OvS manipulation with Go at DigitalOcean

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- Software Engineer at DO for ~3.5 years
- Focused on virtual networking primitives
- Huge fan of Go programming language
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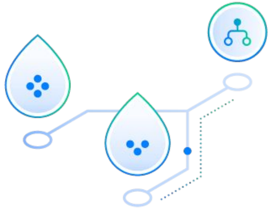
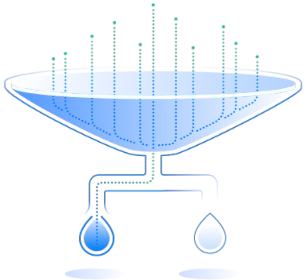
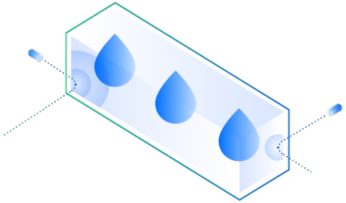
DigitalOcean

Cloud computing designed for developers

- Cloud provider with focus on simplicity
- “Droplet” product is a virtual machine
- Compute, storage, **networking**, and monitoring primitives
    - Load Balancers as a Service
    - Floating IPs
    - Cloud Firewalls (learn more at Kei Nohguchi’s talk!)







DO is powered by Open vSwitch!

- **10,000+** of instances of OvS!
- One of the most **crucial** components in our entire stack.

Open vSwitch at DigitalOcean: The Past

Open vSwitch and Perl

- Events (create droplet, power on, etc.) reach a hypervisor
- Perl event handlers pick up events and performs a series of actions to prepare a droplet
- **Perl builds flow strings and calls `ovs-ofctl`**

Building flows with Perl

```perl
my $ipv4_flow_rules = [
	[
		# Flow priority.
		2020,
		# Hash of flow matches.
		{
			dl_src  => $mac,
			in_port => $ovs_port_id,
			ip      => undef,
			nw_src  => "${ip}/32",
		},
		# Literal string of flow actions.
		"mod_vlan_vid:${ipv4vlan},resubmit(,1)"
	],
	# … many more flows
]
```

Applying flows with Perl

```perl
# Build comma-separated matches from hash.
my $flow = _construct_flow_string($flow_hash);

# Build the flow string with usual fields.
my $cmd = "priority=${priority},idle_timeout=${timeout},${flow},actions=${actions}";

# Once a flow is added, we need a way to delete it later on!
if ($add_delete_hook && defined($delete_hook_handle)) {
      # Flows written into a libvirt hook to be deleted later.
      if (_write_flow_to_be_deleted($bridge, $delete_hook_handle, $flow) != PASS) {
            return FAIL;
      }
}

# Shell out to ovs-ofctl and do the work!
return _run_ovs_cmd("ovs-ofctl add-flow ${bridge} '${cmd}'");
```

Conclusions: Open vSwitch and Perl

- Pros:
  - Straightforward code
  - Perl is well-suited to manipulating strings
- Cons:
  - No sanity checking (other than OvS applying the flow)
  - Lacking test coverage
  - libvirt flow deletion hooks for individual flows proved problematic
  - Shell out once per flow; no atomicity

Open vSwitch at DigitalOcean:
The Present

Open vSwitch and Go

- Events reach a hypervisor
- Perl/Go (it depends) systems perform a series of actions to prepare a droplet
- **Go builds flow strings and calls `ovs-ofctl`**

package ovs

Package ovs is a client library for Open vSwitch which enables programmatic control of the virtual switch.

package ovs

- Go package for manipulating Open vSwitch
- **No DigitalOcean-specific code!**
- **Open source (soon)!**
  - https://github.com/digitalocean/go-openvswitch

Building flows with Go

```go
flow := &ovs.Flow{
	// Commonly used flow pieces are struct fields.
	Priority: 2000,
	Protocol: ovs.ProtocolIPv4,
	InPort:   droplet.PortID,
	// Matches and Actions are Go interfaces; functions create a
	// type that implements the interface.
	Matches: []ovs.Match{
		ovs.DataLinkSource(r.HardwareAddr.String()),
		ovs.NetworkSource(r.IP.String()),
	},
	Actions: []ovs.Action{
		ovs.Resubmit(0, tableL2Rewrite),
	},
}
```

Building flows with Go (cont.)

- Our example flow marshaled to textual format:

```
priority=2000,ip,in_port=1,dl_src=de:ad:be:ef:de:ad, \
nw_src=192.168.1.1,table=0,idle_timeout=0,actions=resubmit(,10)
```

- Mostly string manipulation behind the scenes; just like Perl
- Go is statically typed, reducing chance of programmer errors
- Can validate each match and action for correctness without hitting OvS

The ovs.Match Go interface

```go
type Match interface {
	// MarshalText() (text []byte, err error)
	encoding.TextMarshaler
}
```

- Because of the way Go interfaces work, **any type** with a `MarshalText` method can be used as an `ovs.Match`
- The error return value can be used to catch any bad input
- `ovs.Action`'s definition is identical

The ovs.Client Go type

```go
// Configure ovs.Client with our required OpenFlow flow format and protocol.
client := ovs.New(ovs.FlowFormat("OXM-OpenFlow14"), ovs.Protocols("OpenFlow14"))

// $ ovs-vsctl --may-exist add-br br0
err := client.VSwitch.AddBridge("br0")

// $ ovs-ofctl add-flow --flow-format=OXM-OpenFlow14 --protocols=OpenFlow14 br0 ${flow}
err = client.OpenFlow.AddFlow("br0", exampleFlow())
```

- `ovs.Client` is a wrapper around `ovs-vsctl` and `ovs-ofctl` commands
- `ovs.New` constructor uses “functional options” pattern for sane defaults
- We can still only apply one flow at a time… right?

ovs.Client flow bundle transactions

```go
// Assume we want to apply a new flow set and remove old one.
add, remove := newFlows(), oldFlows()

// We can apply all of these flows atomically using a flow bundle!
err := client.OpenFlow.AddFlowBundle(bridge, func(tx *ovs.FlowTransaction) error {
	// $ echo -e “delete priority=10,cookie=1,actions=drop\n” >> mem
	tx.Delete(remove...)
	// $ echo -e “add priority=10,cookie=1,actions=output:1\n” >> mem
	tx.Add(add...)
	// $ cat mem | ovs-ofctl --bundle add-flow --flow-format=OXM-OpenFlow14 --protocols=OpenFlow14 br0 -
	return tx.Commit()
})
```

- Flow bundle stored in memory, passed directly from buffer to `ovs-ofctl`
- Modifications are processed by OvS in a single, atomic transaction

package hvflow

Package hvflow provides Open vSwitch flow manipulation at the hypervisor level.

package hvflow

- **DigitalOcean-specific** wrapper for package ovs
- Provides **higher-level constructs**, such as:
  - enable public IPv4 and IPv6 connectivity
  - reset and apply security policies
  - disable all connectivity

The hvflow.Client Go type

```
// Configure hvflow.Client to modify bridge “br0”.
client, err := hvflow.NewClient("br0", ovs.New(
	ovs.FlowFormat("OXM-OpenFlow14"), ovs.Protocols("OpenFlow14"),
))
```

- `hvflow.Client` is a **high-level wrapper** around `ovs.Client`
- `hvflow.NewClient` constructor uses “functional options” pattern for sane defaults

Network parameters - “netparams”

- Encode all necessary information about how to enable networking for a given VNIC
- Carries IPv4 and IPv6 addresses, firewall configurations, floating IPs...
- netparams used to configure OvS with `hvflow.Client.Transaction` method


```json
{
 "droplet_id": 1,
 "vnics": [
   {
     "mac": "de:ad:be:ef:de:ad",
     "enabled": 1,
     "name": "tapext1",
     "interface_type": "public",
     "addresses": {
       "ipv4": [
         {
           "ip_address": "10.0.0.10",
           "masklen": 20,
           "gateway": "10.0.0.1"
         }
       ]
     }
   }
 ]
}
```

hvflow.Client transactions

```go
// Assume a netparams structure similar to the one just shown.
params, ifi := networkParams(), "public"
err := client.Transaction(ctx, func(ctx context.Context, tx *hvflow.Transaction) error {
	// Convert netparams into hvflow simplified representation.
	req, ok, err := hvflow.NewIPv4Request(params, ifi)
	if err != nil {
		return err
	}
	if ok {
		// If IPv4 configuration present, apply it!
		if err := tx.EnableIPv4(ctx, req); err != nil {
			return wrapError(err, "failed to enable IPv4 networking")
		}
	}
	return tx.Commit()
})
```

hvflow.Client transactions (cont.)

- Each operation accumulates additional flows to be applied within the context of the transaction.
- Flow set sizes can vary from a couple dozen to several hundred flows.

- Flows are **always applied using a flow bundle**; non-transactional `hvflow.Client` API was deleted!

```
// IPv4 configuration.
err := tx.EnableIPv4(ctx, req4)

// IPv6 configuration.
err = tx.EnableIPv6(ctx, req6)

// Floating IPv4 configuration.
err = tx.EnableFloatingIPv4(ctx, req4F)

// Disable networking on an interface.
err = tx.Disable(ctx, 10, "public")

// Apply flow set to OvS.
err = tx.Commit()
```

The hvflow.Cookie Go interface

```go
type Cookie interface {
        Marshal() (uint64, error)
        Unmarshal(i uint64) error
}
```

- Cookie structs packed and unpacked from uint64 form
- Cookies are versioned using a 4-bit identifier
- Used to store identification metadata about a flow
- Easy deletions of flows; much simpler deletion hooks with libvirt

hvflowctl and hvflowd

gRPC client and server that manipulate Open vSwitch

hvflowctl and hvflowd

- **gRPC** client and server written in **Go**
- `hvflowctl` passes netparams and other data to `hvflowd`
- `hvflowd` manipulates OvS flows via `hvflow` package

hvflowd’s gRPC interface

- gRPC uses protocol buffers (“protobuf”) for RPC communication
- RPCs accept one message type and return another
- `netparamspb` package for encoding netparams in protobuf

```
// The set of RPCs that make up the “HVFlow” service.
service HVFlow {
	// Add flows using the parameters specified in request.
	rpc AddFlows(AddFlowsRequest) returns (AddFlowsResponse);
}

// RPC parameters encoded within a request message.
message AddFlowsRequest {
	// netparams have a protobuf representation too.
	netparamspb.NetworkParams network_params = 1;
	string interface_type = 2;
}

// No need to return any data on success.
message AddFlowsResponse {}
```

hvflowd AddFlows RPC

```go
// AddFlows requests that hvflowd add flows to enable connectivity for one or more droplets.
func (s *server) AddFlows(ctx context.Context, req *hpb.AddFlowsRequest) (*hpb.AddFlowsResponse, error) {
	// Fetch netparams from gRPC request message.
	params := req.GetNetworkParams()
	// Perform the necessary transaction logic to establish connectivity.
	err := s.hvflowc.Transaction(ctx, func(ctx context.Context, tx *hvflow.Transaction) error {
		// hvflow.Client transaction logic …
		return tx.Commit()
	})
	// Inform the caller if the request was successful.
	return &hvflowpb.AddFlowsResponse{}, err
}
```

- RPCs enable **orchestration** among multiple hypervisors and `hvflowd` instances

Testing hvflowctl and hvflowd

- Unit tests verify a flow **looks** a certain way
  - `go test ./...`
- Integration tests verify the **behavior** of flows applied to OvS
  - **mininet**, OvS, `hvflowctl`, `hvflowd`

Testing with mininet

- Network topology created with multi-namespace OvS in mininet
- `hvflowd` spun up in each "hypervisor namespace"

```python
# Spin up hvflowd in the background and set per-hypervisor environment
# variables needed to enable multiple instances to run together.
for key in self.hvflowdEnv:
    self.cmd('export %s=%s' % (key, self.hvflowdEnv[key]))

self.cmd('%s &' % (self.hvflowdPath))
```

- `hvflowctl` issues RPCs using JSON netparams fixtures

```python
# Issue RPCs to hvflowd using flags and netparams JSON.
self.switch.cmd("echo '%s' | %s %s --rpc %s %s" % (stdinBuf, self.hvflowctlPath, command, rpcAddr, opts))
```

Testing with mininet (cont.)

- Docker image built and pulled by Concourse CI
- Virtual droplet and hypervisor topology spun up by mininet
- Tests run on **every** pull request to `hvflow` package

```
Beginning testing with /configs/production.json
==> Outside to public droplet d1 should pass
out1 (8.8.8.8) ----> d1 (192.0.2.10) *** Results: 0% dropped (1/1 received)
==> Outside to floating on d1 should pass
out1 (8.8.8.8) ----> d1 (192.0.2.100) *** Results: 0% dropped (1/1 received)
==> Outside to private d1 should fail
out1 (8.8.8.8) ----> X(d1) (10.60.5.5) *** Results: 100% dropped (0/1 received)
```

Conclusions: Open vSwitch and Go

- Pros:
  - Go is well-suited to building large, highly concurrent, network systems
  - Go compiles to a single, statically-linked binary for trivial deployment
  - Flows are easier to read for those who aren't familiar with OvS
  - Data is statically typed and checked before hitting OvS
  - Flows can be bundled and committed atomically
- Cons:
  - Flows structures are verbose if you are familiar with OvS
  - We are still shelling out to OvS tools

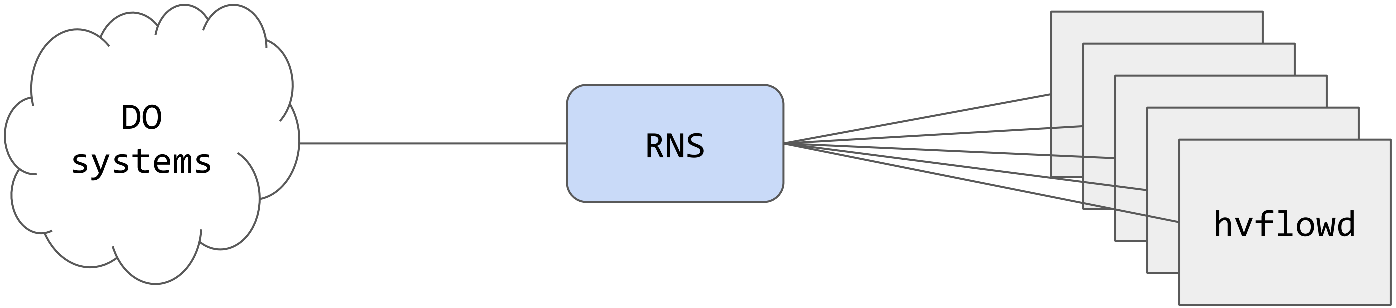
Open vSwitch at DigitalOcean:
The Future

Orchestrated Open vSwitch and Go

- RPC performed to a **“regional network service” (RNS)**
- RNS determines actions, sends RPCs to `hvflowd`
- `hvflowd` builds flows and **speaks OpenFlow directly**

Use cases for an OvS orchestration system

- High level networking actions that apply to many hypervisors and their droplets
    - Apply firewall “open TCP/22” to all droplets for customer X
    - Disable connectivity to all droplets for customer Y



Why speak OpenFlow directly?

- Difficulty parsing unstable OvS tool text output
  - `ovs-ofctl dump-ports br0 tap0`
- Tedious generation and parsing of flow strings

Why not use an OpenFlow controller?

- Industry is moving to a **distributed control plane** approach
  - Need to carefully avoid architectures where it would be difficult to scale a central controller
- We considered OVN, but were concerned about its maturity
  - The “RNS” architecture is similar to OVN
- A **distributed** OpenFlow controller is not off the table!
  - Maybe `hvflowd` becomes OvS’s “controller”?

ovs.Client with OpenFlow

```go
// Configure ovs.Client with our required OpenFlow flow format and protocol.
client := ovs.New(
	ovs.FlowFormat("OXM-OpenFlow14"),
	ovs.Protocols("OpenFlow14"),
	// Toggle on direct OpenFlow support.
	ovs.UseOpenFlow("localhost:6633"),
)

// Flow marshaled to binary instead of text format, and sent via OpenFlow.
err = client.OpenFlow.AddFlow("br0", exampleFlow())
```

- `ovs.New` constructor gains a new option to toggle on OpenFlow
- `ovs.Client` opens a socket and sends raw OpenFlow commands

ovs.Match gains a new method

```go
type Match interface {
	// MarshalText() (text []byte, err error)
	encoding.TextMarshaler
	// New: MarshalBinary() (bin []byte, err error)
	encoding.BinaryMarshaler
}
```

- Implement a `MarshalBinary` method for all `Match` types
- `ovs.Action` would be updated in the same way

Conclusions: orchestrated Open vSwitch and Go

- Pros:
  - Easy to orchestrate changes amongst multiple servers
  - No more parsing OvS tool string output
  - No more generating and parsing the flow text format!
- Cons:
  - Too early to tell!

Open vSwitch at DigitalOcean: **Conclusions**

DO is powered by Open vSwitch!

- We’ve deployed more than **10,000** instances of OvS and have run it in production for **three years**.
- We’ve moved from **Perl to Go,** and our OvS tooling has too.
- We’re excited for the **future** of OvS and OVN!

Thank you!

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https://github.com/digitalocean/go-openvswitch