Leveraging P4 for Fixed Function Switches

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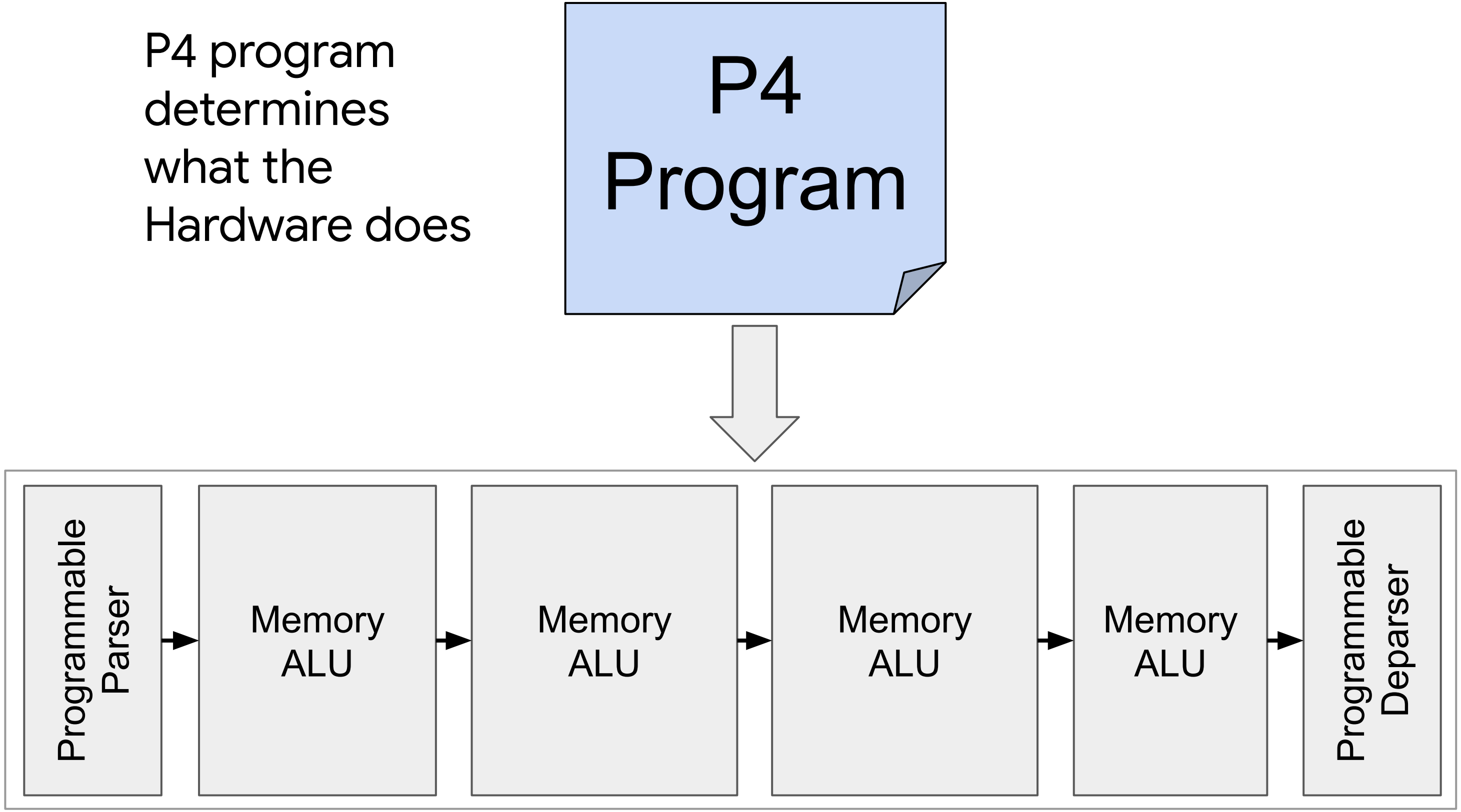
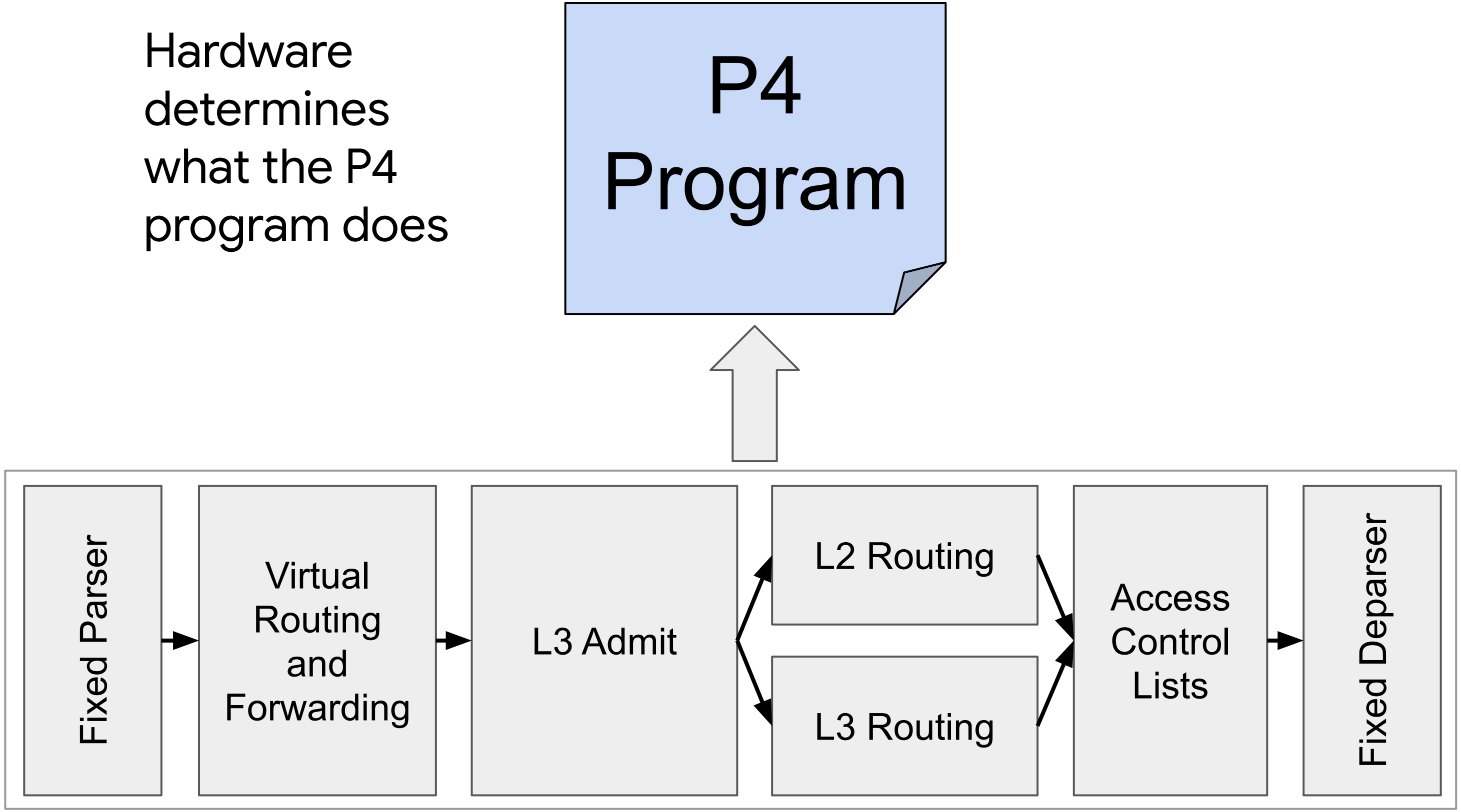
P4 on Programmable Switches

P4 program determines what the Hardware does



P4 on Fixed-Function Switches

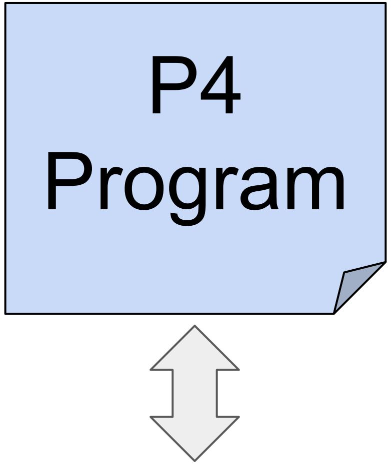
Hardware determines what the P4 program does



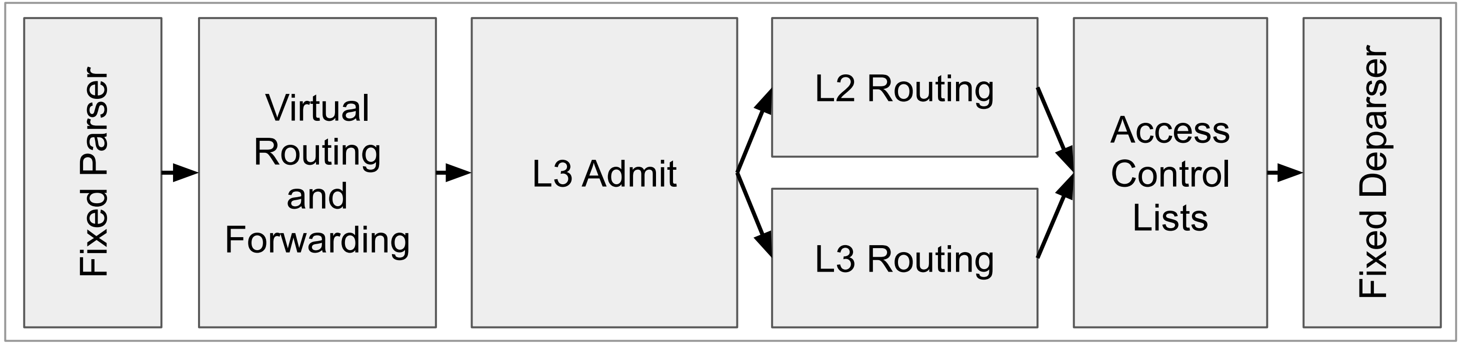
presenter: konne

P4 on Fixed-Function Switches

Hardware determines what the P4 program does



But, only model what we need:
- skip unused features (e.g. L2)
- tables only include actually used keys and actions
- table sizes are what we use
- for configurable aspects, only model our configuration
- ...



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Why would you want to do this?

Clear *contract* of switch behavior:

- Enables operation of a heterogeneous fleet
- Automatically generate switch config
- Enables automated switch validation

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Automated Switch Validation

Automated Switch Validation

Test inputs are automatically generated,
either from production data,
or by analyzing our P4 programs.

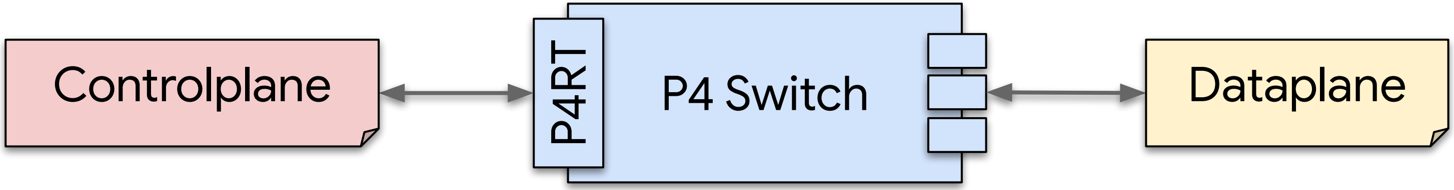
Automated Switch Validation

We validate a single
switch chip, not the
whole network.

Automated Switch Validation

Test outputs are compared to a P4 program simulation.

How do we test the switch?



Replay production flows/groups

Fuzzer to randomly create flow/group insert/delete requests

ATPG: Automated Test Packet Generation

Controlplane Fuzz Testing

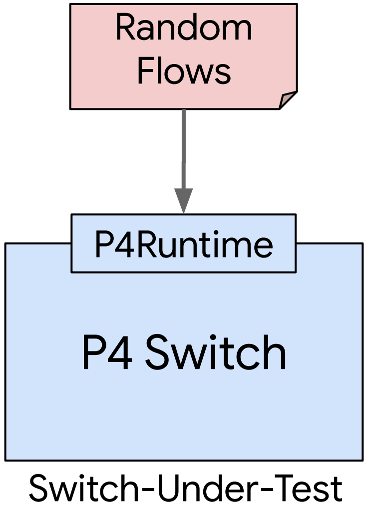
Controlplane Fuzzing

Randomly generate flow requests according to P4 program grammar

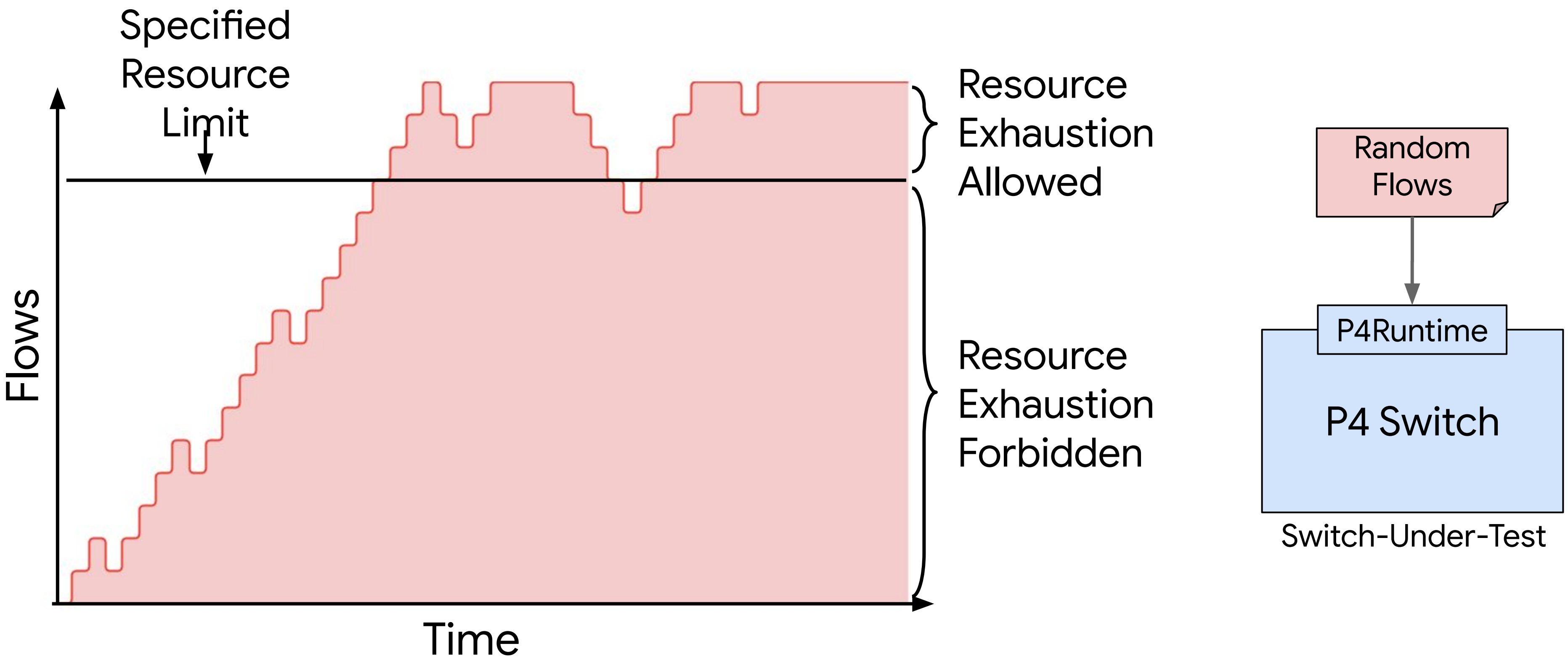
- Mostly generate well-formed requests
- Sometimes generate ill-formed ones
- Intuition: Need to be well-formed enough to not get rejected early

Send flow to switch, check that they are handled correctly

- E.g. well-formed insert must succeed (unless resource exhausted or already present)
- P4 allows us to accurately predict the expected error (or success)

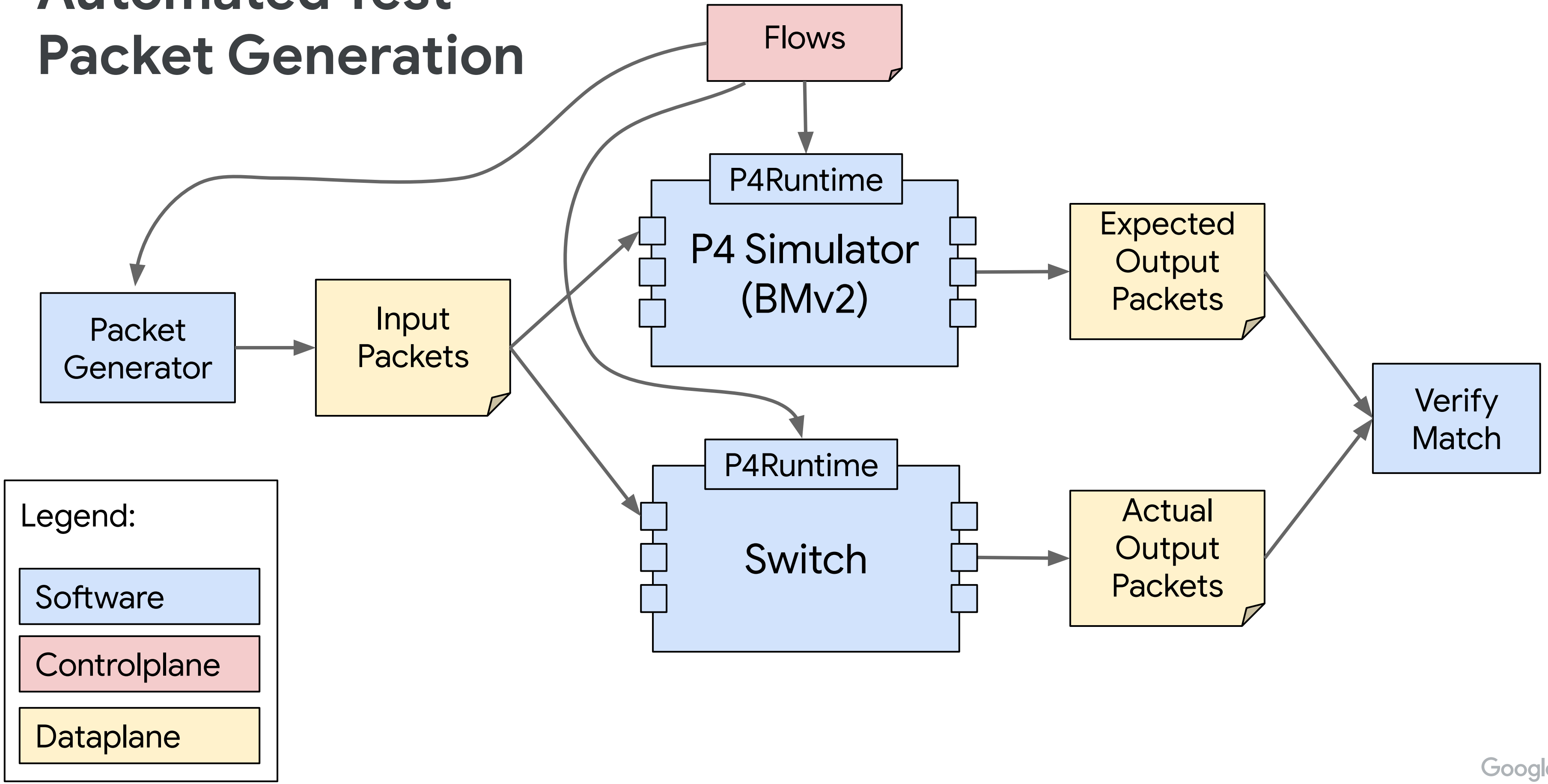


Controlplane Fuzzing: Resource exhaustion



Automated Test Packet Generation

Automated Test Packet Generation



Generation Strategy: Hitting every flow on the switch

VRF Classifier

EthType	SrcMac	Port	Set VRF
0x800	aa:bb:cc: dd:ee:ff	*	1337
0x800	*	4	42

IPv4 LPM

VRF	DstIP
42	10.152.8/24
42	10.152/16
...	...

Want to hit this flow

VRF == 42 & DstIP[32:16] == "10.152" // hit target IPv4 LPM flow

& !(VRF == 42 & DstIP[32:8] == "10.152.8") & !(...) // avoid all other IPv4 LPM flows

// encode VRF assignment

& ((!(EthType == 0x800 & SrcMac == "aa:bb:cc:dd:ee:ff")
& (EthType == 0x800 & Port == 4)) → VRF == 42)

SAT solver finds packets to satisfy the formula

Dataplane Testing: why SAT works

- Everything is finite
  (no lists, loops, recursion, etc)

- Switch semantics are rigorously defined in the P4 program

Dataplane Testing: why it works

P4

Test oracle: Clear semantics allow simulator to precisely predict switch behavior

Test generation: Semantics are simple enough that tools can reason about them automatically

OpenFlow

Lack of formal and computer-readable specification makes both difficult to do automatically

What kind of Bugs did we find?

- Bugs in the Switch
- Bugs in our SDN Controller
- Bugs in our P4 specs
- Bugs in BMv2

Conclusion

Key Takeaways

P4 provides a clear contract of switch behavior:

- Enables operation of a heterogeneous fleet
- Can be used to generate switch config
- Enables automated switch validation
  (it's fast and finds a broad spectrum of bugs)

We're hiring!

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