P4 on the Edge

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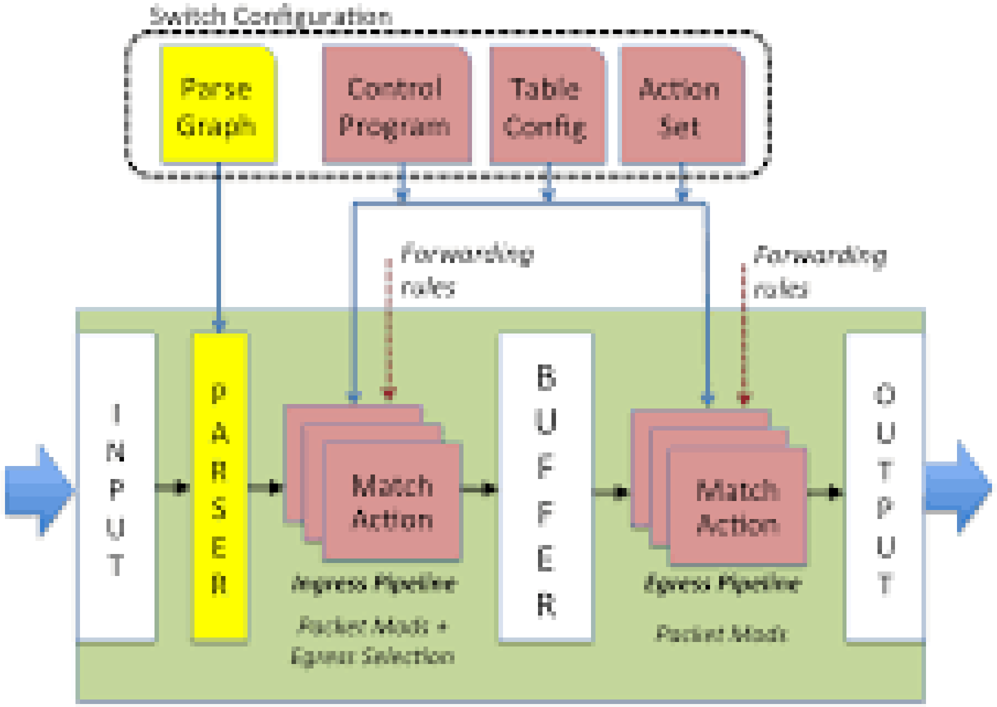
Linux Datapath

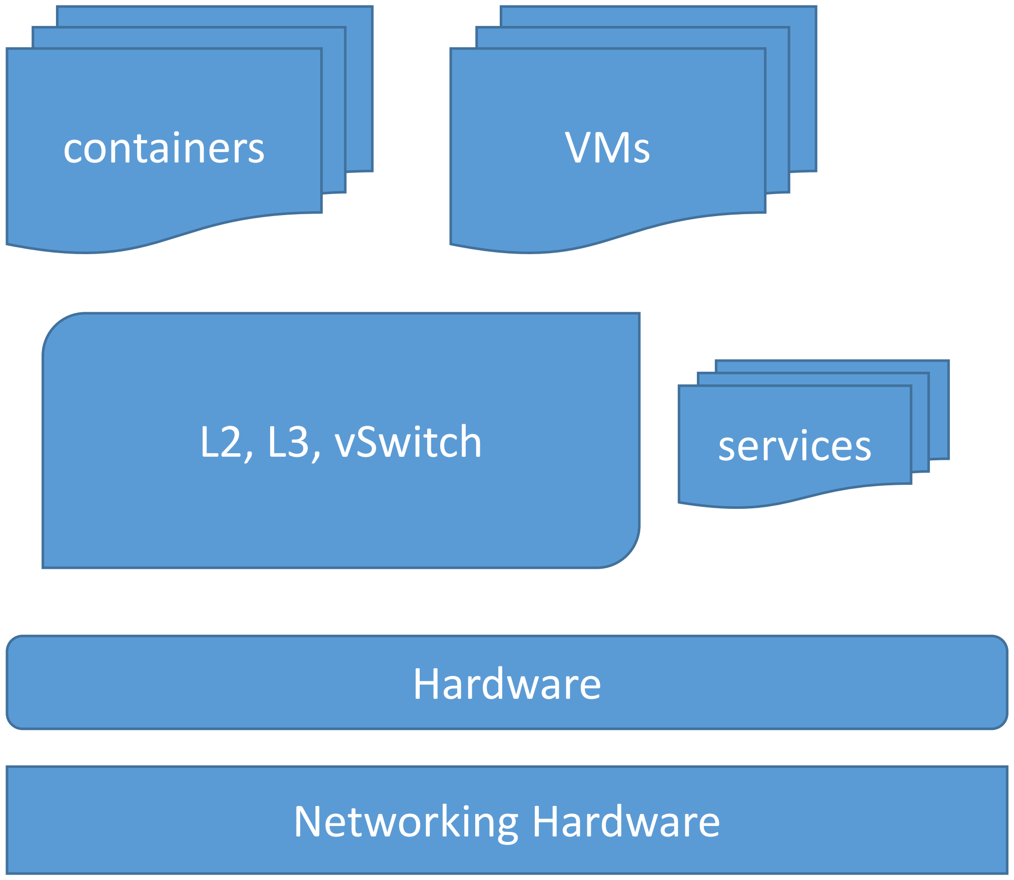
- Using P4 on the edge nodes
  - Is P4 a useful abstraction for an edge node?
- Tools:
  - eBPF : instruction set, “maps”, kernel helper routines
  - LLVM : “The LLVM Project is a collection of modular and reusable compiler and toolchain technologies.”
  - TC : traffic classifier – loads eBPF programs into ingress/egress path of networking stack.

Canonical P4 Model Architecture



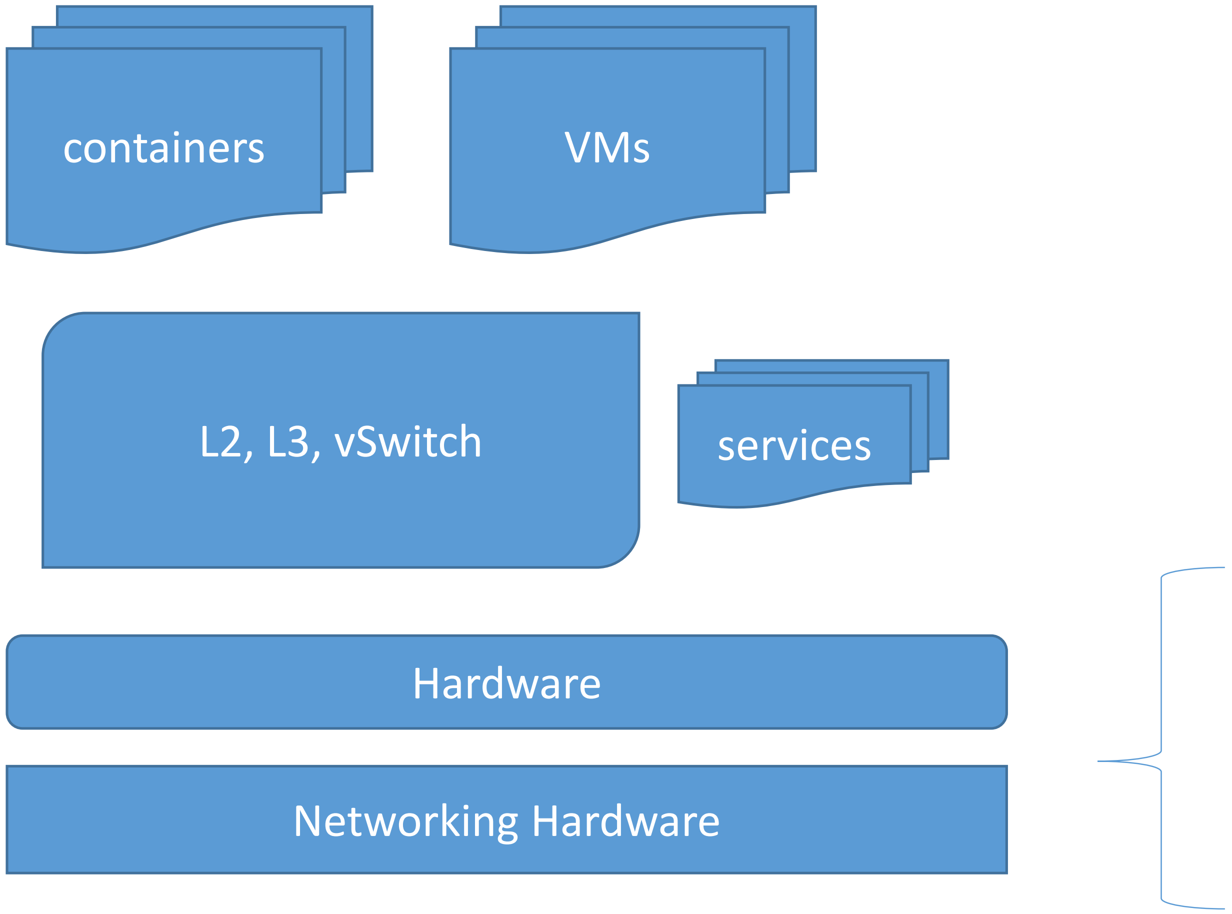
https://arxiv.org/pdf/1312.1719.pdf

Edge platform



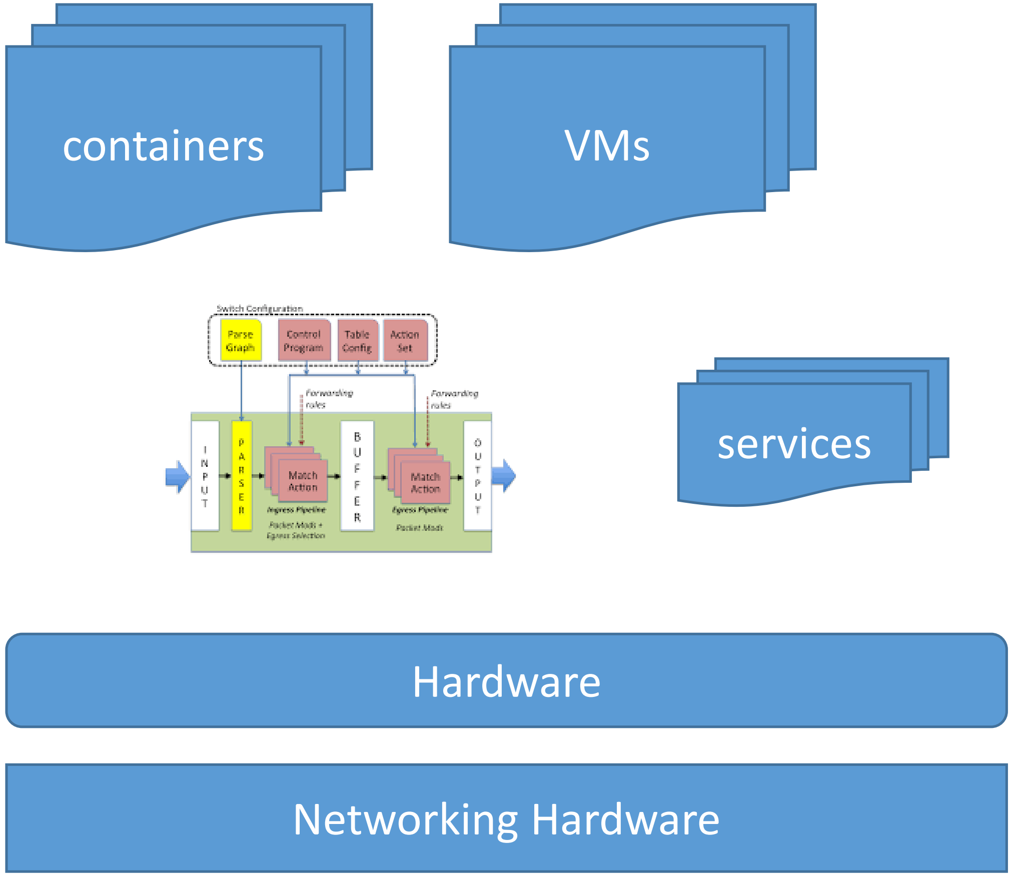
- Containers/VMs
  - virtual ports
  - create/migrate/destroy semantics
- Services (State!)
  - Connection Tracking
  - NAT
  - Load Balancing
- Forwarding Model
  - L2, L3, vSwitch, sockets
  - ACLs
- TEP
  - Port Based
  - Flow Based

Edge platform (hardware)



- Collection of CPUs
- Plus networking component (FPGA, NICs, NPU, etc)

Edge platform



containers

VMs

services

Hardware

Networking Hardware

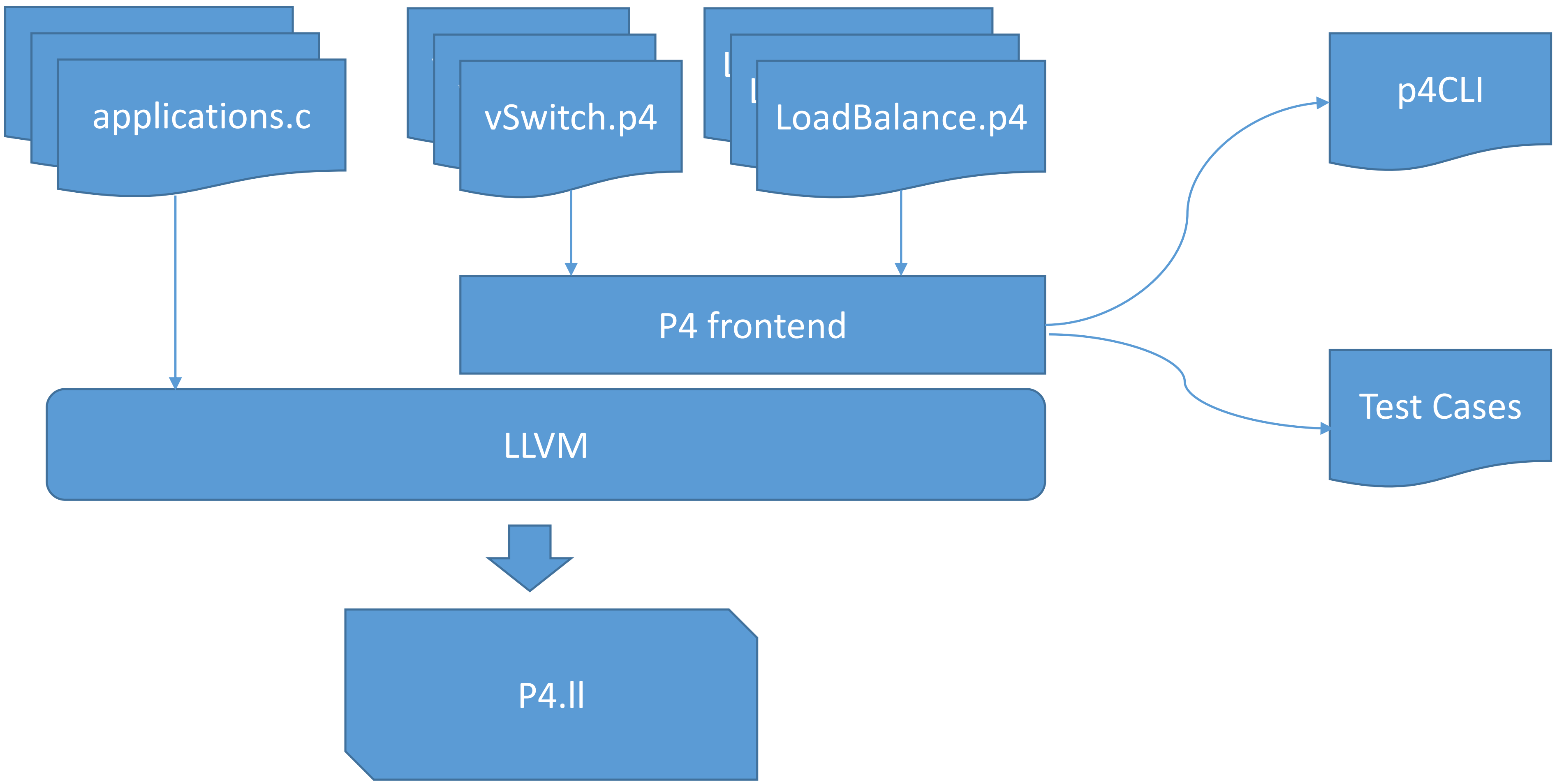
Integrate a P4 programming model with the flexibility of software.

P4 LLVM Development Environment

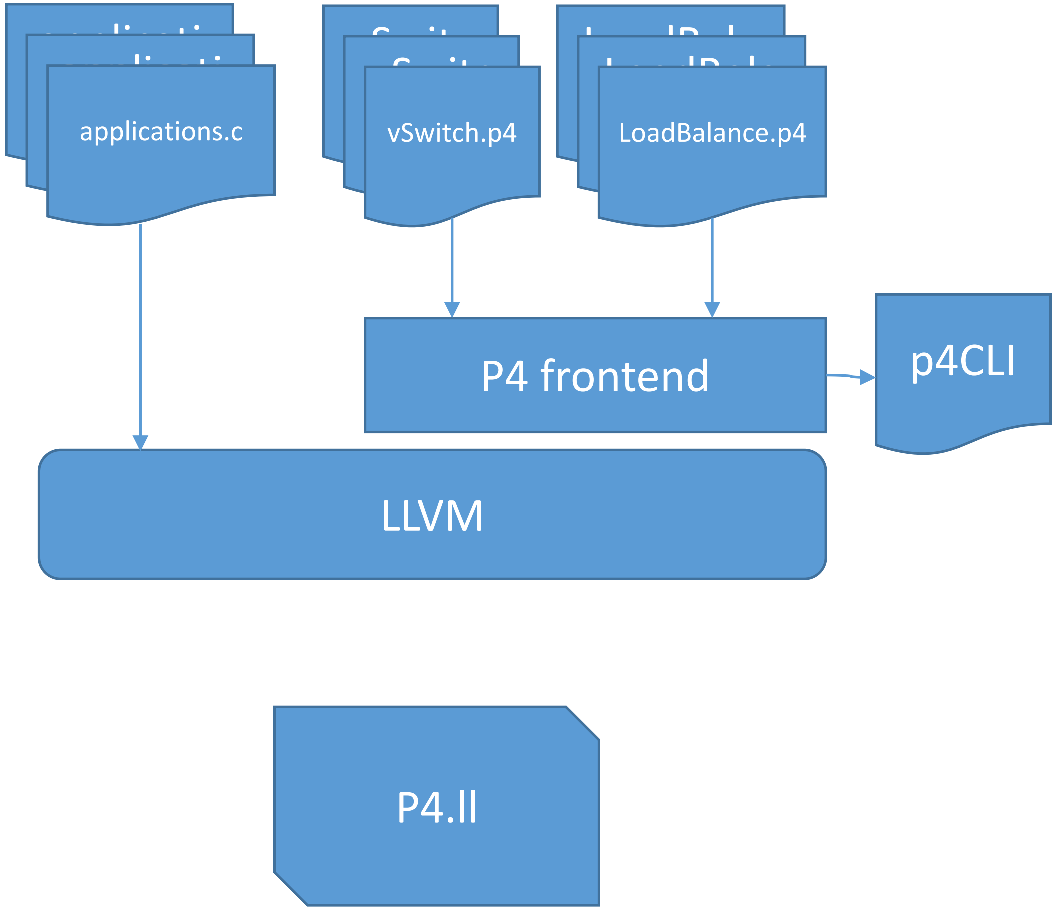
BPF

- Injects “**program**” into Linux kernel at ingress/egress hooks
- “**maps**” share data between programs and user space
- OS helper routines for basic operations, redirect, drop, set_field, etc.
- 10 64-bit registers, supporting arbitrary load/store
- Supported by a **LLVM** backend

LLVM_P4 Development Environment



LLVM_P4 Development Environment



- StdLib “Software SDK” implemented as LLVM IR
- P4 externs can augment stdlib using program files “application.c” written by the developer.
- Leverage OS helpers, data structures, etc. to provide auxiliary data, (e.g. actions, TCP windows size, cpu load, etc).
- Frontend generates eBPF calls for packet operations and uses maps for tables
- LLVM “opt” program to run passes over P4.ll

LLVM_P4 Development Environment

Supported Target: eBPF

```
# p4llvm switch1.p4
# opt –O2 switch1.ll –o switch1.ll
# llc –march=bpf –filetype=obj –o switch1.o switch1.ll
# tc qdisc add dev eth3 ingress
# tc filter add dev eth3 parent ffff: bpf obj switch1.o exp /tmp/p4cli
```

P4.ll
P4.ll
P4.o

StdLib, Services, State, and Functions

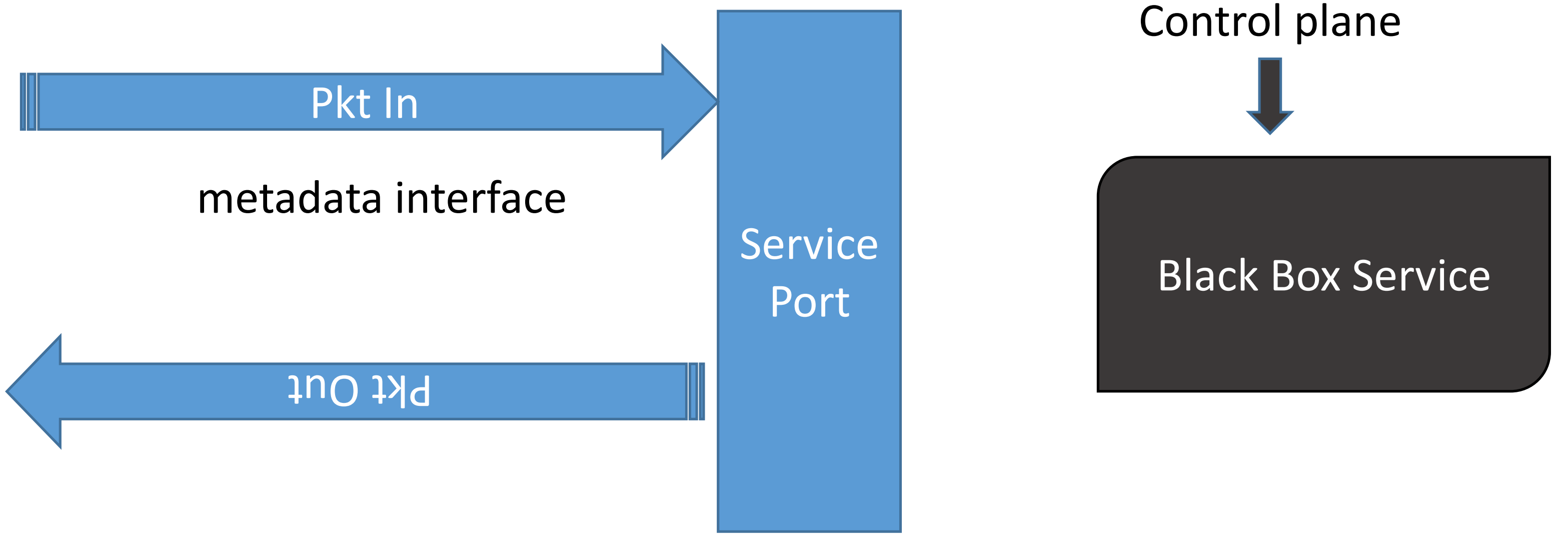
- Stdlib implements all the actions, metering, etc.
  - expected P4 spec features (drop, set_field, meter, counters, …)
- Applications.c (State!)
  - Connection Tracking
    - Not just TCP Flags. Sequence tracking, related flows, etc
  - Load Balancing
    - Operating System state e.g. socket/cpu affinity, cpu state, latency, etc.
  - Functions
    - Anything!

Abstractions for Applications.c

- Service as a parser method / as control flow method
- Service as an Action

Field_a	Field_b	Action
0xabcd	0x1234	do_extern()

- Service as a Port



Abstractions for Applications.c

- Service as an Action
  - Works well for items that map naturally to per packet operations
  - Easy to overload with lots of external dependencies
    - LB_action using OS state
- Service as a Port
  - Works well for “large” bricks for some definition of large
    - FPGA port
    - crypto port
    - connection tracker port
  - Anything that has a natural recirculation path
    - Remember recirculation may impact throughput/latency

P4 Dev Environment Loader

- The interesting problem that has been ignored so far…
  - CPU mapping to program (run to completion vs pipeline)
  - Resource mapping -- cache allocation, memory footprint, etc.
  - Hardware offloads
    - Leverage hardware capabilities
    - Push pipeline across multiple objects, software, NIC, FPGA, etc.

Future Work (even more experimental)

- Auto generate test pcap files
  - 100% test coverage at least on standard featuers
  - Formal methods
- Debugging backend
  - gdb for P4 development workbench
- P4 optimization opportunities
  - Vector operations
- P4 orchestrator
  - OVN(?)

Questions?