Zero Trust, Software Defined Perimeter, and P4

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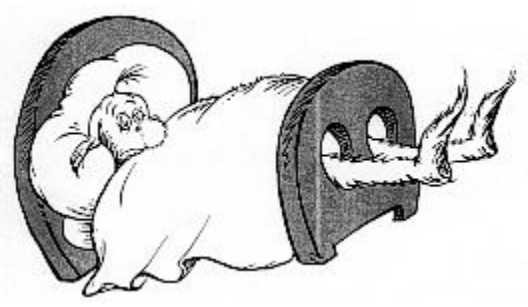
Huawei

Introduction

Who Am I?



- Omer Anson
- Software Physicist
  - About 11 years under the keyboard
  - Almost four years at Huawei
  - Working on (mostly):
    - Linux
    - Networking
    - Cloud

Introduction

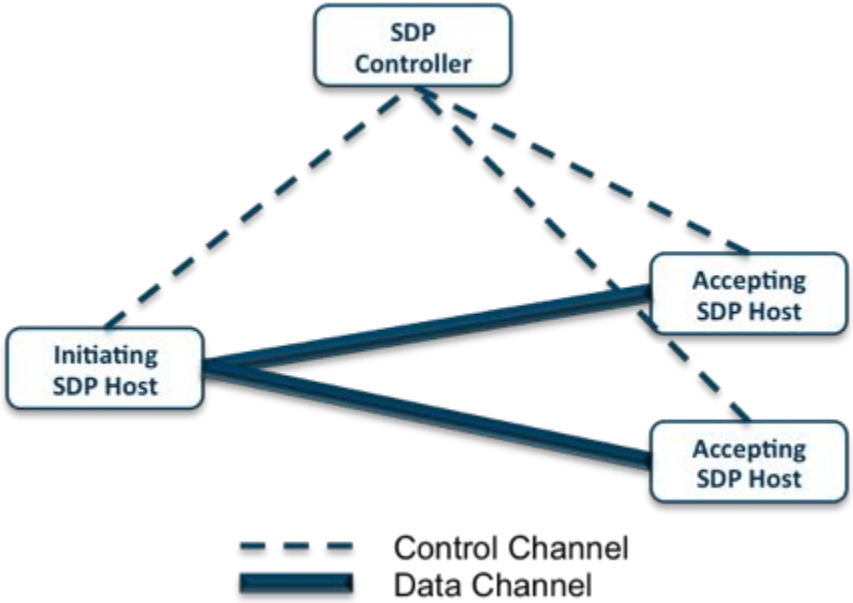
Motivation

Zero-Trust Networking

- Everyone and everything has an identity
- Doesn’t matter who they are
  - Lambda
  - Microservices
  - Users
  - External entities
  - PaaS
  - IaaS
- Pure Whitelist Security
  - Only permitted entities can communicate.
- Helps prevent data breaches
  - Read: Saves money!

Software Defined Perimeter (SDP)

- VPN mesh with whitelist policy
- All endpoints are authenticated and identified
- Endpoints only responded to permitted endpoints



Introduction

Technologies

netfilter

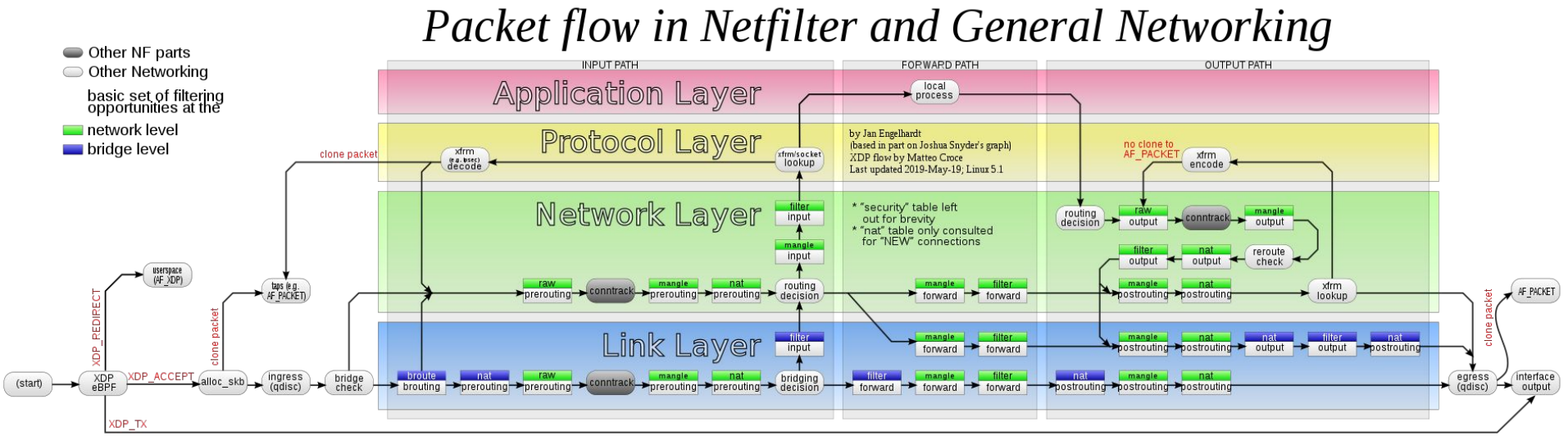
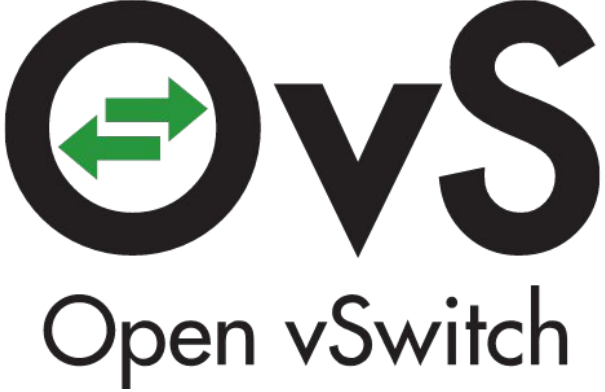


Image from Wikipedia: https://en.wikipedia.org/wiki/Iptables

OVS / OpenFlow



- OpenVSwitch - Virtual OpenFlow switch
- Allows to define whole pipelines
- Match-action rules (flows)
- Example flows:

table=55, priority=100,metadata=0x1f,dl_dst=fa:16:3e:d3:3d:8b actions=load:0x66->NXM_NX_REG7[],resubmit(,75)

table=55, priority=100,metadata=0x1f,dl_dst=fa:16:3e:c6:23:3f actions=load:0x67->NXM_NX_REG7[],resubmit(,75)

table=55, priority=200,metadata=0x1f,dl_dst=fa:16:3e:2e:a1:eb actions=load:0x10->NXM_NX_REG5[],resubmit(,60)

table=55, priority=200,metadata=0x1f,dl_dst=fa:16:3e:3a:39:bf actions=load:0x10->NXM_NX_REG5[],resubmit(,60)

table=55, priority=100,metadata=0x1f,dl_dst=01:00:00:00:00:00/01:00:00:00:00:00
>>>>>>>>actions=load:0x67->NXM_NX_REG7[],resubmit(,75),load:0x66->NXM_NX_REG7[],resubmit(,75),load:0->NXM_NX_REG7[],resubmit(,75)

extended Berkeley Packet Filter (eBPF)

- “Super powers have finally come to Linux”

  - Brendan Gregg

- In-kernel Virtual Machine
- Userspace code running in kernel
  - Change behaviour during runtime
    - In our case: Packet processing
  - Provably safe
- Many entry-points
  - Device and socket packet filtering

Why Not Write Directly in eBPF?

- Lots of boilerplate
  - Redundant verification
    - Can be inferred automatically from P4 code
  - Map structure must be defined beforehand
    - Can be inferred automatically from P4 code
  - Internal test, without defining headers:
    - P4: 70 LOC
    - eBPF: 160 LOC

P4

- From the website:
  - P4 programs specify how a switch processes packets.
- Domain specific language
- Specifies how to process packets
- Protocol Independent
- Compiled to different backends and architectures

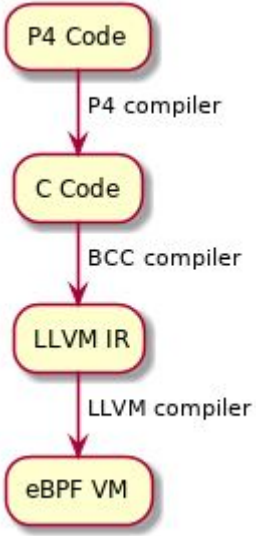
```
// Parse packet
parser ingress_parser(packet_in packet, out headers_t hdr,
                      inout metadata_t meta, inout standard_metadata_t std_meta) {
    state start {
        packet.extract(hdr.ethernet);
        // ...
    }
}
```

P4

- Missing compilation options
- P4 has a reference implementation switch, **but**
  - Slow
    - Userspace
    - Geared towards flexibility, not speed
  - Unstable
    - At least, compared to the Linux kernel
- So let’s compile to eBPF!

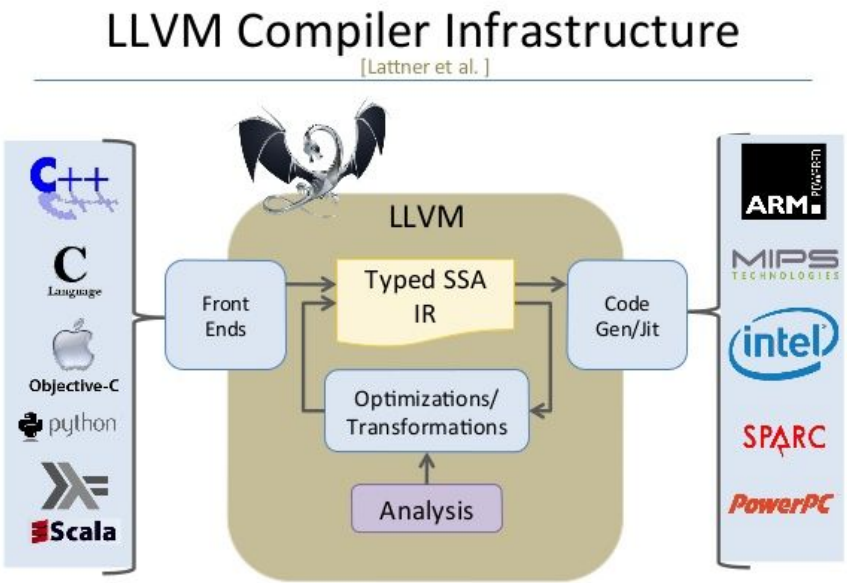
But there **is** a P4->eBPF compiler!

- Current eBPF compilation is feature-poor
  - Can’t change packet structure
  - No redirection
    - Packets either pass or drop
- Translates to C
  - High level language
    - Optimisations are less precise
  - Another layer of indirection
    - Programme structure information loss
    - More code; more room for bugs



So Let’s Write a P4 Compiler

LLVM



- Compiler and toolchain technologies
- Modular and reusable

Skip the Middleman

- Translate Directly to LLVM IR
  - Better support for optimisation
    - Add entry-points and placeholders
    - Example: Strong use of *mem2reg*
    - Example: undef -> 0 replacement
  - Better control over generated code
    - Can add debug symbols and code locators
  - Less computation
    - Meaning less room for bugs

The Technicalities

The Technicalities

- So we wrote our code in P4
  - Implemented identity
    - For Zero-Trust
  - Implemented security
    - For Zero-Trust and SDP
  - Implemented the kitchen sink
- Now what?

The Technicalities

Code

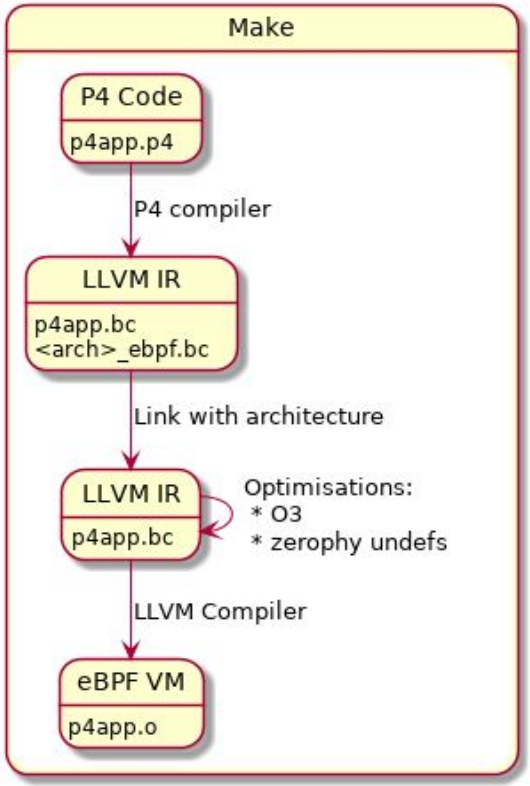
The Technicalities - Code (L2)

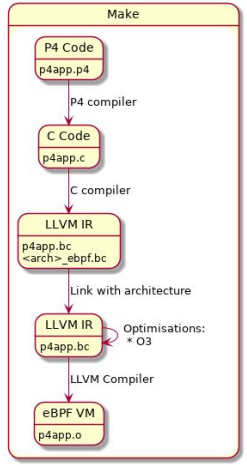
```
1  control l2(inout headers_t hdr, inout metadata_t meta, inout standard_metadata_t istd) {
2          action set_dst_lport(bit<32> port) {
3                  meta.dst_lport = port;
4          }
5          table l2_forward_tbl {
6                  key = {
7                          hdr.ethernet.dstAddr: exact;
8                  }
9                  actions = {
10                         set_dst_lport;
11                 }
12         }
13
14         apply {
15                 l2_forward_tbl.apply();
16         }
17 }
```

The Technicalities

Compilation

Compilation



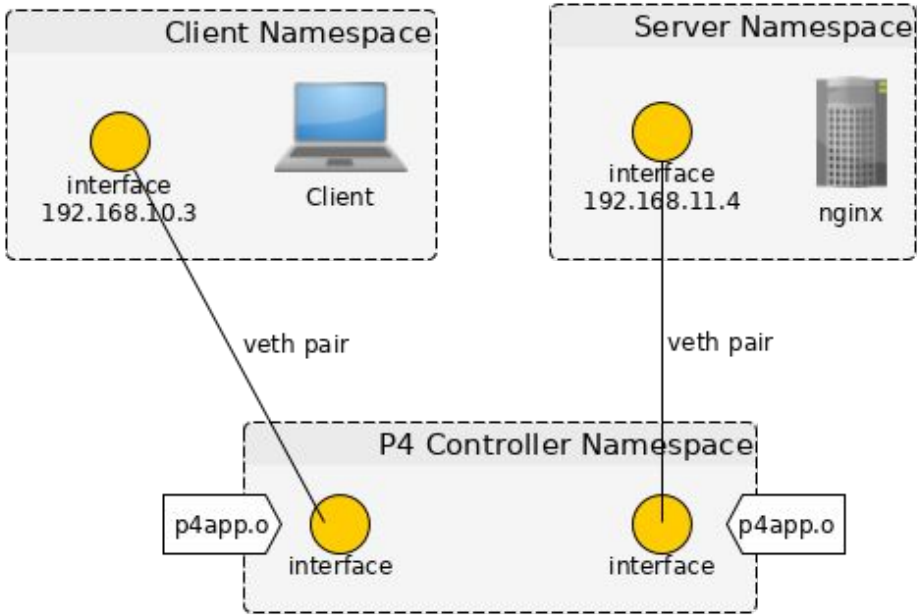


The Technicalities

Loading (an example)

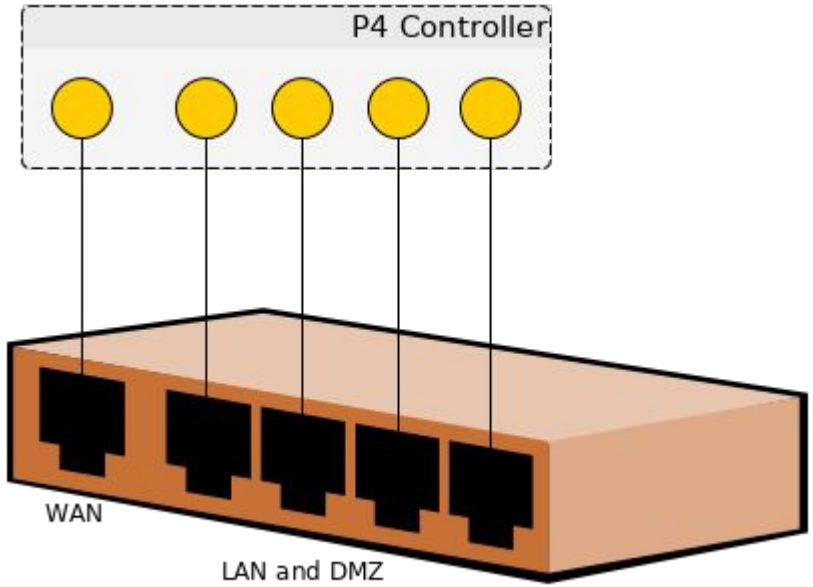
“Physical” Network Structure

- Single P4 Controller namespace
- Each network element in its own namespace
  - Connected with a veth pair
- Where to load compiler output?
  - P4 Controller only
  - Leg of veth pair
- **We’re good to go!**



You Promised Zero-Trust and SDP!

- Write the logic in P4
  - For Zero-Trust
  - For SDP
  - For the pygmy marmoset passing the packets
- Compile it
  - That’s where this work comes in
- Load it in the gateway



Summary

Conclusion

- Wrote a Zero-Trust and SDP Gateway in P4
- Wrote a compiler: P4 -> LLVM
- Use LLVM optimisations
- It works. Managed to compile, run, and test

Thank You!

Questions?

Thank You!

(Come Again)