BPF and XDP Explained

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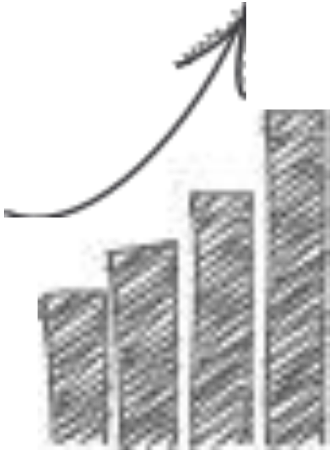
Objectives

Give user a basic understanding of the architecture of eBPF

- What is it
- The programming model
- The kernel hooks

Give user a basic understanding of XDP

- What is it/Where is it
- How to use it (beginner level!)
- How to offload it



What is eBPF?

eBPF is a simple way to extend the functionality of the kernel at runtime

- Effectively a small kernel based machine
  - 10 64bit registers
  - 512 byte stack
  - Data structures known as maps (unlimited size)
  - 4K BPF instructions (Bytecode)
- Verifier to ensure kernel safe
  - no loops, not more than 4K insns, not more than 64 maps etc…
- Can be JITed to ensure maximum performance

Used Within Hyperscale-Not a Toy!

Those who have publically stated they are using BPF or are planning to use BPF include

- Facebook-Load Balancing, Security
- Netflix-Network Monitoring
- Cilium Project
- Cloudflare-Security
- OVS-Virtual Switching

Due to its upstream safety and kernel support BPF provides a safe, flexible and scalable networking tool

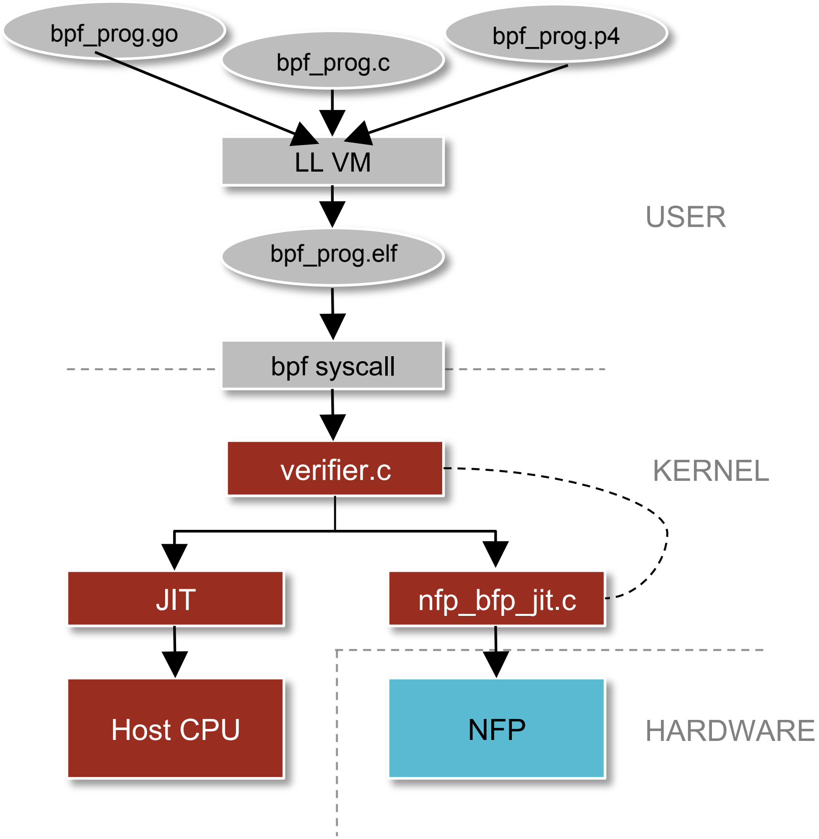
The Programming Model

LLVM is used to compile from supported languages

- C
- Go
- P4

When Programs are loaded

- Verifier is called-ensure safety
- Program is JITed-ensure perf
- Can also be offloaded
  - nfp_bpf_jit **upstream**



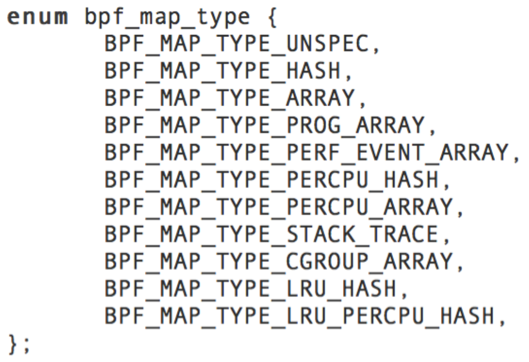
Maps-What They Are

Maps are key value stores

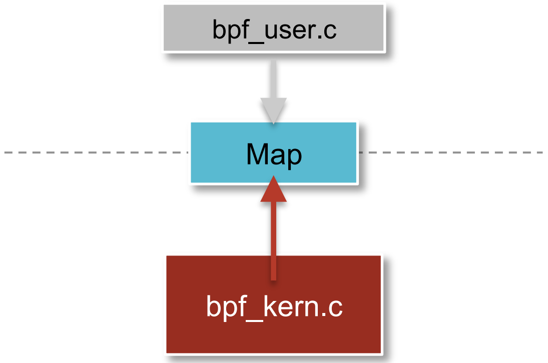
- Can be accessed from kernel or user space
- Used for interaction between kernel and user space programs

Number of different types of maps

- Used for interaction between kernel and user space programs



```
enum bpf_map_type {
        BPF_MAP_TYPE_UNSPEC,
        BPF_MAP_TYPE_HASH,
        BPF_MAP_TYPE_ARRAY,
        BPF_MAP_TYPE_PROG_ARRAY,
        BPF_MAP_TYPE_PERF_EVENT_ARRAY,
        BPF_MAP_TYPE_PERCPU_HASH,
        BPF_MAP_TYPE_PERCPU_ARRAY,
        BPF_MAP_TYPE_STACK_TRACE,
        BPF_MAP_TYPE_CGROUP_ARRAY,
        BPF_MAP_TYPE_LRU_HASH,
        BPF_MAP_TYPE_LRU_PERCPU_HASH,
};
```



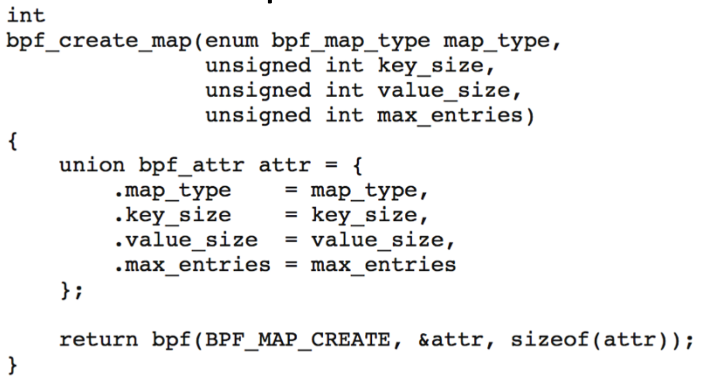
Maps-How to use them

Creating Maps

THIS IS AN OVERSIMPLIFICATION

- Option 1: create map with syscall
  - bpf(BPF_MAP_CREATE, &bpf_attr, sizeof(bpf_attr))
- Option 2: define a struct bpf_map_def with an elf section __attribute__ SEC(“maps”)-also uses syscall!

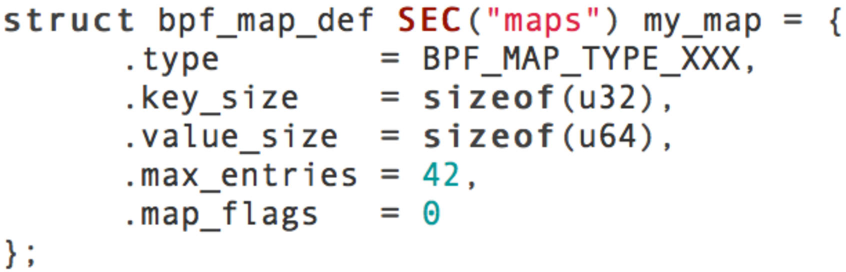
Option 1



```
int
bpf_create_map(enum bpf_map_type map_type,
               unsigned int key_size,
               unsigned int value_size,
               unsigned int max_entries)
{
    union bpf_attr attr = {
        .map_type    = map_type,
        .key_size    = key_size,
        .value_size  = value_size,
        .max_entries = max_entries
    };

    return bpf(BPF_MAP_CREATE, &attr, sizeof(attr));
}
```

Option 2



```
struct bpf_map_def SEC("maps") my_map = {
        .type        = BPF_MAP_TYPE_XXX,
        .key_size    = sizeof(u32),
        .value_size  = sizeof(u64),
        .max_entries = 42,
        .map_flags   = 0
};
```

eBPF Bytecode: Quick Overview

eBPF Bytecode: op:8, dst_reg:4, src_reg:4, off:16, imm:32

- op code is divided into the sections
  - Operation code (4bits) e.g BPF_MOV, BPF_JNE
  - Source bit (1 bit) BPF_X (use src_reg and dst_reg) or BPF_K (use dst_reg and 32 bit imm)
  - instruction class (3 bits) e.g BPF_ALU, BPF_ALU64, BPF_JMP
- BPF_MOV | BPF_X | BPF_ALU64, 0x6, 0x1, 0x0000, 0x00000000
  - Move contents of register 1 to register 6
- BPF_JNE | BPF_K | BPF_JMP, 0x1, 0x0, 0x0011, 0x00008100
  - Jump 11 insns forward-can also jump backwards-if contents of register 1 is not equal to 0x00008100

[redacted]

BPF Kernel Hooks

Many hooks with different purposes

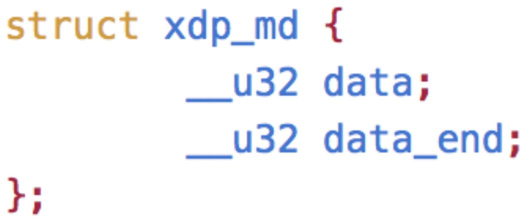
- kprobes
- socket filters-tcpdump-old school!
- seccomp
- netfilter (new)
- TC
- XDP(no skb-super fast!)

XDP will be our focus for the rest of this talk

XDP

BPF hook in the driver

- Allows for high speed processing before skb is attached to packet
- Currently 4 return codes: XDP_ABORT, XDP_DROP, XDP_PASS, XDP_TX
- XDP_REDIRECT in the pipeline
- Usecases include DDoS protection and load balancing
- Includes maximum of 256 bytes of prepend
- Metadata is just pointers to start of packet and end



```
struct xdp_md {
        __u32 data;
        __u32 data_end;
};
```

Program Example (xdp1_kern.c)

Simple drop example

- Note the use of standard header infrastructure
- Associated user space program maintaining a set of counters
- I am not going to go through line by line-for more detail check out Andy and Jesper’s awesome tutorial-in links
- Will come back to this example later on…

This can be found in the recent (4.8+) kernels at

linux/samples/bpf

Optimizing XDP

A simple checklist-not comprehensive!

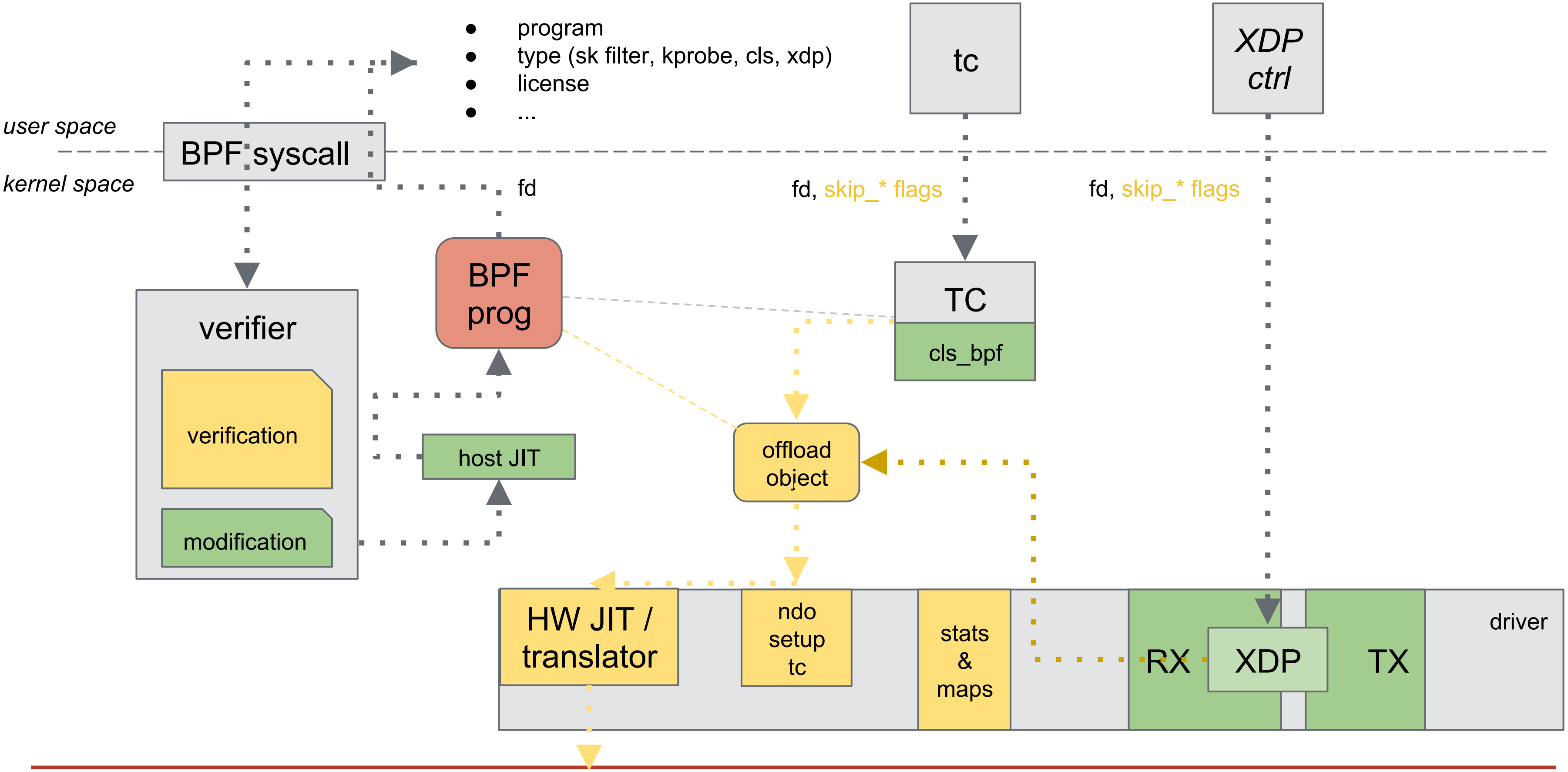
- Ensure BPF JIT is enabled
- Pin queues to interfaces
- Set ringsize to an optimal level for your NIC and application
- To gain some idea of your NIC's driver based XDP performance check simple XDP_DROP and XDP_TX programs
- Many people use single core performance as a reasonable benchmark
  - To do this use the ethtool -X command
  - You will NOT get the simple program performance if you build something complex (Duh)

Offloading XDP

Netronome have upstreamed the initial version of the nfp_bpf_jit

- More to come!
  - Maps
  - Compiler optimizations
  - Magic

Offload Architecture



References

Kernel Docs: https://www.kernel.org/doc/Documentation/networking/filter.txt

Initial XDP Presentation: https://github.com/iovisor/bpf-docs/blob/master/Express_Data_Path.pdf

More Docs: http://prototype-kernel.readthedocs.io/en/latest/README.html

Andy and Jesper's Talk: https://netdevconf.org/2.1/slides/apr7/gospodarek-Netdev2.1-XDP-for-the-Rest-of-Us_Final.pdf

Reading List: https://qmonnet.github.io/whirl-offload/2016/09/01/dive-into-bpf/

Search: google.com :)

Thanks!

ANY QUESTIONS?