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

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)
Integrate a P4 programming model with the flexibility of software.
P4 LLVM Development Environment
BPF

- Injests “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

- applications.c
- vSwitch.p4
- LoadBalance.p4
- P4 frontend
- LLVM
- P4.ll
- p4CLI
- Test Cases
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
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

<table>
<thead>
<tr>
<th>Field_a</th>
<th>Field_b</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>0xabcd</td>
<td>0x1234</td>
<td>doExtern()</td>
</tr>
</tbody>
</table>

• Service as a Port

Pkt In

metadata interface

Pkt Out

Control plane

Black Box Service
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 features
  - Formal methods

- Debugging backend
  - gdb for P4 development workbench

- P4 optimization opportunities
  - Vector operations

- P4 orchestrator
  - OVN(?)
Questions?