Rust in the Kernel

...

via eBPF

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There is a race to re-write the Kernel in BPF and Rust... We say, why not both?

eBPF

eBPF is eating the kernel

- IR decoding can be done with eBPF, replacing the lirc daemon.
- HID-bpf is being actively worked on.
- LSM could replace selinux/apparmor.
- Prediction: More subsystems will follow.
- BPF kernel-space is heavily dominated by C, although Rust is an alternative.

Aya

C -> eBPF compilation (the old, still the most popular way)

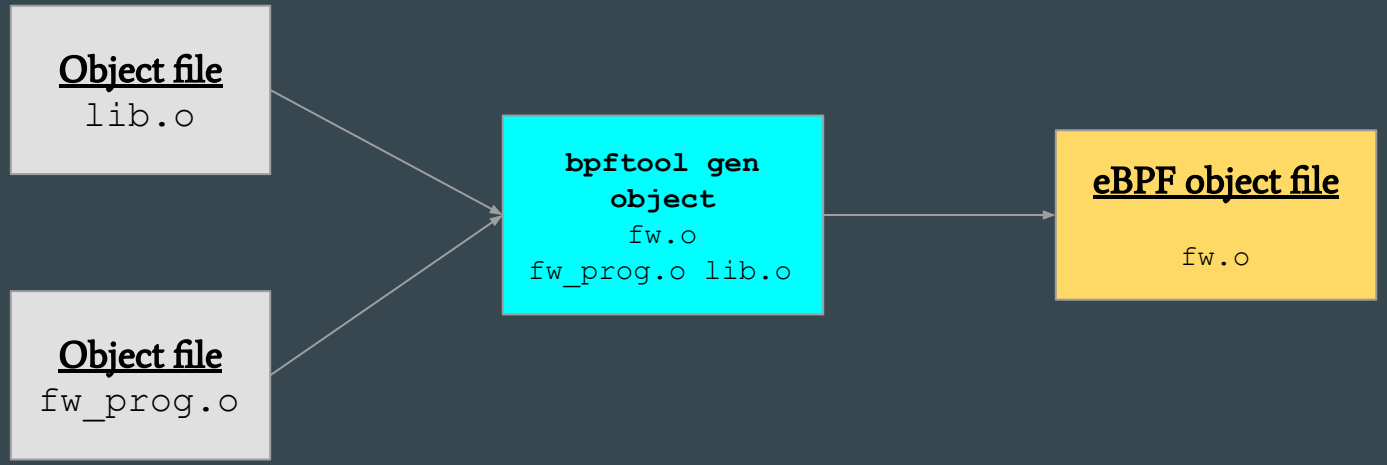
One big source file which `#includes` the other ones.

`-c` means skipping the linking phase.

ld and lld can't link eBPF

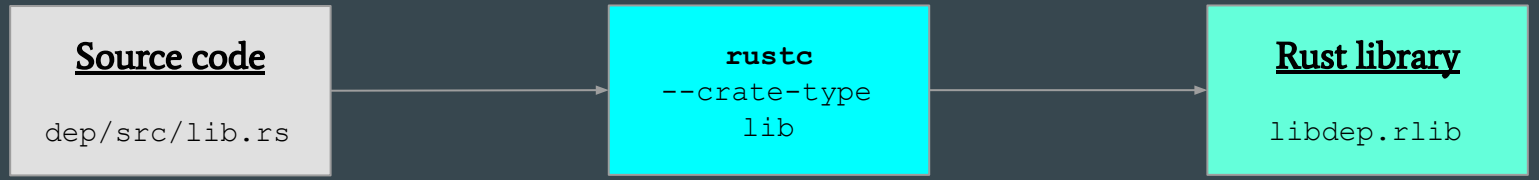
Linking with bpftool (via libbpf)

Inputs (eBPF object files)



Rust compilation

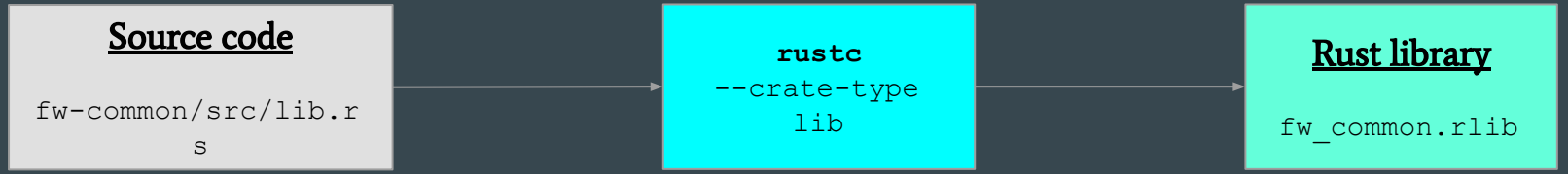
Library crate



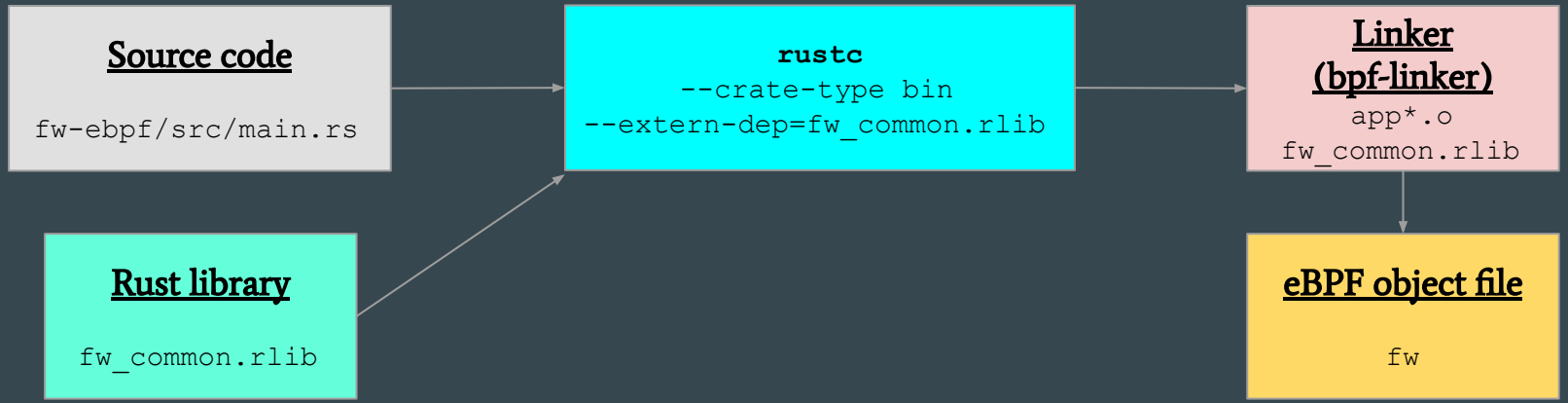
Binary crate

Rust -> eBPF compilation

Library crate

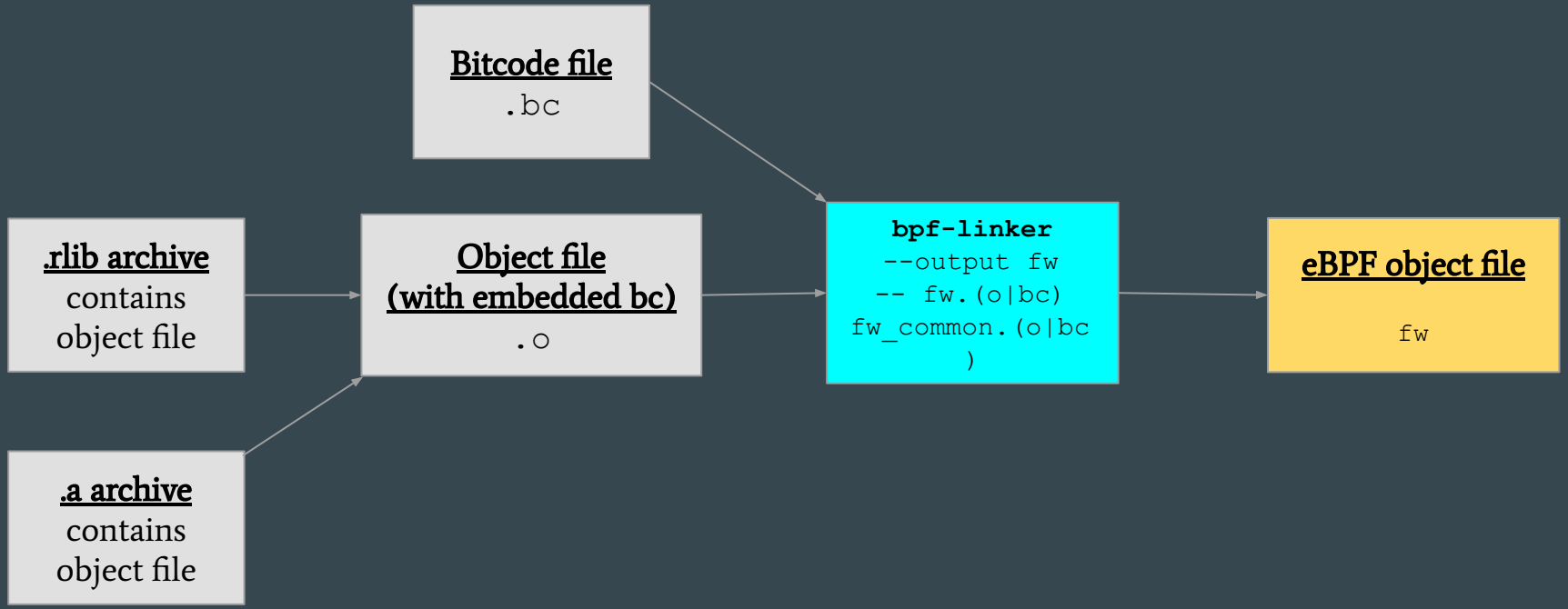


Binary crate

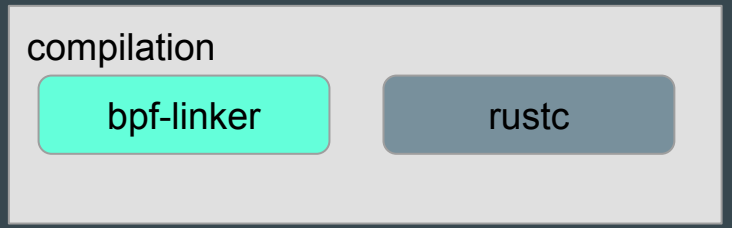


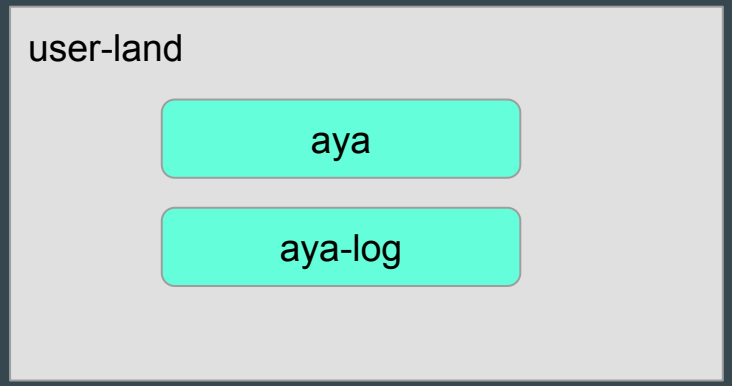
bpf-linker

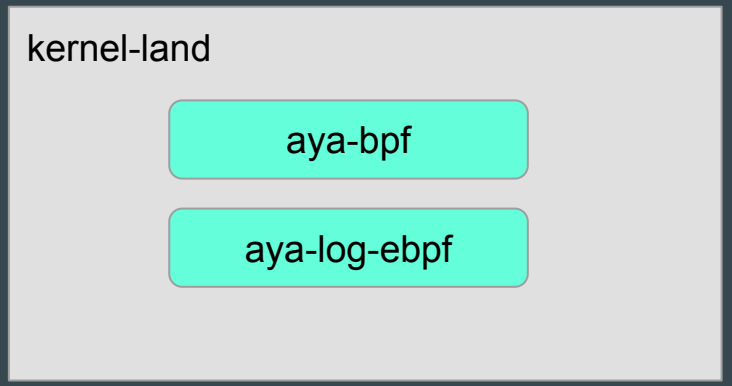
Inputs (LLVM bitcode)



The Aya Ecosystem







Features

- CO:RE support (in userspace only)
- aya-log using perf buffers for logging
- async support (in the userspace) with Tokio and async-std
- Used by Deepfence, Exein, Parca and Red Hat.

Type Safety

```c
#include <linux/bpf.h>
#include <bpf/bpf_helpers.h>
SEC("tracepoint")
int is_it_tracepoint_xdp_or_classifier(struct __sk_buff
*skb) {
    return XDP_PASS;
}
```

```
$ clang -O2 -emit-llvm -c incorrect_xdp.c -o - | llc
-march=bpf -filetype=obj -o bpf.o
$
```

```rust
#[xdp(name = "incorrect_xdp")]
pub fn incorrect_xdp(ctx: SkBuffContext) -> u32 {
    xdp_action::XDP_PASS
}
```

```
$ cargo xtask build-ebpf
[...]
error[E0308]: mismatched types
 --> src/main.rs:7:1
  |
7 | #[xdp(name = "incorrect_xdp")]
  | ^^^^^^^^^^^^^^^^^^^^^^^^^^^^^^ expected struct
`SkBuffContext`, found struct `XdpContext`
8 | pub fn incorrect_xdp(ctx: SkBuffContext) -> u32 {
[...]
```

Error Handling

```
struct {
	__uint(type, BPF_MAP_TYPE_HASH);
	__uint(max_entries, 1024);
	__type(key, pid_t);
	__type(value, u32);
} pids SEC(".maps");

SEC("fentry/kernel_clone")
int BPF_PROG(kernel_clone, struct kernel_clone_args *args)
{
	/* Get the pid */
	pid_t pid = bpf_get_current_pid_tgid() >> 32;
	/* Save the pid in map */
	u32 val = 0;
	int err = bpf_map_update_elem(&pids, &pid, &val,
0);
	if (err < 0)
		return err;
	return 0;
}
```

```
#[map(name = "pids")]
static mut PIDS: HashMap<u32, u32> = HashMap::<u32,
u32>::with_max_entries(1024, 0);
#[fentry(name = "kernel_clone")]
pub fn kernel_clone(ctx: FEntryContext) -> u32 {
    match unsafe { try_kernel_clone(ctx) } {
        Ok(ret) => ret,
        Err(_) => 1,
    }
}

fn try_kernel_clone(ctx: FEntryContext) -> Result<u32,
c_long> {
    // Get the pid
    let pid = ctx.pid();
    // Save the pid in map.
    unsafe { PIDS.insert(&pid, &0, 0)? };
    Ok(0)
}
```

Common Code/Structs

Others:

Manually copy/paste struct definition from kernel code to userspace code (no code sharing).

Use a shared header files to share structs between userspace/kernel. Hard to integrate a linker.

Use BTF to inspect struct definitions from ELF file and generate code for userspace (no code sharing).

Aya:

Use a “common” crate to share structs and code between kernel and userspace.

Minimal build dependencies

C

- LLVM, clang
- libbpf
- make

Rust

- rustup (which installs rustc and cargo)
- bpf-linker

Starting a new project

C

- Getting an inspiration from https://github.com/libbpf/libbpf-bootstrap/
- Your repo and Makefile have to be handcrafted

Rust

Shared Challenges for Aya and Rust in the Kernel

BPF Type Format (BTF)

A compact debug info format

Since 5.xx kernel modules can provide BTF

Required for CO:RE

- The rustc bpf target and LLVM need work to reliably generate BTF
- There are LLVM intrinsics we must use to be able to generate the necessary relocations for CO:RE in kernel-space.
- BTF has been designed to represent C structures-idioms. Can we cleanly map Rust to this?

bindgen

Working with Kernel types isn't fun.

Many anonymous unions.

Macros don't get expanded

How can we make this safer/better?

Questions?

Thanks!