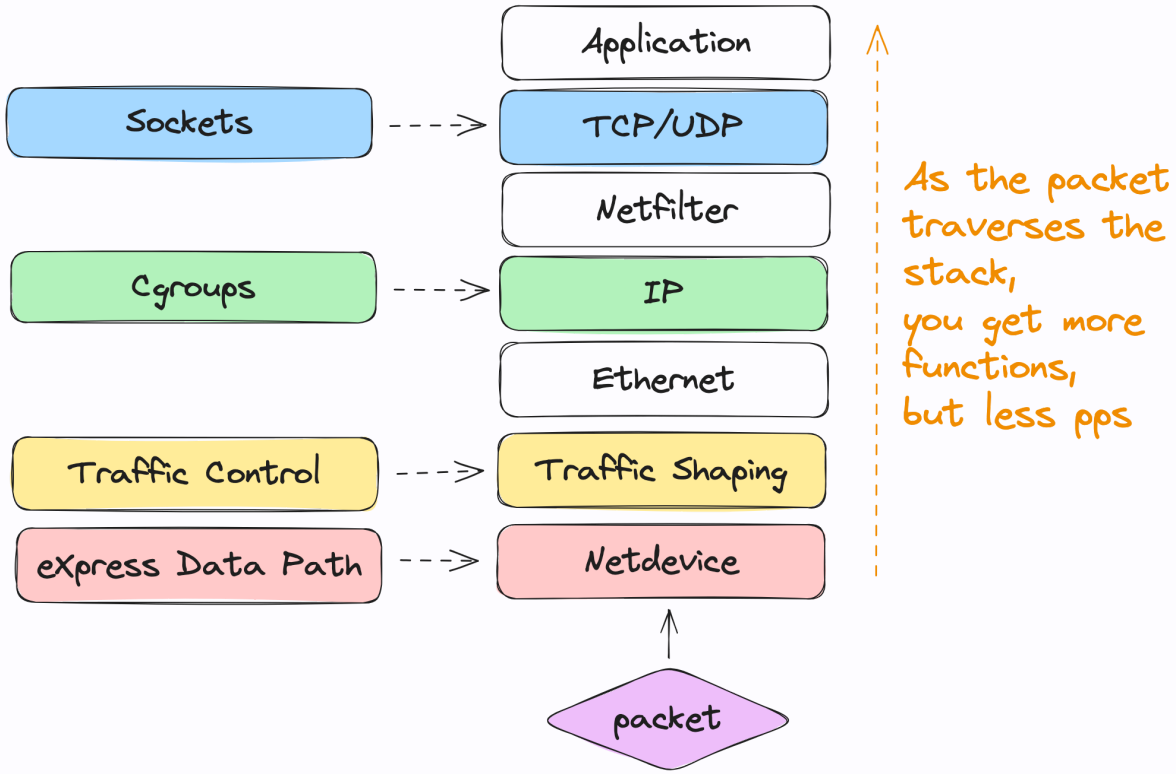


Code available at https://github.com/chadell/ebpf-playground/blob/main/examples/python/hello.py

Hello World - code

```
from bcc import BPF
program = r"""
int hello(void *ctx) {
    bpf_trace_printk("Hello NetBCN!");
    return 0;
}
"""
# Loads the C code from a string
b = BPF(text=program)
# Retrieves the syscall for execve
syscall = b.get_syscall_fnname("execve")
# Attaches the C function hello to the event
b.attach_kprobe(event=syscall, fn_name="hello")
# Outputs the trace in the screen
b.trace_print()
```

The ping example



Code available at https://github.com/chadell/ebpf-playground/blob/main/examples/python/ping.py

The ping example code

```
from bcc import BPF
program = r"""
#include "network.h"
#include <bcc/proto.h>
#include <linux/pkt_cls.h>
int xdp(struct xdp_md *ctx) {
  void *data = (void *)(long)ctx->data;
  void *data_end = (void *)(long)ctx->data_end;
  if (is_icmp_ping_request(data, data_end)) {
        bpf_trace_printk("Got an ICMP packet");
        return XDP_PASS;
  }
  return XDP_PASS;
}
"""
b = BPF(text=program)
fx = b.load_func("xdp", BPF.XDP)
BPF.attach_xdp("lo", fx, 0)
b.trace_print()
```

The HARD way

Let's use C code without helpers:

- Use the `bpftool`
- Compile the C program
- Load the eBPF code
- Attach to the loopback XDP hook

Code available at https://github.com/chadell/ebpf-playground/blob/main/examples/c/hello.bpf.c

C BPF code

```c
#include <linux/bpf.h>
#include <bpf/bpf_helpers.h>
// This global variable it's converted to a MAP
int counter = 0;
// SEC() is a macro that defines the type of eBPF program
SEC("xdp")
int hello(struct xdp_md *ctx) {
    // bpf_printk is a helper function by libbpf
    bpf_printk("Packet received %d", counter);
    counter++;
    // XDP functions return the action for the packet
    return XDP_PASS;
}
// The eBPF verifier inspects the license of eBPF programs
char LICENSE[] SEC("license") = "Dual BSD/GPL";
```

C BPF step by step

- Install `libbpf`
- Compile the program (`-target bpf`)
- Check the compiled object
- Install `bpftool` to
  - Load the eBPF program and check it
  - Attach the eBPF program to an interface
  - Inspect the eBPF Maps
- See what's going on in the `trace_pipe`
- Detach and unload the eBPF program, with `bpftool`
- Let's make the Verifier unhappy

Takeaways

- The Verifier can get complicated
- Some kernel familiarity is needed
- Even there are some helpers, there are some limitations
- Kernel support has to be assessed

Resources

- Book: Learning eBPF, by Liz Rice
- https://ebpf.io/labs/
- https://gist.github.com/satrobit/17eb0ddd4e122425d96f60f45def9627
- https://speakerdeck.com/fedepaol/ebpf-for-the-rest-of-us-golab-2023

Thanks!

Contact via Linkedin @christianadell