bpfilter: packet filtering with BPF and nftables

Quentin Deslandes - Software Engineer

Scale21x, Pasadena

Meta

00 ABOUT ME

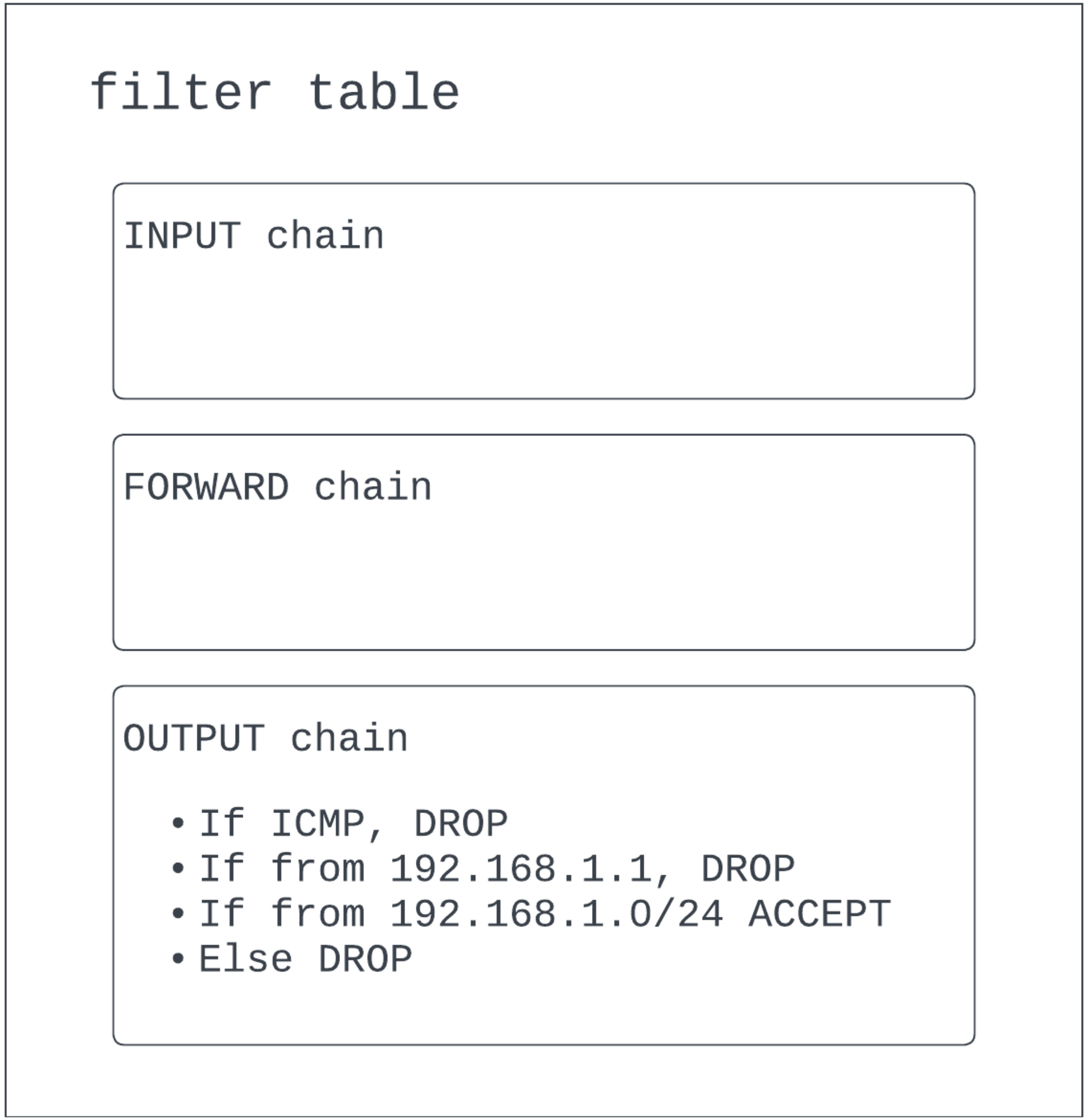
Quentin Deslandes

- Software Engineer @ Meta, working from France
- Member of the Linux Userspace team: we aim to make significant contributions to upstream userspace projects
- Working on bpfilter since September 2022

qde@naccy.de - github.com/qdeslandes

About `iptables`

- Created by Rusty Russels in 1998
- 1998's iptables is not 2024's iptables
- It defines a structure we are familiar with:
  - Tables to decide whether to NAT, filter, or mangle
  - Chains to attach rules to the networking stack
  - Rules to filter packets on specific criteria



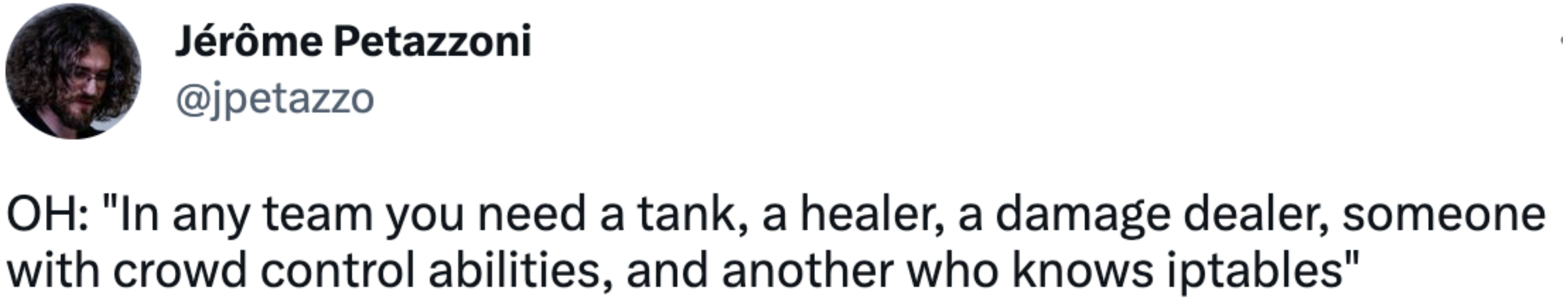
filter table

INPUT chain

FORWARD chain

OUTPUT chain

- If ICMP, DROP
- If from 192.168.1.1, DROP
- If from 192.168.1.0/24 ACCEPT
- Else DROP



Jérôme Petazzoni
@jpetazzo

OH: "In any team you need a tank, a healer, a damage dealer, someone with crowd control abilities, and another who knows iptables"

How does it work?

- What is the workflow?
  - Read and validate command line arguments
  - Uses `getsockopt()` to retrieve the whole ruleset from the kernel
  - Modify the ruleset from userspace and send it back using `setsockopt()`
- The data is sent to / received from the kernel in a binary format (i.e. `struct ipt_entry`)

Let’s talk about the caveats

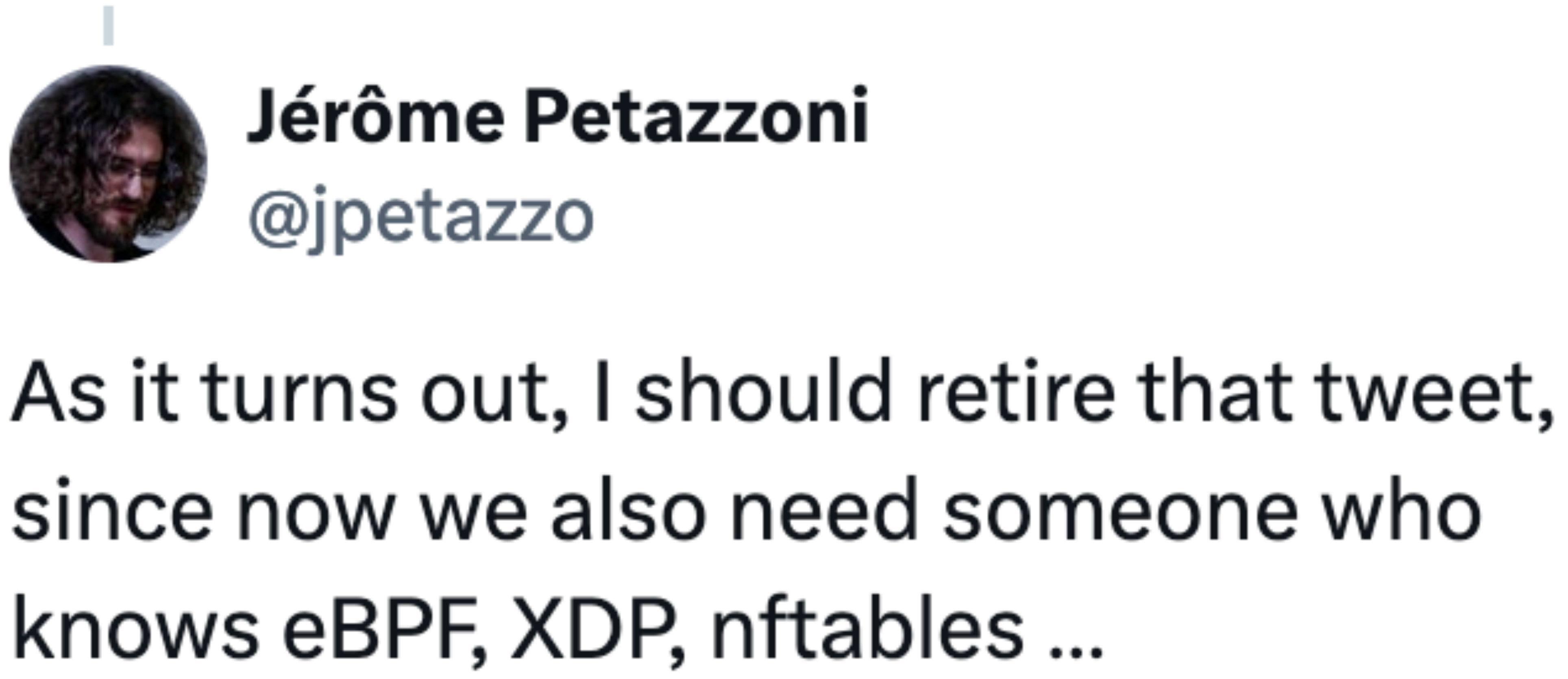
- 1998 was a long time ago, technology evolved (at lot) since then
- Packet filtering and firewall rules become more and more complex
- `iptables`’ architecture is not suited for modern network requirements
- If your firewall can’t keep up: you drop packets
- Can we improve the situation?

“Let there be eBPF”

Alexei Starovoitov, probably

Tutorial: speeding up `iptables`

1. Define a new UMH module
2. Plug the module to `net/ipv4/ip_sockglue.c`
3. Translate `iptables` rules to BPF programs
4. Enjoy!



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As it turns out, I should retire that tweet, since now we also need someone who knows eBPF, XDP, nftables ...

So far, so good

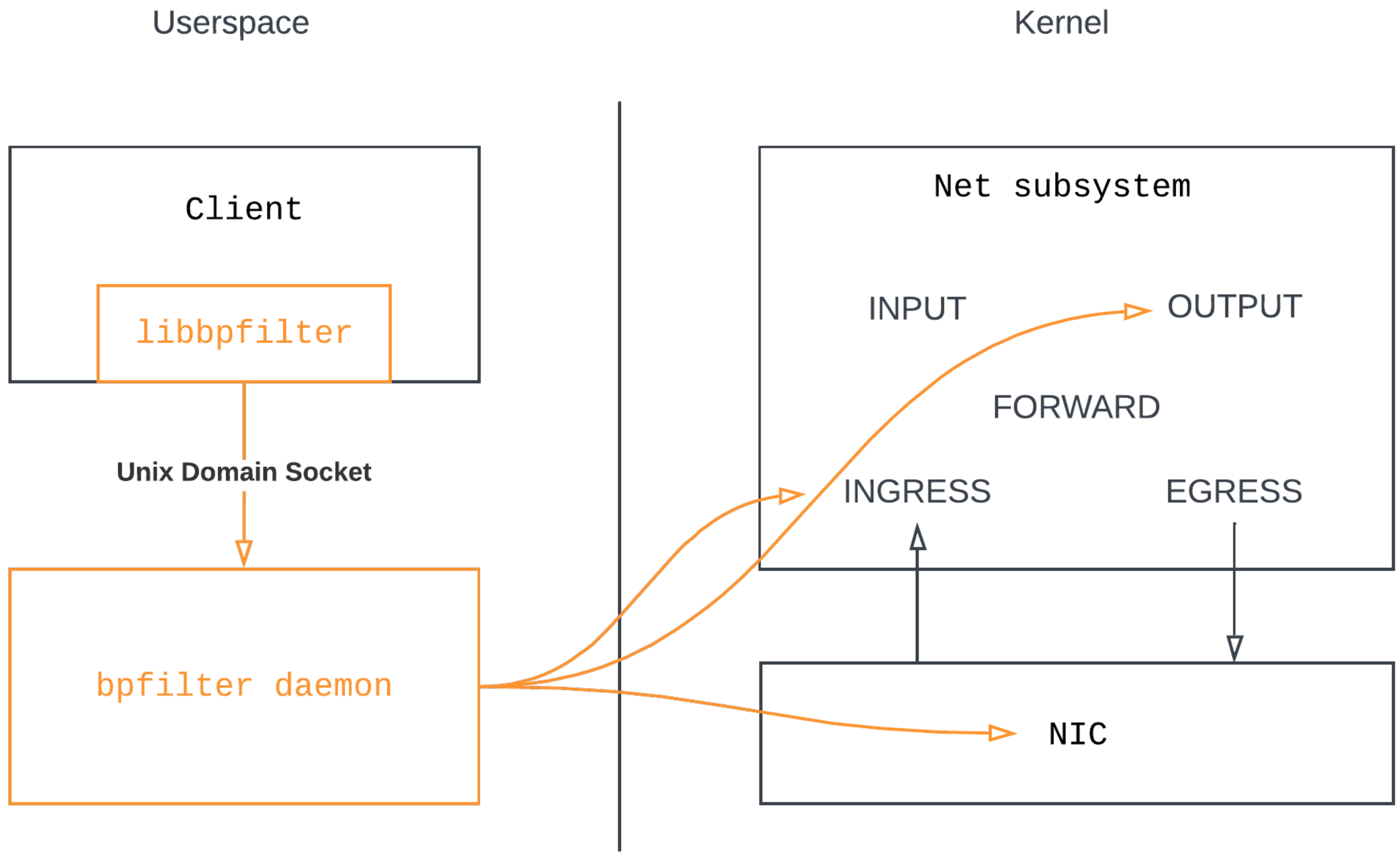
- Alexei Starovoitov, Dave Miller, and Daniel Borkmann created the first version of `bpfilter`.
- Dmitrii Banshchikov tried to implement the BPF bytecode generation
  - Stopped at v2
- I tentatively submitted a v3

Relocation to userspace

- The architecture was difficult to maintain
- `bpfilter` was tied to the kernel development process
- The project being under heavy development, it’s difficult to get timely review

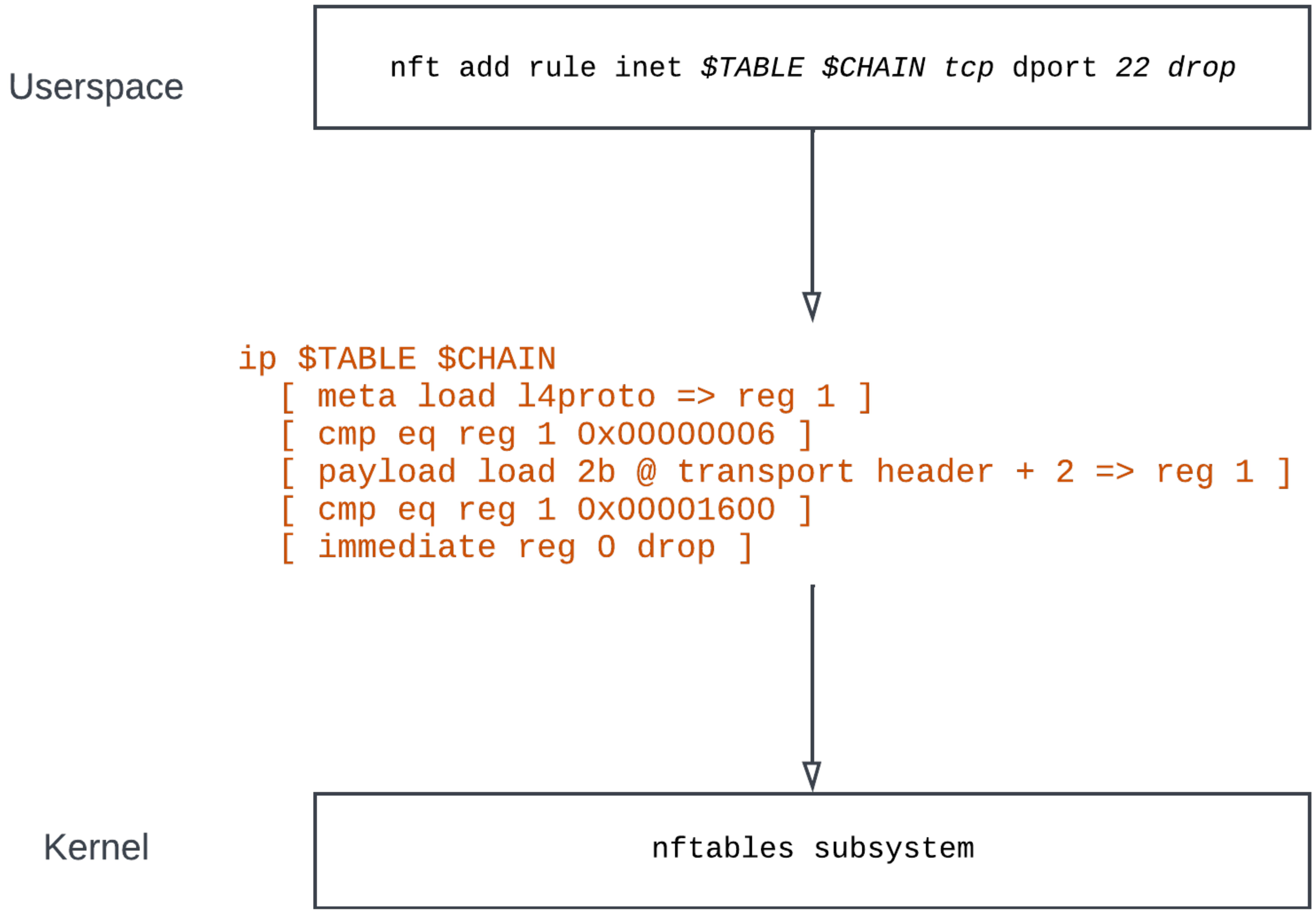
New bpfilter

- Complete refactor of the project
- Two main parts now:
  - `libbpfilter`
  - `bpfilter` daemon



nftables 101

- Packet filtering framework
- Replaces `iptables`
- Uses Netlink, not `{get,set}sockopt()`



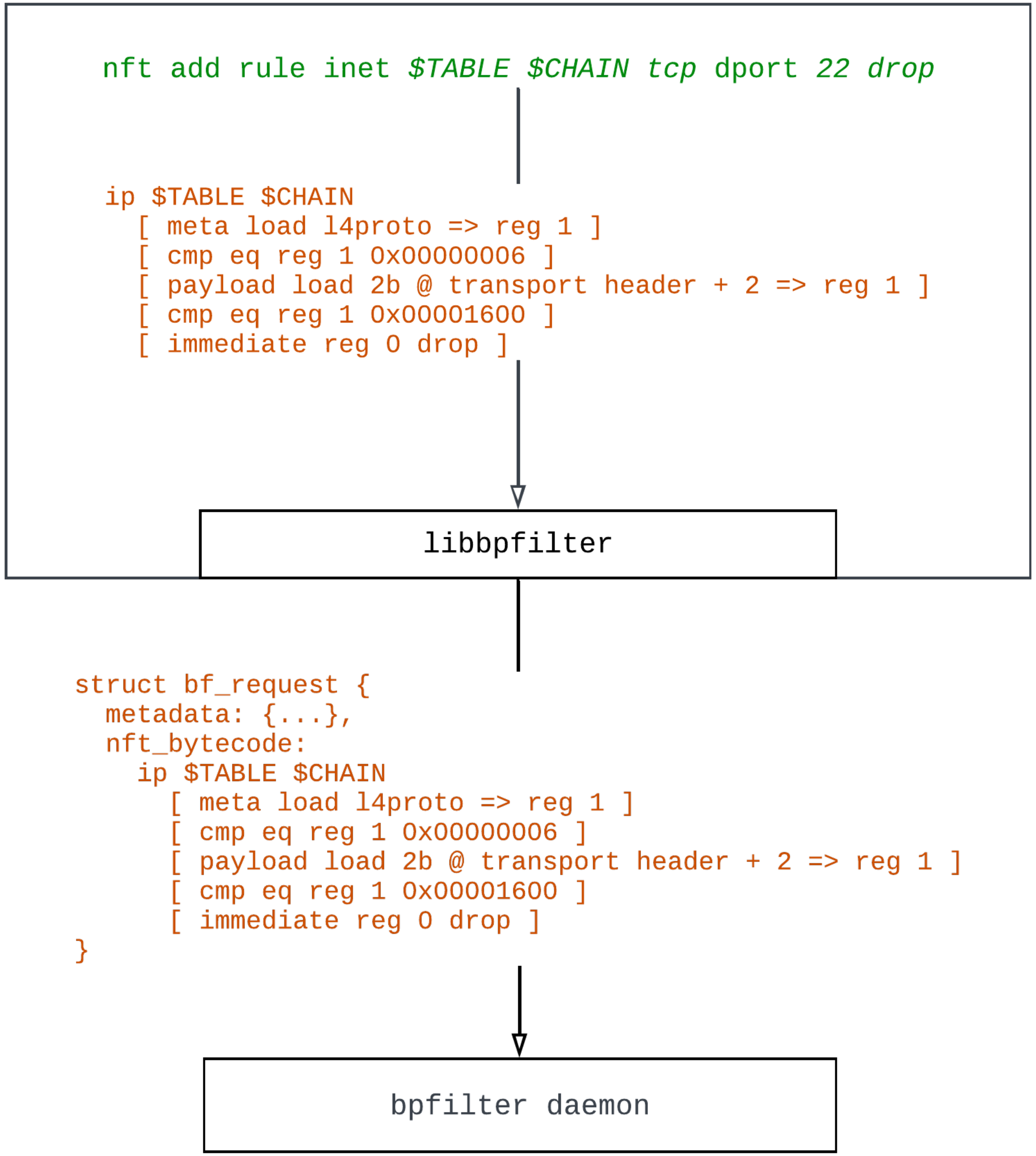
```
nft add rule inet $TABLE $CHAIN tcp dport 22 drop
```

```
ip $TABLE $CHAIN
  [ meta load l4proto => reg 1 ]
  [ cmp eq reg 1 0x00000006 ]
  [ payload load 2b @ transport header + 2 => reg 1 ]
  [ cmp eq reg 1 0x00001600 ]
  [ immediate reg 0 drop ]
```

```
nftables subsystem
```

libbpfilter

- Lightweight library
- Aims to ease integration to bpfilter
- Data-independant



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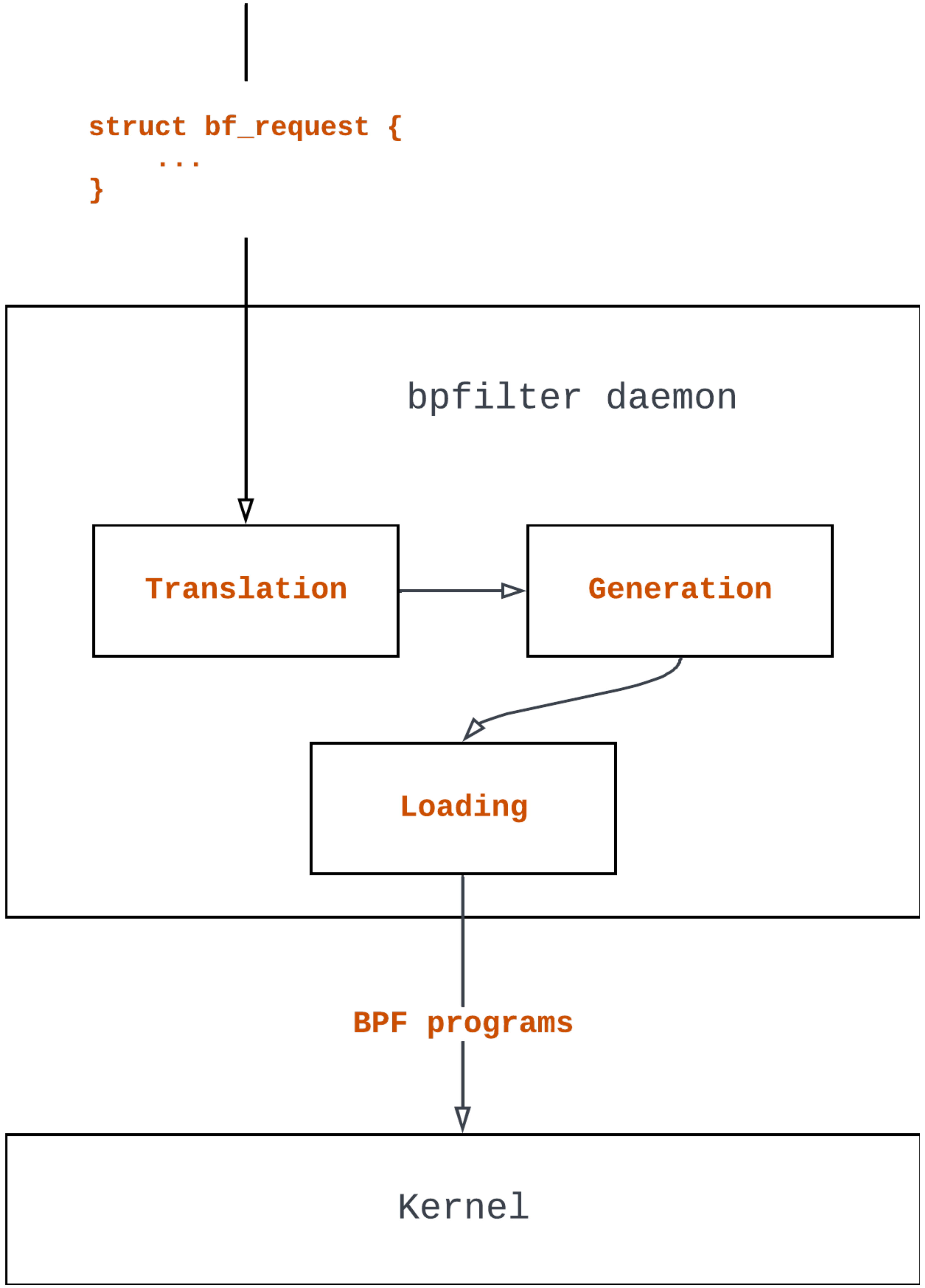
  [ immediate reg 0 drop ]
```

```
struct bf_request {
  metadata: {...},
  nft_bytecode:
    ip $TABLE $CHAIN
      [ meta load l4proto => reg 1 ]
      [ cmp eq reg 1 0x00000006 ]
      [ payload load 2b @ transport header + 2 => reg 1 ]
      [ cmp eq reg 1 0x00001600 ]
      [ immediate reg 0 drop ]
}
```

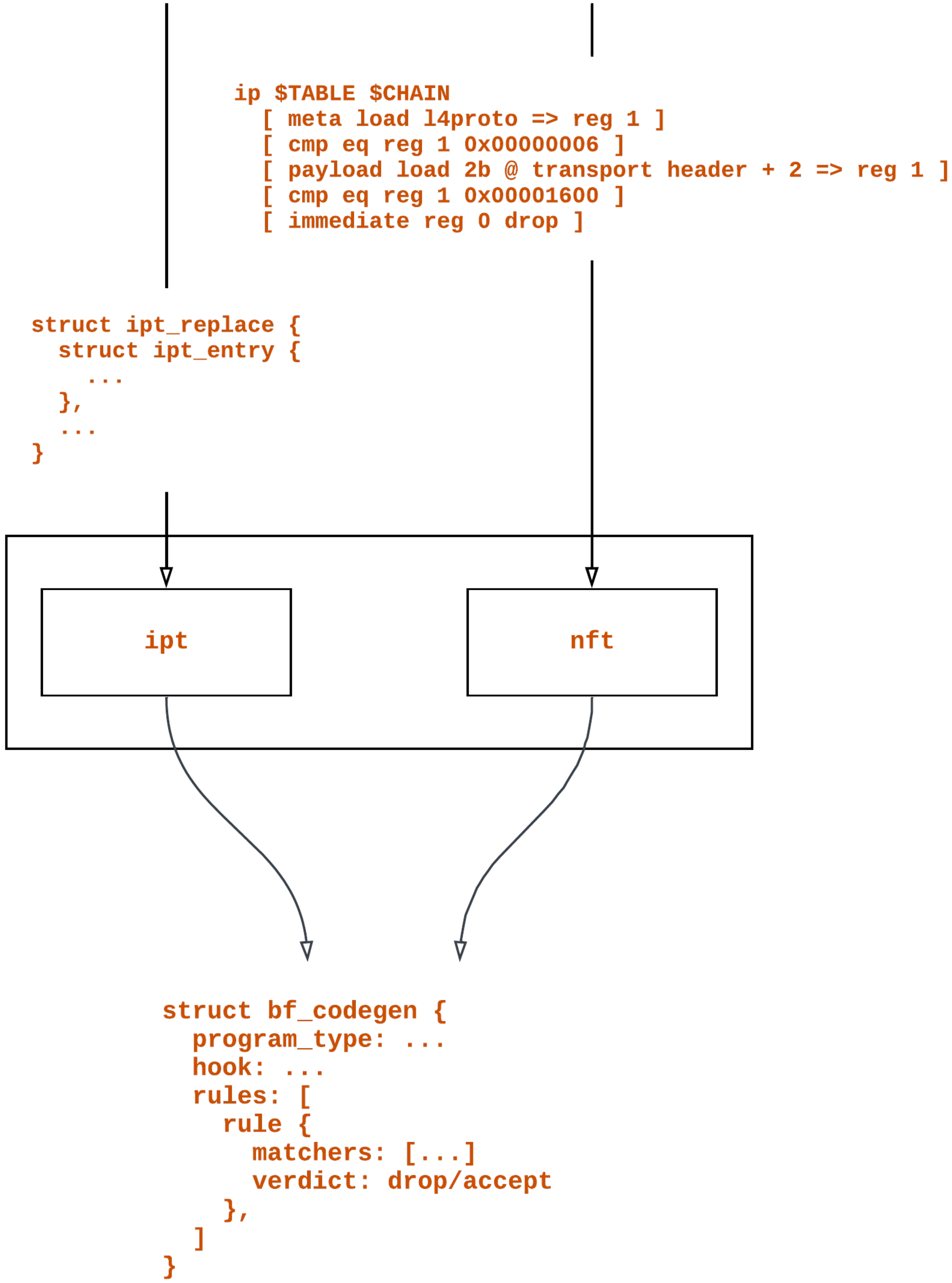
The daemon

- Listens on a Unix Domain Socket
- Perform the heavy lifting:
  - Translation of the client-specific format
  - Generation of the BPF programs
  - Management of the BPF programs



Translation

- Dedicated front-end for each client
- Convert client-specific data into an internal format
- Allows for code reuse during bytecode generation



```
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  [ meta load l4proto => reg 1 ]
  [ cmp eq reg 1 0x00000006 ]
  [ payload load 2b @ transport header + 2 => reg 1 ]
  [ cmp eq reg 1 0x00001600 ]
  [ immediate reg 0 drop ]
```

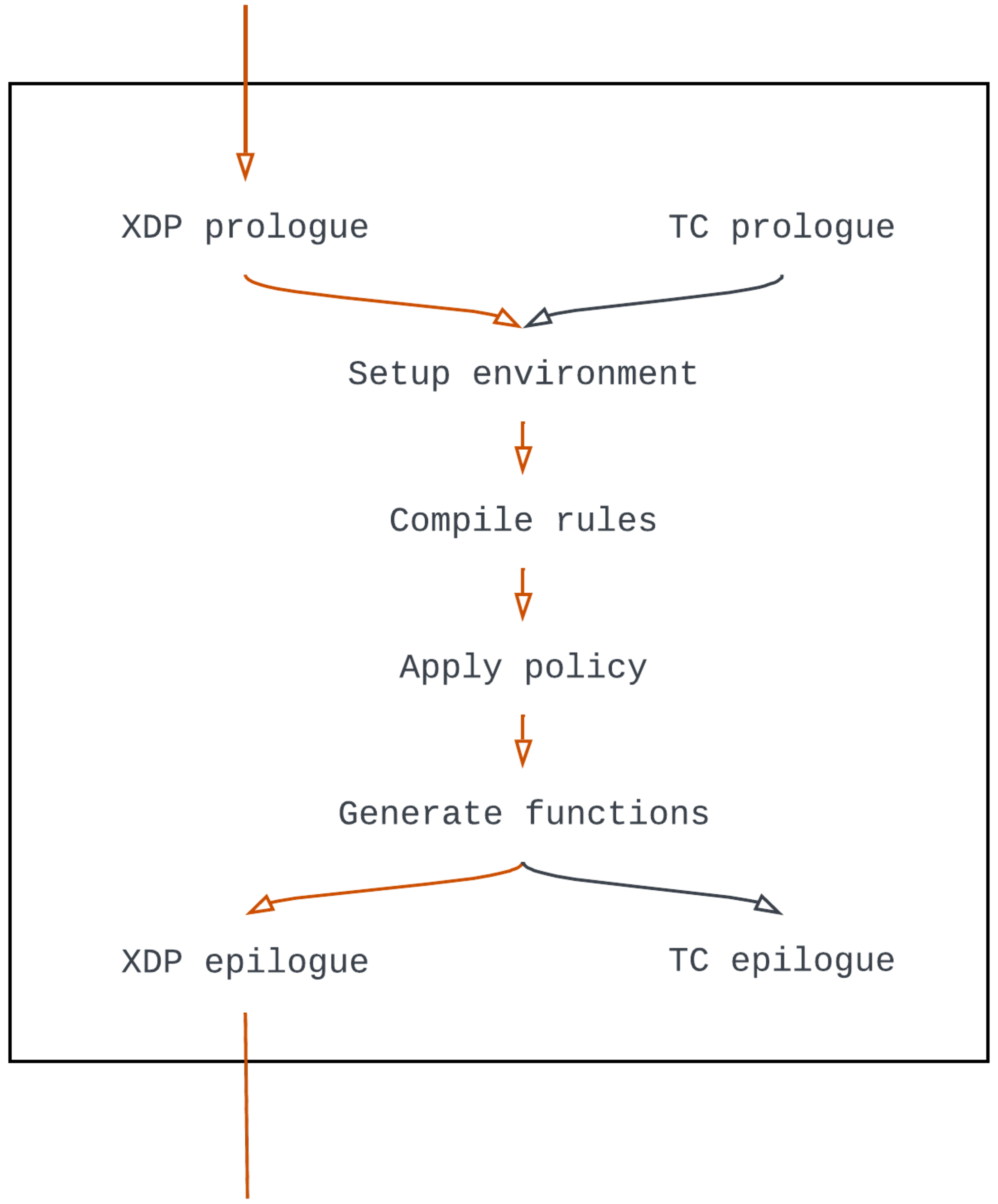
```
struct ipt_replace {
  struct ipt_entry {
    ...
  },
  ...
}
```

```
struct bf_codegen {
  program_type: ...
  hook: ...
  rules: [
    rule {
      matchers: [...]
      verdict: drop/accept
    },
  ]
}
```

Generation

- This is the compilation step
- Outputs 1 or more BPF programs
- Creates a prologue and an epilogue which are specific to the BPF program type
- Rules are unrolled at BPF bytecode

```
struct bf_codegen {
  program_type: BPF_PROG_TYPE_XDP
  hook: ...
  rules: [
    rule {
      matchers: [tcp dport 22]
      verdict: drop
    },
  ]
}
```



XDP prologue

TC prologue

Setup environment

Compile rules

Apply policy

Generate functions

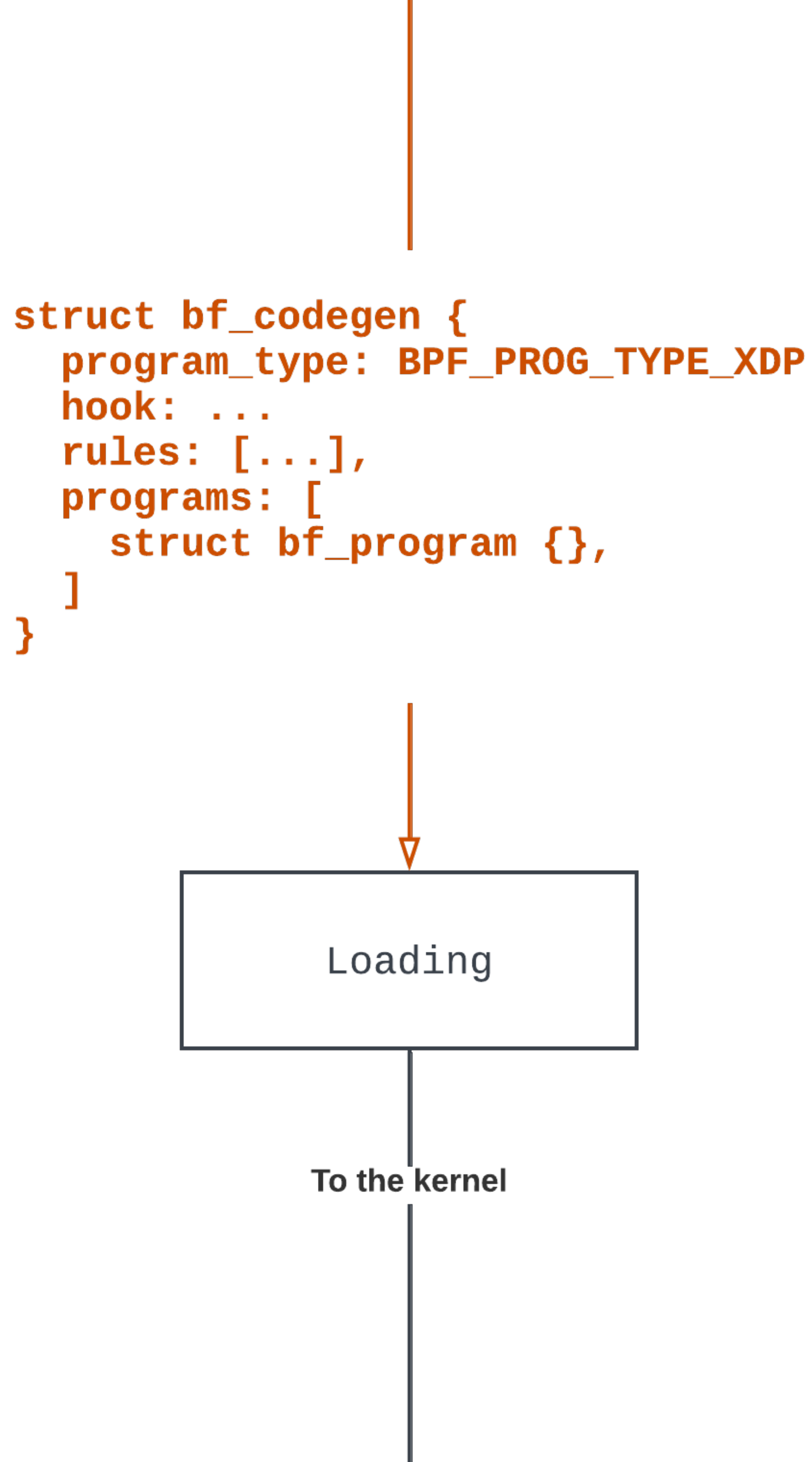
XDP epilogue

TC epilogue

```
struct bf_codegen {
  program_type: BPF_PROG_TYPE_XDP
  hook: ...
  rules: [...],
  programs: [
    struct bf_program {},
  ]
}
```

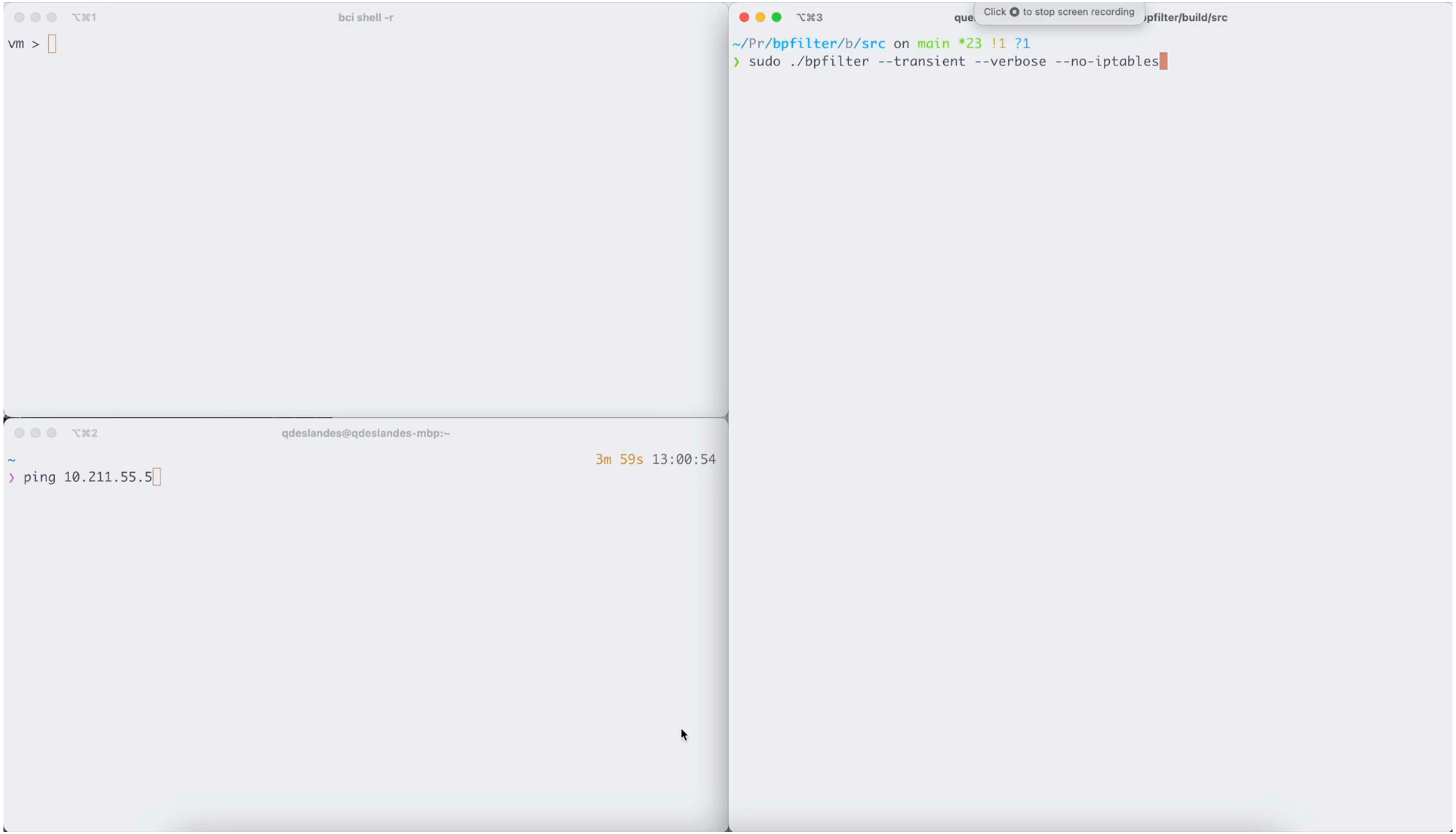
Loading

- Use BPF subsystem to attach a program
- Up to 1 program per interface
- Program replacement is atomic: no down time



```
struct bf_codegen {
  program_type: BPF_PROG_TYPE_XDP
  hook: ...
  rules: [...],
  programs: [
    struct bf_program {},
  ]
}
```

04 DEMO



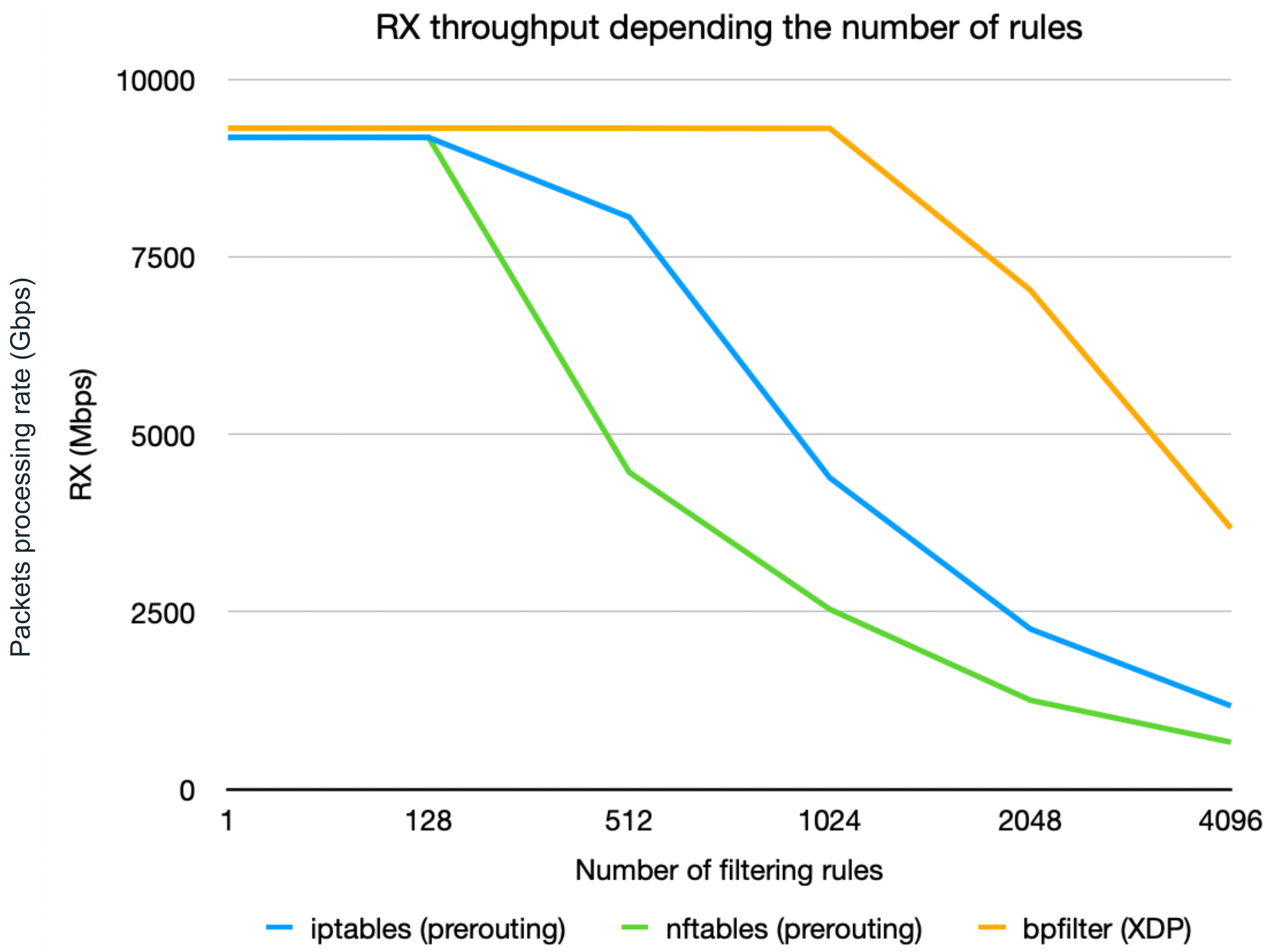
```
vm > 
```

```
~                                                  3m 59s 13:00:54
❯ ping 10.211.55.5
```

```
~/Pr/bpfilter/b/src on main *23 !1 ?1
❯ sudo ./bpfilter --transient --verbose --no-iptables
```

Benchmarks

- 2 servers connected through a 10G link.
- Using Linux' pktgen to generate packets at ~10Gbps.
- Increase the number of rules to increase overhead.
- Last rule drop all UDP packets



Current features and capabilities

- `iptables` and `nftables` are available (from a fork)
- Filter packets based on:
  - Source/destination IP address and/or port
  - L3 protocol
  - Source network interface.
- Collecting statistics
- Support XDP, TC, `BPF_NETFILTER` programs
- Supports `kfuncs`, BPF helpers, BPF dynamic pointers, custom functions…

Future work

- IPv6 (in progress)
- Sets support
- Partial rules re-generation
- Generic client
- CGroups support

Resources

- `bpfilter` repository: github.com/facebook/bpfilter
- `nftables` fork: github.com/qdeslandes/nftables/tree/bpfilter_support
- `iptables` fork: github.com/qdeslandes/iptables/tree/bpfilter
- Status report and project's progress: naccy.de
- Email: qde@naccy.de

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