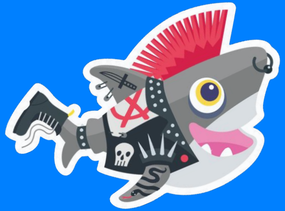

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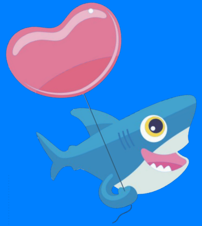
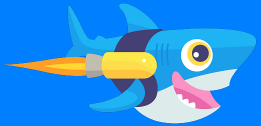




Testing our datapath

Our journey into creating a framework to automate testing of our datapath

Nick Bouliane
Software Engineer at DO since 2017

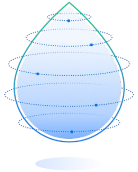
Started hacking on iptables/netfilter early 2000
http://people.netfilter.org/acidfu

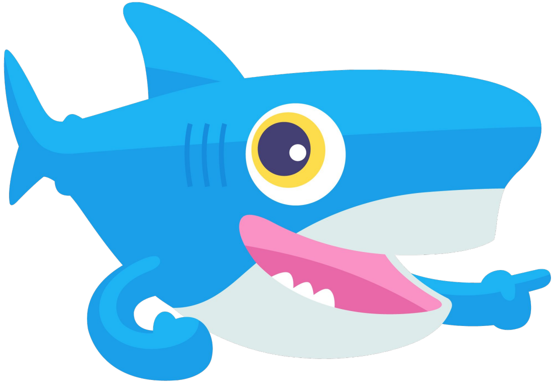
Working on SDN primitives
Open vSwitch
Exploring ebpf

Blue Thunder Somogyi
Software Engineer at DO since 2018

Hacked XConq 1.0
(with help from K&R)
Spent too many years at Cisco
Huge DTrace and ZFS Fan

DigitalOcean

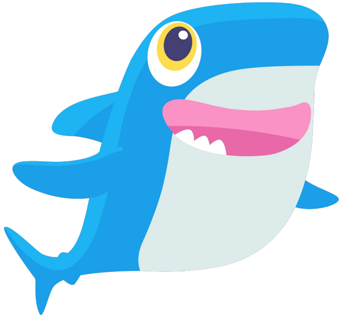




cloud-hosting company
1.15 million droplets

Topics

- Landscape of the datapath
- How things are organized
- What complexifies the testing of our datapath
- What is our datapath composed of



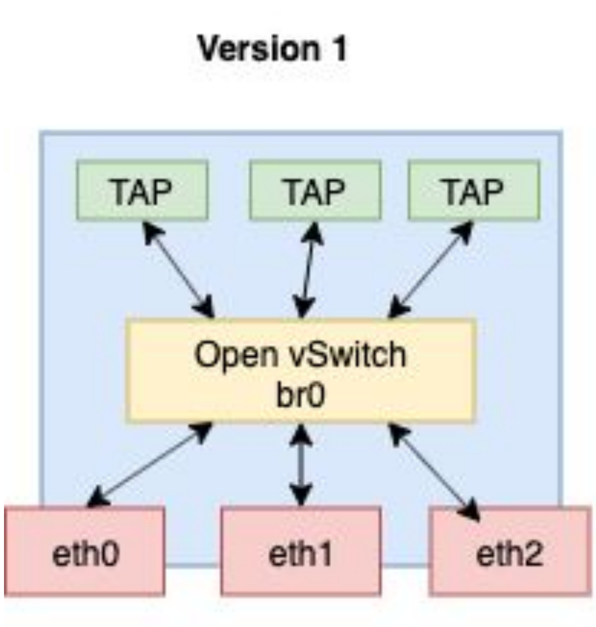
Networking at Digital Ocean

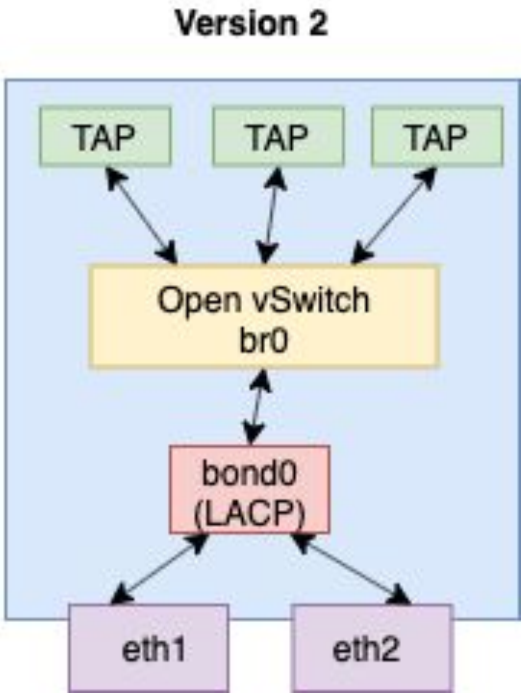
- Initially used linux bridge, iptables, ebtables and a bunch of perl scripts
- Started using OVS in 2014
- Helps unify the logic of our datapath
- Easier to test, reason about and less moving parts

Open vSwitch at Digital Ocean

- More than 18 500 hypervisors
- 12 Data centers
  - **NYC1**, **NYC2**, **NYC3**: New York City, United States
  - **AMS2**, **AMS3**: Amsterdam, the Netherlands
  - **SFO1**, **SFO2**: San Francisco, United States
  - **SGP1**: Singapore
  - **LON1**: London, United Kingdom
  - **FRA1**: Frankfurt, Germany
  - **TOR1**: Toronto, Canada
  - **BLR1**: Bangalore, India

Data center complexity





Open vSwitch version

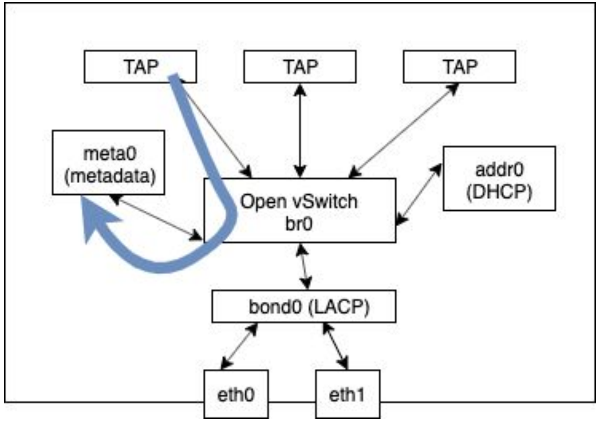
- Ubuntu Trusty → Ubuntu Bionic
- Open vSwitch 2.7.3 → 2.11.0 (our own package)
- Bionic provides 2.9.2

Some projects that use openflow

- Floating IP
- Firewall
- VPC (Virtual Private Chassis)
- LBaaS - Load Balancer as a Service

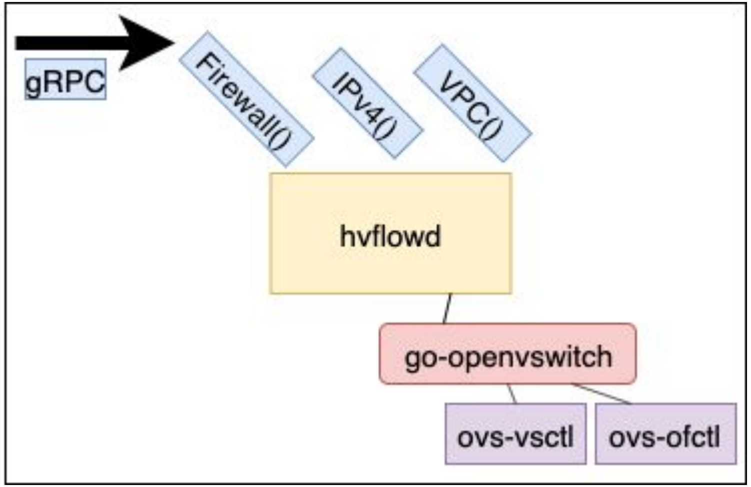
Some projects that use openflow

- Bandwidth billing
- L3/Gateway
  - underlay traffic is now routed instead of being switched
- Internal services
  - DHCP (behind addr0 interface)
  - Metadata (behind meta0 interface)
  - ...

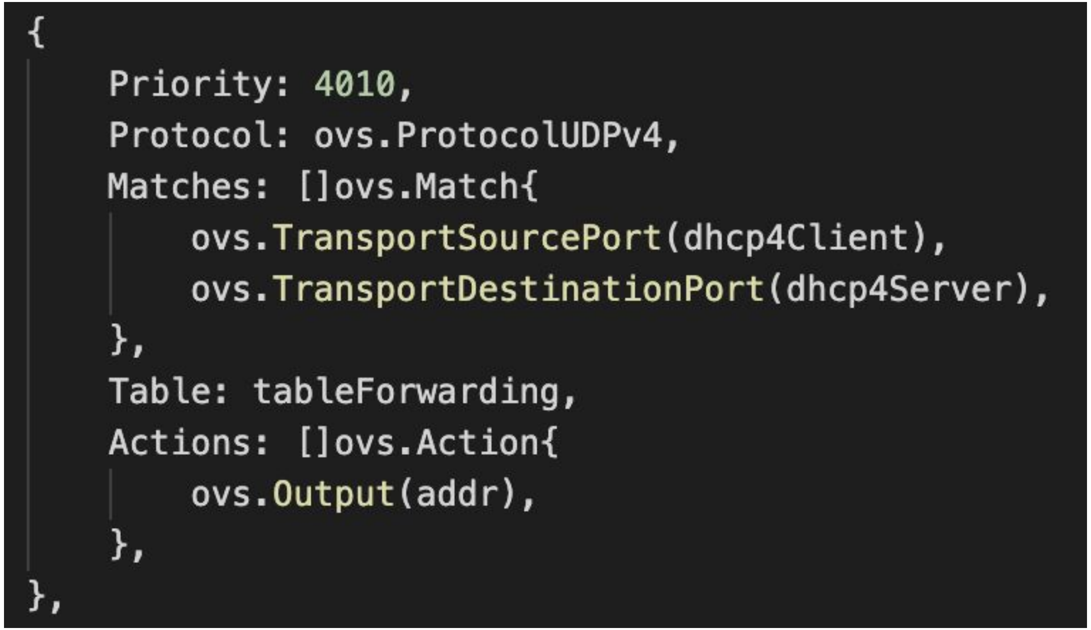


Hvflowd

- No SDN controller
- We control MAC and IP
- Push flows as soon as possible
- gRPC calls
  - Droplet creation
  - Firewall applied
- Use go-openvswitch
  - ovs-vsctl and ovs-ofctl



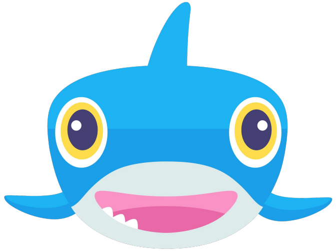
go-openvswitch



```
{
    Priority: 4010,
    Protocol: ovs.ProtocolUDPv4,
    Matches: []ovs.Match{
        ovs.TransportSourcePort(dhcp4Client),
        ovs.TransportDestinationPort(dhcp4Server),
    },
    Table: tableForwarding,
    Actions: []ovs.Action{
        ovs.Output(addr),
    },
},
```

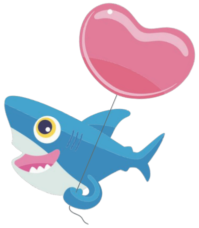
Recap

- Many projects
- Flowset orchestration
- Multiple configurations



The Datapath Validation Framework

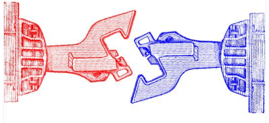
Datapath (DP) Validation Framework Topics



- DP Validation Design Goals
- DP Validation Implementation Choice
- DP Validation Modes of Operation
- Example Validation Test
- Challenges Encountered With DP Validation
- Next Steps for DP Validation

Design Goals

- Detect breaking changes
- CI/CD Integration
- Non-disruptive Production Flow Validation
- Decouple Tests from OVS



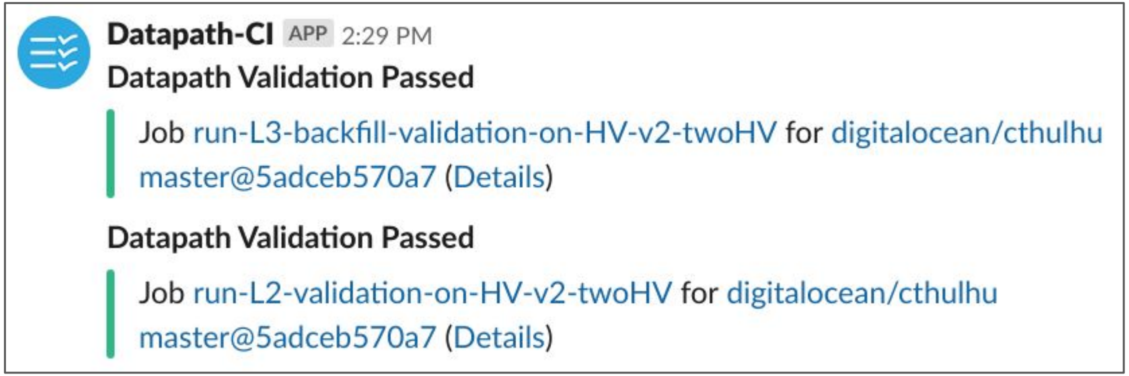
- Improve product team agility

Some icons made by Freepik

Implementation Direction

Utilized `` `go test` `` tooling driven by **`Make`** targets

- Allows for easy integration with CI/CD infrastructure (Concourse)



Datapath-CI APP 2:29 PM

Datapath Validation Passed

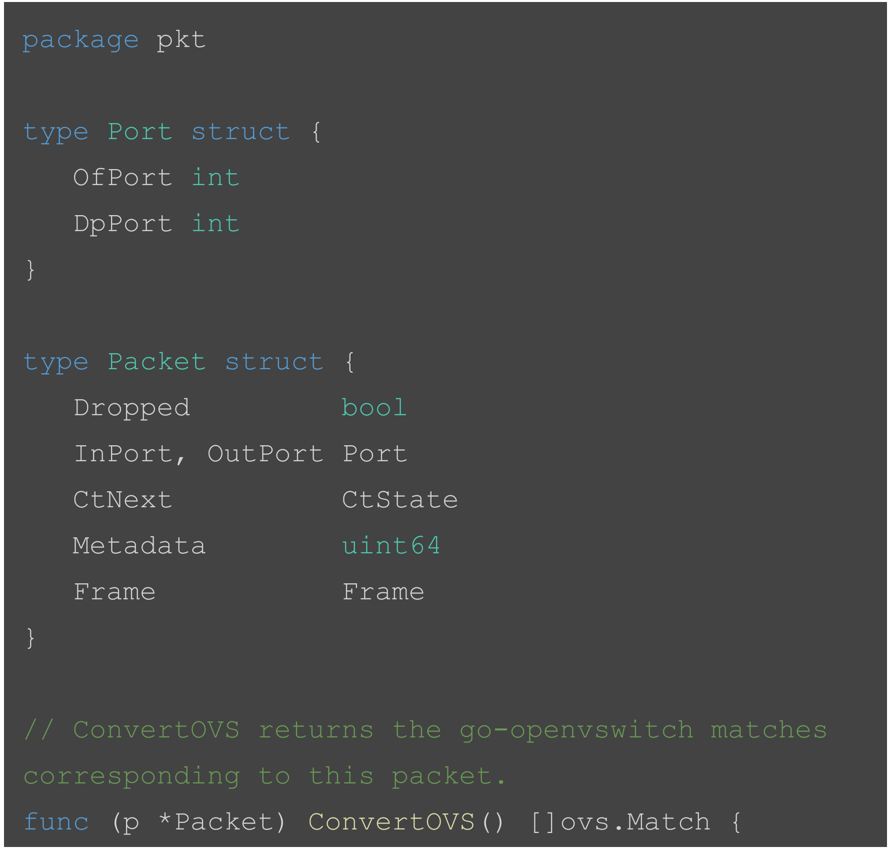
Job run-L3-backfill-validation-on-HV-v2-twoHV for digitalocean/cthulhu master@5adceb570a7 (Details)

Datapath Validation Passed

Job run-L2-validation-on-HV-v2-twoHV for digitalocean/cthulhu master@5adceb570a7 (Details)

- Local testing with validation framework seamless
- `` `go test -o` `` binary generation

OVS Abstraction Examples

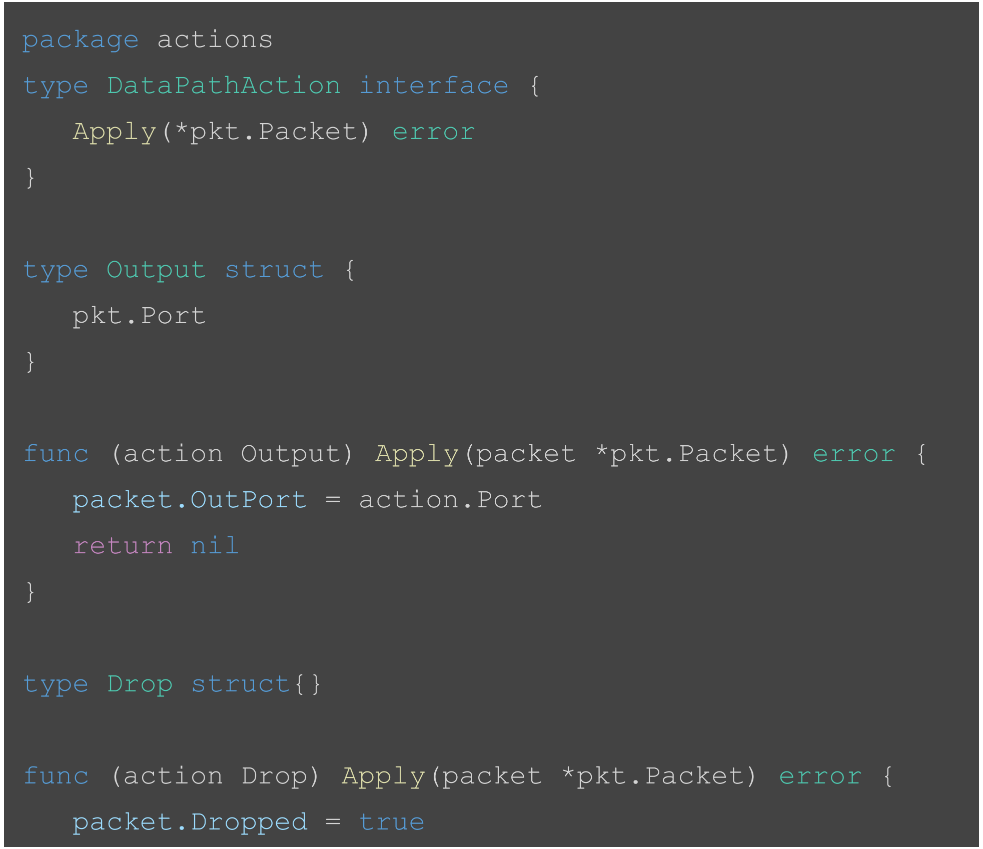


```go
package pkt

type Port struct {
    OfPort int
    DpPort int
}

type Packet struct {
    Dropped          bool
    InPort, OutPort  Port
    CtNext           CtState
    Metadata         uint64
    Frame            Frame
}

// ConvertOVS returns the go-openvswitch matches
corresponding to this packet.
func (p *Packet) ConvertOVS() []ovs.Match {
```



```go
package actions
type DataPathAction interface {
    Apply(*pkt.Packet) error
}

type Output struct {
    pkt.Port
}

func (action Output) Apply(packet *pkt.Packet) error {
    packet.OutPort = action.Port
    return nil
}

type Drop struct{}

func (action Drop) Apply(packet *pkt.Packet) error {
    packet.Dropped = true
```

Example Test

TestL2V4InternetEgressArpRequestForGateway

```go
func TestL2V4InternetEgressArpRequestForGateway(t
*testing.T, publicPort *netparams.NetworkParamsVNIC) {
<...SNIP...>
    packet := pkt.Packet{
        InPort: f.GetPortByName(publicPort.Name).Port,
        Frame: &pkt.EthernetFrame{
            Src: sourceMac,
            Dst: "ff:ff:ff:ff:ff:ff",
            Frame: &pkt.ArpFrame{
                Op:  f.ArpOpRequest,
                Sha: sourceMac,
                Spa: address,
                Tpa: gw,
            },
        },
    }
```

(continued)

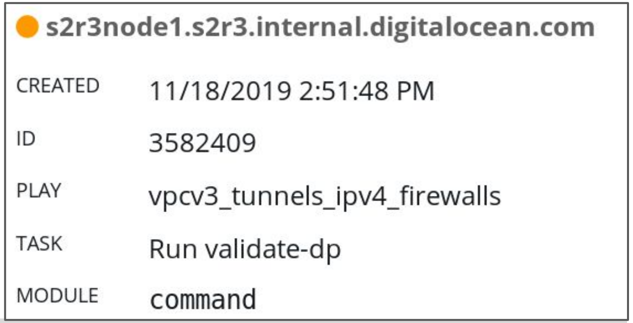
```go
    port := f.GetHVPublicPort()
    expected := []actions.DataPathAction{
        actions.PushVlan{Vid: vlan},
        actions.Output{Port: port.Port},
    }

    if f.HvConf.L3State ==
hvflow.Layer3GatewayStateCompleteStr {
        port := f.GetPortByName(f.RespondPort)
        expected = []actions.DataPathAction{
            actions.Output{Port: port.Port},
        }
    }

    f.ValidateDataPathActions(t, packet, expected)
}
```

Modes of Operation

- Local `make test` or `make <test target>`
- Local `make sandbox`
- Execution of `validate-dp` binary on staging or production hosts



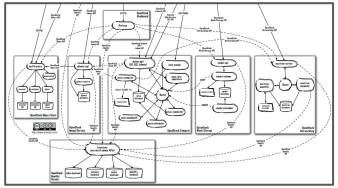
● s2r3node1.s2r3.internal.digitalocean.com

CREATED	11/18/2019 2:51:48 PM
ID	3582409
PLAY	vpcv3_tunnels_ipv4_firewalls
TASK	Run validate-dp
MODULE	command

```
/opt/apps/hvflow/bin/validate-dp --hv /etc/dp-validation.yaml --vpc
/etc/dp-validation/testbed/vpcs/2.json --droplet
/etc/dp-validation/testbed/droplets/1194037.json --remote-droplet
/etc/dp-validation/testbed/droplets/998969.json --source-mac
6a:07:3e:99:4e:f8 --target-mac 62:ab:6f:15:81:e0 --test.v  --test.run
TestDroplet2RemoteDroplet
```

Implementation Challenges

- HVFlowd Interface Expectations
- Static HV and Droplet configurations
- Test-to-Configuration Mapping & Test Coverage

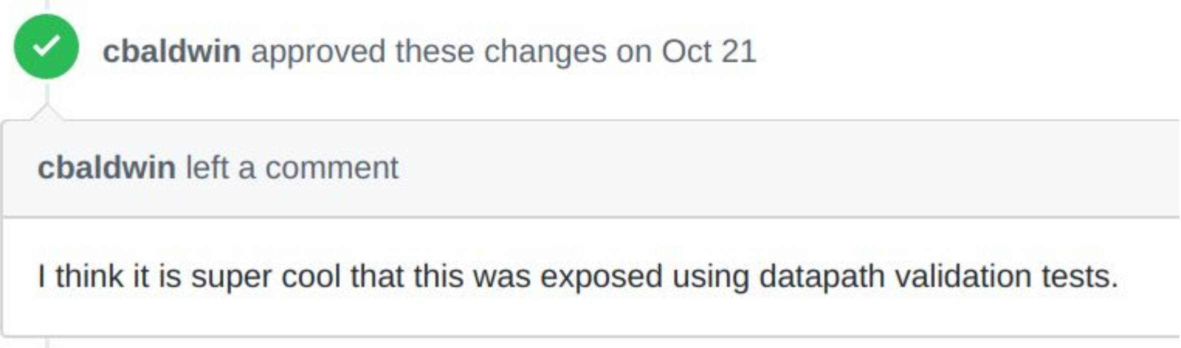


- No-ops and OVS Action String Ordering

https://icon-library.net/icon/icon-for-file-23.html

Bugs Found

- Removal of Legacy (pre-encapsulation) VLAN from private traffic causes v2/v3 Interop problem
- Incorrect Priority on Overlapping IP addresses (in fix for above issues)



cbaldwin approved these changes on Oct 21

cbaldwin left a comment

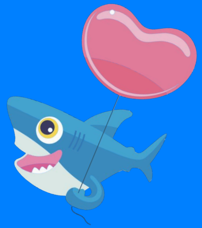
I think it is super cool that this was exposed using datapath validation tests.

What’s Next

- Dynamic Configuration
- Table-Driven Tests
- Test Coverage Tracking
- Connection Tracker Traversal
- HVFlowd Binary Testing
- Datapath Versioning

Conclusion

- Confidence Provided by Version 1 of Datapath Validation
- Instrumental in both L3 Public rollout and VPCv3 migrations
- Rapid Growth of Number of Tests and Configurations Supported Created Usability Challenges
- Existing Validation Framework a Solid Foundation for Next Generation of Validation Features



Thank You!

DigitalOcean