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1.1 Introduction to Faucet

1.1.1 What is Faucet?

Faucet is a compact open source OpenFlow controller, which enables network operators to run their networks the same way they do server clusters. Faucet moves network control functions (like routing protocols, neighbor discovery, and switching algorithms) to vendor independent server-based software, versus traditional router or switch embedded firmware, where those functions are easy to manage, test, and extend with modern systems management best practices and tools. Faucet controls OpenFlow 1.3 hardware which delivers high forwarding performance.

You can read more about our approach to networking by reading our ACM Queue article Faucet: Deploying SDN in the Enterprise.

1.1.2 What is Gauge?

Faucet has two main OpenFlow controller components, Faucet itself, and Gauge. Faucet controls all forwarding and switch state, and exposes its internal state, e.g. learned hosts, via Prometheus (so that an open source NMS such as Grafana graph it).

Gauge also has an OpenFlow connection to the switch and monitors port and flow state (exporting it to Prometheus or InfluxDB, or even flat text log files). Gauge, however, does not ever modify the switch’s state, so that switch monitoring functions can be upgraded, restarted, without impacting forwarding.

1.1.3 Why Faucet?

Design

Faucet is designed to be very small, simple (1000s of lines of code, versus millions in other systems), and keep relatively little state. Faucet does not have any implementation-specific or vendor driver code, which considerably reduces complexity. Faucet does not need connectivity to external databases for forwarding decisions. Faucet provides “hot/hot” high availability and scales through the provisioning of multiple Faucets with the same configuration - Faucet controllers are not inter-dependent.
Performance and scaling

As well as being compact, Faucet offloads all forwarding to the OpenFlow switch, including flooding if emulating a traditional switch. Faucet programs the switch pre-emptively, though will receive packet headers from the switch if, for example, a host moves ports so that the switch’s OpenFlow FIB can be updated (again, if traditional switching is being emulated). In production, Faucet controllers have been observed to go many seconds without needing to process a packet from a switch. In cold start scenarios, Faucet has been observed to completely program a switch and learn connected hosts within a few seconds.

Faucet uses a multi-table packet processing pipeline as shown in *Faucet Openflow Switch Pipeline*. Using multiple flow tables over a single table allows Faucet to implement more complicated flow-based logic while maintaining a smaller number of total flows. Using dedicated flow tables with a narrow number of match fields, or limiting a table to exact match only, such as the IPv4 or IPv6 FIB tables allows us to achieve greater scalability over the number of flow entries we can install on a datapath.

A large network with many devices would run many Faucets, which can be spread over as many (or as few) machines as required. This approach scales well because each Faucet uses relatively few server resources and Faucet controllers do not have to be centralized - they can deploy as discrete switching or routing functional units, incrementally replacing (for example) non-SDN switches or routers.

An operator might have a controller for an entire rack, or just a few switches, which also reduces control plane complexity and latency by keeping control functions simple and local.

Testing

Faucet follows open source software engineering best practices, including unit and systems testing (python unittest based), as well static analysis (pytype, pylint, and codecov) and fuzzing (python-afl). Faucet’s systems tests test all Faucet features, from switching algorithms to routing, on virtual topologies. However, Faucet’s systems tests can also be configured to run the same feature tests on real OpenFlow hardware. Faucet developers also host regular PlugFest events specifically to keep switch implementations broadly synchronized in capabilities and compatibility.

### 1.1.4 Release Notes

### 1.7.0 Release Notes

We are making a few potentially breaking features in faucet 1.7.0. This document covers how to navigate the changes and safely upgrade from earlier versions to 1.7.0.

1. **Configuration and log directory changed**

   Starting in 1.7.0 and onwards faucet has changed which directories it uses for configuration and log files. The new paths are:

<table>
<thead>
<tr>
<th>Old path</th>
<th>New path</th>
</tr>
</thead>
<tbody>
<tr>
<td>/etc/ryu/faucet</td>
<td>/etc/faucet</td>
</tr>
<tr>
<td>/var/log/ryu/faucet</td>
<td>/var/log/faucet</td>
</tr>
</tbody>
</table>

   Faucet 1.7.0 when being installed by pip will automatically attempt to migrate your old configuration files to /etc/faucet assuming it has permissions to do so. Failing this faucet when started will fallback to loading configuration from /etc/ryu/faucet. The search paths for configuration files are documented on the *Environment variables* page.
Note: Consider the /etc/ryu/faucet directory deprecated, we will in a future release stop reading config files stored in this directory.

If you currently set your own configuration or log directory by setting the appropriate environment variables you will be unaffected. In most other cases the migration code or the fallback configuration search path will allow the upgrade to 1.7.0 to be seamless. We have however identified two cases where manual intervention is required:

Dockers

Dockers will need to be started with new mount directories, the commands to start a 1.7.0 docker version of faucet or gauge are detailed in the Installation with Docker section.

Virtualenvs

We are unable to migrate configuration files automatically when faucet is run inside of a virtualenv, please copy the configuration directory over manually.

2. Changing default flood mode

Currently faucet defaults to using combinatorial_port_flood when it comes to provisioning flooding flows on a datapath, faucet implicitly configures a datapath like this today:

```
dps:
  mydp:
    combinatorial_port_flood: True
```

The default is True, in 1.7.0 and previously. The default will change to False in 1.7.1.

When True, flood rules are explicitly generated for each input port, to accommodate early switch implementations which (differing from the OpenFlow standard - see below) did not discard packets output to the packet input port. False generates rules per faucet VLAN which results in fewer rules and better scalability.

See OpenFlow 1.3.5 specification, section B.6.3:

```
The behavior of sending out the incoming port was not clearly defined in earlier versions of the specification. It is now forbidden unless the output port is explicitly set to OFPP_IN_PORT virtual port (0xfff8) is set.
```

1.9.0 Release Notes

There are some changes in version 1.9.0 of faucet that may affect how you use it. Below are the changes and how they might affect you.

1. Removing support for older python versions

   Starting from faucet 1.9.0 and onwards, faucet now requires a version of python 3.5 or newer to function.

   Most currently supported distributions of linux should have a version of python that is compatible, with the notable exception of Debian Jessie which is no longer supported by faucet.

2. Change BGP configuration syntax

   Previously, BGP configuration for faucet was attached to a VLAN, for example:
As BGP peering in faucet now has the ability to resolve next hops in all VLANs, we have elected to move where BGP is configured.

We have now implemented a new `bgp` router type that can be configured in faucet, similar to how inter-VLAN routing works today, for example this is an example of the new syntax showing how we would convert the configuration shown above:

```
Listing 1: Older style bgp configuration

vlans:
  internet:
    description: 'internet peering'
    vid: 200
    bgp_routerid: '127.0.0.2'
    bgp_as: 14031
    bgp_neighbor_as: 14031
    bgp_neighbor_addresses: ['127.0.0.1', '::1']
    bgp_server_addresses: ['127.0.0.2', '::1']
    bgp_port: 9179
    bgp_connect_mode: 'passive'
```

```
Listing 2: Newer style bgp configuration

vlans:
  internet:
    description: 'internet peering'
    vid: 200

routers:
  internet-router:
    bgp:
      vlan: internet
      routerid: '127.0.0.2'
      as: 14031
      neighbor_as: 14031
      neighbor_addresses: ['127.0.0.1', '::1']
      server_addresses: ['127.0.0.2', '::1']
      port: 9179
      connect_mode: 'passive'
```

It is also possible to combine inter-VLAN routing and bgp routing in a single routing instance:

```
Listing 3: Newer style bgp configuration (with IVR)

vlans:
  office:
    description: 'internet peering'
    vid: 100
  internet:
    description: 'internet peering'
    vid: 200

routers:
  office-internet-router:
    vlans: ['office', 'internet']
    bgp:
      vlan: internet
```
routerid: '127.0.0.2'
as: 14031
neighbor_as: 14031
neighbor_addresses: ['127.0.0.1', '::1']
server_addresses: ['127.0.0.2', '::1']
port: 9179
connect_mode: 'passive'

For more information on what each option does, please see the BGP documentation section.

1.1.5 Getting Help

We use maintain a number of mailing lists for communicating with users and developers:

- faucet-announce
- faucet-dev
- faucet-users

We also have the #faucetsdn IRC channel on freenode.

A few tutorial videos are available on our YouTube channel.

The FAUCET dev log and faucetsdn twitter are good places to keep up with the latest news about faucet.

If you find bugs, or if have feature requests, please create an issue on our bug tracker.

1.2 Tutorials

1.2.1 Installing faucet for the first time

This tutorial will run you through the steps of installing a complete faucet system for the first time.

We will be installing and configuring the following components:

<table>
<thead>
<tr>
<th>Component</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>faucet</td>
<td>Network controller</td>
</tr>
<tr>
<td>gauge</td>
<td>Monitoring controller</td>
</tr>
<tr>
<td>prometheus</td>
<td>Monitoring system &amp; time series database</td>
</tr>
<tr>
<td>grafana</td>
<td>Monitoring dashboard</td>
</tr>
</tbody>
</table>

This tutorial was written for Ubuntu 16.04, however the steps should work fine on any newer supported version of Ubuntu or Debian.
Package installation

1. Add the faucet official repo to our system:

```
sudo apt-get install curl gnupg apt-transport-https lsb-release
echo "deb https://packagecloud.io/faucetsdn/faucet/$(lsb_release -si | awk '{print tolower($0)}')/ $(lsb_release -sc) main" | sudo tee /etc/apt/sources.list.d/faucet.list
curl -L https://packagecloud.io/faucetsdn/faucet/gpgkey | sudo apt-key add -
sudo apt-get update
```

2. Install the required packages, we can use the faucet-all-in-one metapackage which will install all the correct dependencies.

```
sudo apt-get install faucet-all-in-one
```

Configure prometheus

We need to configure prometheus to tell it how to scrape metrics from both the faucet and gauge controllers. To help make life easier faucet ships a sample configuration file for prometheus which sets it up to scrape a single faucet and gauge controller running on the same machine as prometheus. The configuration file we ship looks like:

```
# my global config
global:
  scrape_interval: 15s # Set the scrape interval to every 15 seconds. Default is every 1 minute.
  evaluation_interval: 15s # Evaluate rules every 15 seconds. The default is every 1 minute.
  # scrape_timeout is set to the global default (10s).
  rule_files:
    - "faucet.rules.yml"

# A scrape configuration containing exactly one endpoint to scrape:
# Here it's Prometheus itself.
scrape_configs:
  - job_name: 'prometheus'
    static_configs:
      - targets: ['localhost:9090']
  - job_name: 'faucet'
    static_configs:
      - targets: ['localhost:9302']
  - job_name: 'gauge'
    static_configs:
      - targets: ['localhost:9303']
```

To learn more about what this configuration file does you can look at the Prometheus Configuration Documentation. The simple explanation is that it includes an additional faucet.rules.yml file that performs some automatic queries in prometheus for generating some additional metrics as well as setting up scrape jobs every 15 seconds for faucet listening on localhost:9302 and gauge listening on localhost:9303.
Steps to make prometheus use the configuration file shipped with faucet:

1. Change the configuration file prometheus loads by editing the file `/etc/default/prometheus` to look like:

   ```
   # Set the command-line arguments to pass to the server.
   ARGS="--config.file=/etc/faucet/prometheus/prometheus.yml"
   ```

2. Restart prometheus to apply the changes:

   ```
   sudo systemctl restart prometheus
   ```

Configure grafana

Grafana running in it’s default configuration will work just fine for our needs. We will however need to make it start on boot, configure prometheus as a data source and add our first dashboard:

1. Make grafana start on boot and then start it manually for the first time:

   ```
   sudo systemctl daemon-reload
   sudo systemctl enable grafana-server
   sudo systemctl start grafana-server
   ```

2. To finish setup we will configure grafana via the web interface.

   First load `http://localhost:3000` in your web browser (by default both the username and password are admin).

3. The web interface will first prompt us to add a data source. Use the following settings then click Save & Test:

   ```
   Name: Prometheus
   Type: Prometheus
   URL: http://localhost:9090
   ```

4. Next we want to add some dashboards so that we can later view the metrics from faucet.

   Hover over the + button on the left sidebar in the web interface and click Import.

   We will import the following dashboards, just download the following links and upload them through the grafana dashboard import screen:

   - Instrumentation
   - Inventory
   - Port Statistics
Configure faucet

For this tutorial we will configure a very simple network topology consisting of a single switch with two ports.

1. Configure faucet

   We need to tell faucet about our topology and VLAN information, we can do this by editing the faucet configuration `/etc/faucet/faucet.yaml` to look like:

   ```yaml
   vlans:
     office:
       vid: 100
       description: "office network"
   dps:
     sw1:
       dp_id: 0x1
       hardware: "Open vSwitch"
       interfaces:
         1:
           name: "host1"
           description: "host1 network namespace"
           native_vlan: office
         2:
           name: "host2"
           description: "host2 network namespace"
           native_vlan: office
   ``

   **Note:** Tabs are forbidden in the YAML language, please use only spaces for indentation.

   This will create a single VLAN and a single datapath with two ports.

2. Verify configuration

   The `check_faucet_config` command can be used to verify faucet has correctly interpreted your configuration before loading it. This can avoid shooting yourself in the foot by applying configuration with typos. We recommend either running this command by hand or with automation each time before loading configuration.

   ```bash
   check_faucet_config /etc/faucet/faucet.yaml
   ```

   This script will either return an error, or in the case of successfully parsing the configuration it will return a JSON object containing the entire faucet configuration that would be loaded (including any default settings), for example:

   ```json
   [{
     'advertise_interval': 30,
     'arp_neighbor_timeout': 30,
     'cache_update_guard_time': 150,
     'combinatorial_port_flood': False,
     'cookie': 1524372928,
     'description': 'sw1',
     'dot1x': None,
     'dp_acls': None,
     'dp_id': 1,
     'drop_broadcast_source_address': True,
     'drop_spoofed_faucet_mac': True,
   }
   ```

   (continues on next page)
'egress_pipeline': False,
'fast_advertise_interval': 5,
'faucet_dp_mac': '0e:00:00:00:00:01',
'global_vlan': 0,
'group_table': False,
'hardware': 'Open vSwitch',
'high_priority': 9001,
'highest_priority': 9099,
'idle_dst': True,
'ignore_learn_ins': 10,
'interface_ranges': OrderedDict(),
'interfaces': {'host1': {'acl_in': None,
                     'acls_in': None,
                     'description': 'host1 network namespace',
                     'dot1x': False,
                     'enabled': True,
                     'hairpin': False,
                     'hairpin_unicast': False,
                     'lacp': 0,
                     'lacp_active': False,
                     'lldp_beacon': OrderedDict(),
                     'loop_protect': False,
                     'loop_protect_external': False,
                     'max_hosts': 255,
                     'max_lldp_lost': 3,
                     'mirror': None,
                     'native_vlan': 'office',
                     'number': 1,
                     'opstatus_reconf': True,
                     'output_only': False,
                     'permanent_learn': False,
                     'receive_lldp': True,
                     'stack': OrderedDict(),
                     'tagged_vlans': [],
                     'unicast_flood': True},
               'host2': {'acl_in': None,
                         'acls_in': None,
                         'description': 'host2 network namespace',
                         'dot1x': False,
                         'enabled': True,
                         'hairpin': False,
                         'hairpin_unicast': False,
                         'lacp': 0,
                         'lacp_active': False,
                         'lldp_beacon': OrderedDict(),
                         'loop_protect': False,
                         'loop_protect_external': False,
                         'max_hosts': 255,
                         'max_lldp_lost': 3,
                         'mirror': None,
                         'native_vlan': 'office',
                         'number': 2,
                         'opstatus_reconf': True,
                         'output_only': False,
                         'permanent_learn': False,
                         'receive_lldp': False,
                         'stack': OrderedDict(),
                         'tagged_vlans': []}},
3. Reload faucet

To apply this configuration we can reload faucet which will cause it to compute the difference between the old and new configuration and apply the minimal set of changes to the network in a hitless fashion (where possible).

```
sudo systemctl reload faucet
```

4. Check logs

To verify the configuration reload was successful we can check `/var/log/faucet/faucet.log` and make sure faucet successfully loaded the configuration we can check the faucet log file `/var/log/faucet/faucet.log`: 

```
Listing 7: /var/log/faucet/faucet.log

faucet INFO Loaded configuration from /etc/faucet/faucet.yaml
faucet INFO Add new datapath DPID 1 (0x1)
faucet INFO Add new datapath DPID 2 (0x2)
faucet INFO configuration /etc/faucet/faucet.yaml changed, analyzing...
faucet INFO Reconfiguring existing datapath DPID 1 (0x1)
faucet.valve INFO DPID 1 (0x1) skipping configuration because datapath not up
faucet INFO Deleting de-configured DPID 2 (0x2)

If there were any issues (say faucet wasn’t able to find a valid pathway from the old config to the new config) we could issue a faucet restart now which will cause a cold restart of the network.

Configure gauge

We will not need to edit the default gauge configuration that is shipped with faucet as it will be good enough to complete the rest of this tutorial. If you did need to modify it the path is /etc/faucet/gauge.yaml and the default configuration looks like:

Listing 8: gauge.yaml

```yaml
# Recommended configuration is Prometheus for all monitoring, with all_dps: True
faucet_configs:
- '/etc/faucet/faucet.yaml'

watchers:
  port_status_poller:
    type: 'port_state'
    all_dps: True
    #dps: ['sw1', 'sw2']
    db: 'prometheus'
  port_stats_poller:
    type: 'port_stats'
    all_dps: True
    #dps: ['sw1', 'sw2']
    interval: 10
    db: 'prometheus'
    #db: 'influx'
  flow_table_poller:
    type: 'flow_table'
    all_dps: True
    interval: 60
    db: 'prometheus'

dbs:
  prometheus:
    type: 'prometheus'
    prometheus_addr: '0.0.0.0'
    prometheus_port: 9303
  ft_file:
    type: 'text'
    compress: True
    path: 'flow_tables'
  influx:
    type: 'influx'
    influx_db: 'faucet'
    influx_host: 'influxdb'
```

(continues on next page)
This default configuration will set up a Prometheus exporter listening on port `0.0.0.0:9303` and write all the different kind of gauge metrics to this exporter.

We will however need to restart the current gauge instance so it can pick up our new faucet configuration:

```shell
sudo systemctl restart gauge
```

## Connect your first datapath

Now that we’ve set up all the different components let’s connect our first switch (which we call a *datapath*) to faucet. We will be using Open vSwitch for this which is a production-grade software switch with very good OpenFlow support.

1. Add WAND Open vSwitch repo

   The bundled version of Open vSwitch in Ubuntu 16.04 is quite old so we will use WAND’s package repo to install a newer version (if you’re using a more recent Debian or Ubuntu release you can skip this step).

   **Note:** If you’re using a more recent Debian or Ubuntu release you can skip this step

   ```shell
   sudo apt-get install apt-transport-https
   echo "deb https://packages.wand.net.nz `{lsb_release -sc}` main" | sudo tee /etc/apt/sources.list.d/wand.list
   sudo curl https://packages.wand.net.nz/keyring.gpg -o /etc/apt/trusted.gpg.d/wand.gpg
   sudo apt-get update
   ```

2. Install Open vSwitch

   ```shell
   sudo apt-get install openvswitch-switch
   ```

3. Add network namespaces to simulate hosts

   We will use two Linux network namespaces to simulate hosts and this will allow us to generate some traffic on our network.

   First let’s define some useful bash functions by coping and pasting the following definitions into our bash terminal:

   ```bash
   # Run command inside network namespace
   as_ns () {
     NAME=$1
     NETNS=faucet-$NAME
     shift
     sudo ip netns exec $NETNS @
   }
   ```

   ```bash
   sudo apt-get install apt-transport-https
   echo "deb https://packages.wand.net.nz `{lsb_release -sc}` main" | sudo tee /etc/apt/sources.list.d/wand.list
   sudo curl https://packages.wand.net.nz/keyring.gpg -o /etc/apt/trusted.gpg.d/wand.gpg
   sudo apt-get update
   ```
### Create network namespace

```bash
create_ns() {
    NAME=$1
    IP=$2
    NETNS=faucet-$NAME
    sudo ip netns add $NETNS
    sudo ip link add dev veth-$NAME type veth peer name veth0 netns $NETNS
    sudo ip link set dev veth-$NAME up
    as_ns $NAME
    ip link set dev lo up
    [ -n "$IP" ] && as_ns $NAME ip addr add dev veth0 $IP
    as_ns $NAME ip link set dev veth0 up
}
```

**NOTE:** all the tutorial helper functions can be defined by sourcing `helper-funcs` into your shell environment.

Now we will create `host1` and `host2` and assign them some IPs:

```bash
create_ns host1 192.168.0.1/24
create_ns host2 192.168.0.2/24
```

2. **Configure Open vSwitch**

We will now configure a single Open vSwitch bridge (which will act as our datapath) and add two ports to this bridge:

```bash
sudo ovs-vsctl add-br br0 \
-- set bridge br0 other-config:datapath-id=0000000000000001 \
-- set bridge br0 other-config:disable-in-band=true \
-- set bridge br0 fail_mode=secure \
-- add-port br0 veth-host1 -- set interface veth-host1 ofport_request=1 \
-- add-port br0 veth-host2 -- set interface veth-host2 ofport_request=2 \
-- set-controller br0 tcp:127.0.0.1:6653 tcp:127.0.0.1:6654
```

The [Open vSwitch documentation](http://openvswitch.org/) is very good if you wish to find out more about configuring Open vSwitch.

3. **Verify datapath is connected to faucet**

At this point everything should be working, we just need to verify that is the case. If we now load up some of the grafana dashboards we imported earlier, we should see the datapath is now listed in the **Faucet Inventory** dashboard.

If you don’t see the new datapath listed you can look at the faucet log files `/var/log/faucet/faucet.log` or the Open vSwitch log `/var/log/openvswitch/ovs-vswitchd.log` for clues.

4. **Generate traffic between virtual hosts**

With `host1` and `host2` we can now test our network works and start generating some traffic which will show up in grafana.

Let’s start simple with a ping:

```bash
as_ns host1 ping 192.168.0.2
```

If this test is successful this shows our Open vSwitch is forwarding traffic under faucet control, `/var/log/faucet/faucet.log` should now indicate those two hosts have been learnt:
We can also use iperf to generate a large amount of traffic which will show up on the Port Statistics dashboard in grafana, just select sw1 as the Datapath Name and All for the Port.

```bash
sudo apt-get install iperf3
as_ns host1 iperf3 --server --pidfile /run/iperf3-host1.pid --daemon
as_ns host2 iperf3 --client 192.168.0.1
```

Further steps

Now that you know how to setup and run faucet in a self-contained virtual environment you can build on this tutorial and start to make more interesting topologies by adding more Open vSwitch bridges, ports and network namespaces. Check out the faucet Configuration document for more information on features you can turn on and off. In future we will publish additional tutorials on layer 3 routing, inter-VLAN routing, ACLs.

You can also easily add real hardware into the mix as well instead of using a software switch. See the Vendor-specific Documentation section for information on how to configure a wide variety of different vendor devices for faucet.

### 1.2.2 ACL tutorial

In the Installing faucet for the first time tutorial we covered how to install and set-up Faucet. Next we are going to introduce Access Control Lists (ACLs).

ETA: ~25 minutes.

**Prerequisites**

- Install Faucet - Package installation steps 1 & 2
- Install Open vSwitch - Connect your first datapath steps 1 & 2
- Useful Bash Functions - Copy and paste the following definitions into your bash terminal, or to make them persistent between sessions add them to the bottom of your .bashrc and run `source .bashrc`.

```bash
# Run command inside network namespace
as_ns () {
    NAME=$1
    NETNS=faucet-$NAME
    shift
    sudo ip netns exec $NETNS $@
}

# Create network namespace
create_ns () {
    NAME=$1
    NETNS=faucet-$NAME
    shift
    sudo ip netns exec $NETNS $@
}
```

(continues on next page)
IP=$2
NETNS=faucet-$NAME
sudo ip netns add $NETNS
sudo ip link add dev veth-$NAME type veth peer name veth0 netns $NETNS
sudo ip link set dev veth-$NAME up
as_ns $NAME ip link set dev lo up
[ -n "$IP" ] && as_ns $NAME ip addr add dev veth0 $IP
as_ns $NAME ip link set dev veth0 up
}

Note: If not continuing on from the ‘Installing Faucet for first time tutorial’ to setup the hosts and switch run:

create_ns host1 192.168.0.1/24
create_ns host2 192.168.0.2/24
sudo ovs-vsctl add-br br0 \  
  -- set bridge br0 other-config:datapath-id=0000000000000001 \  
  -- set bridge br0 other-config:disable-in-band=true \  
  -- set bridge br0 fail_mode=secure \  
  -- add-port br0 veth-host1 -- set interface veth-host1 ofport_request=1 \  
  -- add-port br0 veth-host2 -- set interface veth-host2 ofport_request=2 \  
  -- set-controller br0 tcp:127.0.0.1:6653 tcp:127.0.0.1:6654

And the faucet.yaml configuration file looks like:

Listing 10: /etc/faucet/faucet.yaml

vlans:
  office:
    vid: 100
    description: "office network"

dps:
  sw1:
    dp_id: 0x1
    hardware: "Open vSwitch"
    interfaces:
      1:
        name: "host1"
        description: "host2 network namespace"
        native_vlan: office
      2:
        name: "host2"
        description: "host2 network namespace"
        native_vlan: office
Overview

Faucet ACLs are made up of lists of rules. The order of the rules in the list denote the priority with the first rules being highest and last lowest. The first rule that matches a packet, will set the actions for the packet. Each of these lists has a name (e.g. ‘block-ping’), and can be used on multiple port or VLAN ‘acls_in’ fields. Again these are applied in order so all of ‘block-ping’ rules will be higher than ‘allow-all’.

Each rule contains two main items ‘matches’ and ‘actions’. Matches are any packet field such as MAC/IP/transport source/destination fields. For a full list visit the Ryu documentation. If no matches are specified, the rule will match all packets.

Actions are used to control what the packet does, for example normal L2 forwarding (‘allow’), apply a ‘meter’ to rate limit traffic, and manipulation of the packet contents and output destination. The full list is available in the Meters section of the documentation.

The example below has defined two ACLs ‘block-ping’ & ‘allow-all’ these can be used on any and multiple ports or VLANs (more on VLANs later) using the ‘acls_in’ key. The block-ping ACL has two rules, one to block ICMP on IPv4 and another for ICMPv6 on IPv6. The allow-all ACL has one rule, which specifies no match fields, and therefore matches all packets, and the action ‘allow’. The ‘allow’ action is a boolean, if it’s True allow the packet to continue through the Faucet pipeline, if False drop the packet. ‘allow’ can be used in conjunction with the other actions to let the traffic flow with the expected layer 2 forwarding behaviour AND be mirrored to another port. The default ‘allow’ for ACLs is False (i.e. drop the packet). ACL rules will need to define ‘allow: True’ for those packets that are to be forwarded.

Network setup

We are going to create the following network:

![Network setup diagram]

First we will add two new hosts to our network:

```
create_ns host3 192.168.0.3/24
create_ns host4 192.168.0.4/24
```

And connect them to br0

```
sudo ovs-vsctl add-port br0 veth-host3 -- set interface veth-host3 ofport_request=3 \
    -- add-port br0 veth-host4 -- set interface veth-host4 ofport_request=4
```

The configuration below will block ICMP on traffic coming in on port 3, and allow everything else. Add this to `/etc/faucet/faucet.yaml` below the ‘dps’.

```
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```
Listing 11: /etc/faucet/faucet.yaml

```
3:
  name: "host3"
  native_vlan: office
  acls_in: [block-ping, allow-all]

4:
  name: "host4"
  native_vlan: office

acls:
  block-ping:
    - rule:
      dl_type: 0x800  # IPv4
      ip_proto: 1     # ICMP
      actions:
        allow: False
    - rule:
      dl_type: 0x86dd # IPv6
      ip_proto: 58    # ICMPv6
      actions:
        allow: False
  allow-all:
    - rule:
      actions:
        allow: True
```

Now tell Faucet to reload its configuration, this can be done by restarting the application. But a better way is to send Faucet a SIGHUP signal.

```
check_faucet_config /etc/faucet/faucet.yaml
```

```
sudo systemctl reload faucet
```

Pings to/from host3 should now fail:

```
as_ns host1 ping 192.168.0.3
```

But the other three hosts should be fine:

```
as_ns host1 ping 192.168.0.2
as_ns host1 ping 192.168.0.4
```

**ACL actions**

**Mirroring**

Mirroring traffic is useful if we want to send it to an out of band NFV service (e.g. Intrusion Detection System, packet capture a port or VLAN). To do this Faucet provides two ACL actions: mirror & output.

The mirror action copies the packet, before any modifications, to the specified port.

**Note:** Mirroring is done in input direction only.

Let’s add the mirror action to our block-ping ACL /etc/faucet/faucet.yaml

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Listing 12: /etc/faucet/faucet.yaml

```yaml
...  
  block-ping:
    - rule:
        dl_type: 0x800
        ip_proto: 1
        actions:
          allow: False
          mirror: 4
    - rule:
        dl_type: 0x86dd
        ip_proto: 58
        actions:
          allow: False
          mirror: 4
```

And again send the sighup signal to Faucet

```bash
sudo systemctl reload faucet
```

To check this we will ping from host1 to host3, while performing a tcpdump on host4 who should receive the ping replies. It is a good idea to run each from a different terminal (screen, tmux, . . .)

```bash
as_ns host4 tcpdump -l -e -n -i veth0
```

```bash
as_ns host1 ping 192.168.0.3
```

Ping should have 100% packet loss.

```bash
$ as_ns host4 tcpdump -l -e -n -i veth0
```

tcpdump: verbose output suppressed, use -v or -vv for full protocol decode
listening on veth0, link-type EN10MB (Ethernet), capture size 262144 bytes
   length 98: 192.168.0.3 > 192.168.0.1: ICMP echo reply, id 23660, seq 16, length 64
   length 98: 192.168.0.3 > 192.168.0.1: ICMP echo reply, id 23660, seq 17, length 64
   length 98: 192.168.0.3 > 192.168.0.1: ICMP echo reply, id 23660, seq 18, length 64
   length 98: 192.168.0.3 > 192.168.0.1: ICMP echo reply, id 23660, seq 19, length 64
   length 98: 192.168.0.3 > 192.168.0.1: ICMP echo reply, id 23660, seq 20, length 64
```

**Output**

There is also the ‘output’ action which can be used to achieve the same thing.

Listing 13: /etc/faucet/faucet.yaml

```yaml
block-ping:
  - rule:
      dl_type: 0x800
      ip_proto: 1
```

(continues on next page)
actions:
  allow: False
  output:
    port: 4
- rule:
  dl_type: 0x86dd
  ip_proto: 58
actions:
  allow: False
  output:
    port: 4

The output action also allows us to change the packet by setting fields (mac/ip addresses, …), VLAN operations (push/pop/swap VIDs). It can be used in conjunction with the other actions, e.g. output directly but do not allow through the Faucet pipeline (allow: false).

Let’s create a new ACL for host2’s port that will change the MAC source address.

Listing 14: /etc/faucet/faucet.yaml

dps:
  sw1:
    ... 
  2:
    name: "host2"
    description: "host2 network namespace"
    native_vlan: office
    acls_in: [rewrite-mac, allow-all]
    ... 
  acls:
    rewrite-mac:
      - rule:
        actions:
          allow: True
          output:
            set_fields:
              - eth_src: "00:00:00:00:00:02"
    ... 

Again reload Faucet.

Start tcpdump on host1

```
as_ns host1 tcpdump -1 -e -n -i veth0
```

Ping host1 from host2

```
as_ns host2 ping 192.168.0.1
```

Here we can see ICMP echo requests are coming from the MAC address “00:00:00:00:00:02” that we set in our output ACL. (The reply is destined to the actual MAC address of host2 thanks to ARP).
With the output action we could also use it to mirror traffic to a NFV server (like our fake mirror output action above), and use a VLAN tag to identify what port the traffic originated on on the switch. To do this we will use both the ‘port’ & ‘vlan_vid’ output fields.

Listing 15: /etc/faucet/faucet.yaml

```yaml
block-ping:
  - rule:
      dl_type: 0x8000
      ip_proto: 1
      actions:
        allow: False
        output:
          vlan_vid: 3
          port: 4
  - rule:
      dl_type: 0x86dd
      ip_proto: 58
      actions:
        allow: False
        output:
          vlan_vid: 3
          port: 4
```

Again reload Faucet, start a tcpdump on host4, and ping from host1 to host3. Ping should still not be allowed through and the tcpdump output should be similar to below (Note the 802.1Q tag and VLAN 3):

```bash
$ as_ns host4 tcpdump -l -e -n -i veth0
tcpdump: verbose output suppressed, use -v or -vv for full protocol decode
listening on veth0, link-type EN10MB (Ethernet), capture size 262144 bytes
14:14:15.285329 2e:d4:1a:ca:54:4b > 06:5f:14:fc:47:02, ethertype 802.1Q (0x8100),
   length 102: vlan 3, p 0, ethertype IPv4, 192.168.0.3 > 192.168.0.1: ICMP echo reply,
   id 23747, seq 1, length 64
14:14:16.293016 2e:d4:1a:ca:54:4b > 06:5f:14:fc:47:02, ethertype 802.1Q (0x8100),
   length 102: vlan 3, p 0, ethertype IPv4, 192.168.0.3 > 192.168.0.1: ICMP echo reply,
   id 23747, seq 1, length 64
14:14:17.300898 2e:d4:1a:ca:54:4b > 06:5f:14:fc:47:02, ethertype 802.1Q (0x8100),
   length 102: vlan 3, p 0, ethertype IPv4, 192.168.0.3 > 192.168.0.1: ICMP echo reply,
   id 23747, seq 1, length 64
```
1.2.3 VLAN tutorial

Next we are going to introduce VLANs.
ETA: ~30 mins.

Prerequisites

- Install Faucet - Package installation steps 1 & 2
- Install Open vSwitch - Connect your first datapath steps 1 & 2
- Useful Bash Functions - Copy and paste the following definitions into your bash terminal, or to make them persistent between sessions add them to the bottom of your .bashrc and run `source .bashrc`.

```bash
# Run command inside network namespace
as_ns () { 
  NAME=$1
  NETNS=faucet-$NAME
  shift
  sudo ip netns exec $NETNS @
}

# Create network namespace
create_ns () { 
  NAME=$1
  IP=$2
  NETNS=faucet-$NAME
  sudo ip netns add $NETNS
  sudo ip link add dev veth-$NAME type veth peer name veth0 netns $NETNS
  sudo ip link set dev veth-$NAME up
  as_ns $NAME ip link set dev lo up
  [ -n "$IP" ] && as_ns $NAME ip addr add dev veth0 $IP
  as_ns $NAME ip link set dev veth0 up
}

# Clean up namespaces, bridges and processes created during faucet tutorial
cleanup () { 
  for NETNS in $(sudo ip netns list | grep "faucet" | awk '{print $1}'); do 
    [ -n "$NETNS" ] || continue
    NAME=$NETNS
    NETNS=faucet-$NAME
    if [ -f "/run/dhcclient-$NAME.pid" ]; then 
      # Stop dhclient
      sudo pkill -F "/run/dhcclient-$NAME.pid"
    fi
    if [ -f "/run/iperf3-$NAME.pid" ]; then 
      # Stop iperf3
      sudo pkill -F "/run/iperf3-$NAME.pid"
    fi
    if [ -f "/run/bird-$NAME.pid" ]; then 
      # Stop bird
      sudo pkill -F "/run/bird-$NAME.pid"
    fi
    # Remove netns and veth pair
  done
}
```

(continues on next page)
Overview

In this tutorial we will look at how to do the following tasks using Faucet:

- Use VLANs to segment traffic.
- Create VLAN Trunks.
- Apply an ACL to an entire VLAN.

Note: We cover Routing between VLANs in a later tutorial.

A port can be in several VLAN modes:

1. Native - where packets come into the switch with no 802.1Q tag.
2. Tagged - where packets come into the switch with a 802.1Q tag.
3. Mixed - where both native and tagged packets appear on the same port.

If a packet comes in with a tag for a VLAN that the port is not configured for it will be dropped.
Configuring VLANs

To demonstrate these tasks we will use a demo network where a single switch br0 connects to 9 hosts. Ports 1, 2, 5, 6 will be native (untagged) ports. While ports 3, 4, 7, 8, and 9 will be tagged ports. Here is the structure of the demo setup.

Tip: Keep this diagram nearby to simplify following the rest of the tutorial.

Network setup

Let’s start. Keep host1, host2 on the native VLAN 100 (office VLAN) as in the first and second tutorials.

Note: To create the hosts and switch again run

```
cleanup
create_ns host1 192.168.0.1/24
create_ns host2 192.168.0.2/24
sudo ovs-vsctl add-br br0 \ -- set bridge br0 other-config:datapath-id=0000000000000001 \ -- set bridge br0 other-config:disable-in-band=true \ -- set bridge br0 fail_mode=secure \
```

(continues on next page)
Then add the following hosts with the corresponding VLAN:

- Assign host3 and host4 a VLAN interface (vid:100) as they are on a tagged port.

```plaintext
create_ns host3 0.0.0.0
create_ns host4 0.0.0.0
add_tagged_interface host3 100 192.168.0.3/24
add_tagged_interface host4 100 192.168.0.4/24
```

- Assign host5 and host6 an IP address from the VLAN 200 range.

```plaintext
create_ns host5 192.168.2.5/24
create_ns host6 192.168.2.6/24
```

- Assign host7 and host8 a VLAN interface (vid:300) as they are on a tagged port.

```plaintext
create_ns host7 0.0.0.0
create_ns host8 0.0.0.0
add_tagged_interface host7 300 192.168.3.7/24
add_tagged_interface host8 300 192.168.3.8/24
```

- Add host9 to all VLANs (100, 200, 300) to work as a NFV host.

```plaintext
create_ns host9 0.0.0.0
add_tagged_interface host9 100 192.168.0.9/24
add_tagged_interface host9 200 192.168.2.9/24
add_tagged_interface host9 300 192.168.3.9/24
```

Then connect all the hosts to the switch (br0)

```plaintext
sudo ovs-vsctl add-port br0 veth-host3 -- set interface veth-host3 ofport_request=3 \
-- add-port br0 veth-host4 -- set interface veth-host4 ofport_request=4 \
-- add-port br0 veth-host5 -- set interface veth-host5 ofport_request=5 \
-- add-port br0 veth-host6 -- set interface veth-host6 ofport_request=6 \
-- add-port br0 veth-host7 -- set interface veth-host7 ofport_request=7 \
-- add-port br0 veth-host8 -- set interface veth-host8 ofport_request=8 \
-- add-port br0 veth-host9 -- set interface veth-host9 ofport_request=9
```

Now we have everything to start working with faucet through its configuration file. Each time we will only need to change the configuration file and restart faucet (or send it HUP signal to reload the configuration file).

---

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(continued from previous page)

```plaintext
-- add-port br0 veth-host1 -- set interface veth-host1 ofport_request=1 \
-- add-port br0 veth-host2 -- set interface veth-host2 ofport_request=2 \
-- set-controller br0 tcp:127.0.0.1:6653 tcp:127.0.0.1:6654
```
**Basic VLAN settings**

Change `/etc/faucet/faucet.yaml` to reflect our setting.

```yaml
Listing 16: /etc/faucet/faucet.yaml

vlans:
  vlan100:
    vid: 100
  vlan200:
    vid: 200
  vlan300:
    vid: 300
dps:
  sw1:
    dp_id: 0x1
    hardware: "Open vSwitch"
    interfaces:
      1:
        name: "host1"
        description: "host2 network namespace"
        native_vlan: vlan100
      2:
        name: "host2"
        description: "host2 network namespace"
        native_vlan: vlan100
      3:
        name: "host3"
        tagged_vlans: [vlan100]
      4:
        name: "host4"
        tagged_vlans: [vlan100]
      5:
        name: "host5"
        native_vlan: vlan200
      6:
        name: "host6"
        native_vlan: vlan200
      7:
        name: "host7"
        tagged_vlans: [vlan300]
      8:
        name: "host8"
        tagged_vlans: [vlan300]
      9:
        name: "host9"
        tagged_vlans: [vlan100,vlan200,vlan300]
```

Send SIGHUP signal to reload the configuration file, and check how its log the new configuration in `/var/log/faucet/faucet.log`

```
sudo systemctl reload faucet
cat /var/log/faucet/faucet.log
```

Let’s do the following simple tests:

1. Ping between hosts in the same VLAN (all should work)
2. Ping between hosts in the same VLAN where the one host is native and the other is tagged should work also. In particular between host1 (native VLAN 100) to host3 (tagged VLAN 100).

3. Ping between hosts in different VLANs should fail. To test that let’s add the IP address 192.168.0.5 to host5 (native VLAN 200) and try to ping it from host1 (native VLAN 100).

4. Now we can test the trunk link to host9 from different VLANs (all should work)

VLAN ACL

Let’s apply an ACL on a particular VLAN (e.g. VLAN 300). We will block any ICMP packets on VLAN 300. First create an ACL to block the ping. Open /etc/faucet/faucet.yaml and add the ‘acls’ section.

Listing 17: /etc/faucet/faucet.yaml

```yaml
acls:
  block-ping:
    - rule:
      dl_type: 0x800  # IPv4
      ip_proto: 1    # ICMP
      actions:
        allow: False
    - rule:
      dl_type: 0x86dd # IPv6
      ip_proto: 58   # ICMPv6
      actions:
        allow: False
```

Then apply this ACL on VLAN 300.

Listing 18: /etc/faucet/faucet.yaml

```yaml
vlans:
  vlan100:
    vid: 100
  vlan200:
    vid: 200
  vlan300:
    vid: 300
  acls_in: [block-ping] # Apply ACL only on vlan300
```
Faucet Documentation

Just before we reload the configuration file. Let’s verify that pinging is working between hosts in VLAN 300.

```bash
as_ns host7 ping 192.168.3.8
```

Now let’s apply the configuration, send SIGHUP signal to reload the configuration file.

```bash
sudo systemctl reload faucet
```

Now if you try to ping from host7 and host8, it will not work as it is specified by their VLAN ACL.

```bash
as_ns host7 ping 192.168.3.8
```

### 1.2.4 Routing tutorial

This tutorial will cover routing with Faucet.

There are three types of routing we can use.

- Inter-VLAN routing
- Static routing
- BGP via an external application (Quagga, Bird, EXABGP, etc)

#### Prerequisites

- Install Faucet - *Package installation* steps 1 & 2
- Install Open vSwitch - *Connect your first datapath* steps 1 & 2
- Useful Bash Functions - Copy and paste the following definitions into your bash terminal, or to make them persistent between sessions add them to the bottom of your .bashrc and run `source .bashrc`.

```bash
# Run command inside network namespace
as_ns () {
  NAME=$1
  NETNS=faucet-$NAME
  shift
  sudo ip netns exec $NETNS @
}

# Create network namespace
create_ns () {
  NAME=$1
  IP=$2
  NETNS=faucet-$NAME
  sudo ip netns add $NETNS
  sudo ip link add dev veth-$NAME type veth peer name veth0 netns $NETNS
  sudo ip link set dev veth-$NAME up
  as_ns $NAME ip link set dev lo up
  [ -n "$IP" ] && as_ns $NAME ip addr add dev veth0 $IP
  as_ns $NAME ip link set dev veth0 up
}
```
# Clean up namespaces, bridges and processes created during faucet_tutorial

cleanup () { 
  for NETNS in $(sudo ip netns list | grep "faucet-" | awk '{print $1} -r'); do 
    [ -n "$NETNS" ] || continue 
    NAME=$NETNS/faucet-
    if [ -f "/run/dhclient-$NAME.pid" ]; then 
      # Stop dhclient
      sudo pkill -F "/run/dhclient-$NAME.pid"
    fi
    if [ -f "/run/iperf3-$NAME.pid" ]; then 
      # Stop iperf3
      sudo pkill -F "/run/iperf3-$NAME.pid"
    fi
    if [ -f "/run/bird-$NAME.pid" ]; then 
      # Stop bird
      sudo pkill -F "/run/bird-$NAME.pid"
    fi
    # Remove netns and veth pair
    sudo ip link delete veth-$NAME
    sudo ip netns delete $NETNS
  done
  for isl in $(ip -o link show | awk -F': ' '{print $2}' | grep -oE "^l-br[0-9](_[0-9]*)?-br[0-9](_[0-9]*)?"); do 
    # Delete inter-switch links
    sudo ip link delete dev $isl 2>/dev/null || true
  done
  for DNSMASQ in /run/dnsmasq-vlan*.pid; do 
    [ -e "$DNSMASQ" ] || continue 
    # Stop dnsmasq
    sudo pkill -F "$DNSMASQ"
  done
  # Remove faucet dataplane connection
  sudo ip link delete veth-faucet 2>/dev/null || true
  # Remove openvswitch bridges
  sudo ovs-vsctl --if-exists del-br br0
  sudo ovs-vsctl --if-exists del-br br1
  sudo ovs-vsctl --if-exists del-br br2
  sudo ovs-vsctl --if-exists del-br br3
}

- Run the cleanup script to remove old namespaces and switches:

  cleanup

Routing between VLANs

Let's start with a single switch connected to two hosts in two different VLANs.

create_ns host1 10.0.0.1/24
create_ns host2 10.0.1.2/24
sudo ovs-vsctl add-br br0 
-- set bridge br0 other-config:datapath-id=0000000000000001 
-- set bridge br0 other-config:disable-in-band=true 
-- set bridge br0 fail_mode=secure 

(continues on next page)
In this section we will be using faucet as a gateway for our two hosts and using faucet to route between them. To do this we are going to need to give faucet an IP address on the network. This is accomplished with by using two new options that we haven’t seen before:

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>faucet_vips</td>
<td>The IP address for Faucet’s routing interface on this VLAN. Multiple IP addresses (IPv4 &amp; IPv6) can be used.</td>
</tr>
<tr>
<td>faucet_mac</td>
<td>The MAC address of Faucet’s routing interface on this VLAN. If we do not set faucet_mac for each VLAN, routed packets will be dropped unless ‘drop_spoofed_faucet_mac’ is set to false.</td>
</tr>
</tbody>
</table>

Let’s add the following faucet configuration which makes use of these options.

```yaml
vlans:
  vlan100:
    vid: 100
    faucet_vips: ["10.0.0.254/24"] # Faucet’s virtual IP address for vlan100
    faucet_mac: "00:00:00:00:00:11"

  vlan200:
    vid: 200
    faucet_vips: ["10.0.1.254/24"] # Faucet’s virtual IP address for vlan200
    faucet_mac: "00:00:00:00:00:22"

dps:
  sw1:
    dp_id: 0x1
    hardware: "Open vSwitch"
    interfaces:
      1:
        name: "host1"
        description: "host1 network namespace"
        native_vlan: vlan100
```

(continues on next page)
Now let’s signal faucet to reload the configuration file.

```
sudo systemctl reload faucet
```

Add a default route on each host to set the gateway to the value we used for `faucet_vips` above.

```
as_ns host1 ip route add default via 10.0.0.254 dev veth0
as_ns host2 ip route add default via 10.0.1.254 dev veth0
```

By default traffic between our two hosts will be dropped since they are in different VLANs with different subnets. We can show that by doing the following:

```
as_ns host1 ping 10.0.1.2
```

We can change this by enabling inter-VLAN routing between these two VLANs. In faucet you do this by creating a router and specifying which VLANs can route between each other.

In our case we to enable routing between VLAN 100 and VLAN 200 so we add the following to our configuration file.

```
Listing 20: /etc/faucet/faucet.yaml

routers:  
  router-1:  
    vlans: [vlan100, vlan200]  # Names of vlans to allow routing between
```

Reload faucet to enable inter-VLAN routing.

```
sudo systemctl reload faucet
```

Our ping before from host1 to host2 should now work (the first few packets may get lost as faucet needs to resolve the MAC address of the next hop with ARP).

```
as_ns host1 ping 10.0.1.2
```

Inter-VLAN routing by default will allow all traffic to pass between VLANs, if we wanted to change this and restrict communication to a few different IP addresses or TCP/UDP ports, we could apply a VLAN ACL to each VLAN to limit the types of traffic that may pass and what should be dropped.

### Static routing

For this we will set-up a Faucet switch with three hosts. One of these hosts will act like a server.

Run the cleanup script to remove old namespaces and switches.

```
cleanup
```

Create 3 hosts, in 2 different subnets:

```
create_ns host1 10.0.0.1/24
create_ns host2 10.0.0.2/24
create_ns server 10.0.1.1/24
```
Add a default route for each host to the gateway which is faucet’s virtual IP address.

```
as_ns host1 ip route add default via 10.0.0.254
as_ns host2 ip route add default via 10.0.0.254
as_ns server ip route add default via 10.0.1.254
```

Create the bridge and add host1, host2 and the server to br0.

```
sudo ovs-vsctl add-br br0 \
  -- set bridge br0 other-config:datapath-id=00000000000000001 \
  -- set bridge br0 other-config:disable-in-band=true \
  -- set bridge br0 fail_mode=secure \
  -- add-port br0 veth-host1 -- set interface veth-host1 ofport_request=1 \
  -- add-port br0 veth-host2 -- set interface veth-host2 ofport_request=2 \
  -- add-port br0 veth-server -- set interface veth-server ofport_request=3 \
  -- set-controller br0 tcp:127.0.0.1:6653 tcp:127.0.0.1:6654
```

For this Faucet configuration we will start from scratch. First we need to define 2 VLANs one for hosts and one for servers. We will also note that inside the configuration for the servers VLAN we see a static route that routes the subnet 192.0.2.0/24 to the server namespace (10.0.1.1).

Listing 21: /etc/faucet/faucet.yaml

```
vlans:
  hosts:
    vid: 100
    description: "vlan for clients"
    faucet_mac: "00:00:00:00:00:11"
    faucet_vips: ["10.0.0.254/24"]

  servers:
    vid: 200
    description: "vlan for servers"
    faucet_mac: "00:00:00:00:00:22"
    faucet_vips: ["10.0.1.254/24"]
    routes:
      - route:
          ip_dst: "192.0.2.0/24"

(continues on next page)
Faucet Documentation

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```yaml
ip_gw: '10.0.1.1'

routers:
  router-hosts-servers:
    vlans: [hosts, servers]

dps:
  br0:
    dp_id: 0x1
    hardware: "Open vSwitch"
    interfaces:
      1:
        name: "host1"
        description: "host1 network namespace"
        native_vlan: hosts
      2:
        name: "host2"
        description: "host2 network namespace"
        native_vlan: hosts
      3:
        name: "server"
        description: "server network namespace"
        native_vlan: servers
```

Reload Faucet to apply the new configuration.

```bash
sudo systemctl reload faucet
```

We can verify the inter-VLAN Routing is working by pinging the IP address of the server namespace:

```bash
as_ns host1 ping 10.0.1.1
```

We also need to add an additional IP alias to server to test the static route works.

```bash
as_ns server ip address add 192.0.2.1/24 dev veth0
```

And we should now be able to ping our IP alias.

```bash
as_ns host1 ping 192.0.2.1
```

**BGP routing**

For this section we are going to change our static routes from above into BGP routes.

BGP (and other routing) is provided by a NFV service, here we will use BIRD. Other applications such as ExaBGP & Quagga could be used. Faucet imports all routes provided by this NFV service. This means we can use our service for other routing protocols (OSPF, RIP, etc) and apply filtering using the service’s policy language.
Setup

Our data plane will end up looking like below, you may notice how we have the Faucet application connected to the control plane and dataplane.

Remove the following lines from `/etc/faucet/faucet.yaml` to remove the static route from faucet:

```
Listing 22: /etc/faucet/faucet.yaml

routes:
  - route:
      ip_dst: "192.0.2.0/24"
      ip_gw: "10.0.1.1"
```

Reload Faucet

```
sudo systemctl reload faucet
```

Verify that we can no longer ping the address we were previously static routing.

```
as_ns host1 ping 192.0.2.1
```

Let’s add a new network namespace to run BIRD

```
create_ns bgp 10.0.1.2/24
sudo ovs-vsctl add-port br0 veth-bgp -- set interface veth-bgp ofport_request=4
```

Next we will add a dataplane connection for Faucet so that it can communicate with BIRD running on the bgp namespace.
Now install BIRD on the system and stop it from running:

```bash
sudo apt-get install bird
sudo systemctl stop bird
sudo systemctl stop bird6
```

To configure BIRD add the following to `/etc/bird/bird.conf`, this will create a simple routing setup where BIRD originates a static route for 192.0.2.0/24 and sends this to faucet over BGP.

```
Listing 23: /etc/bird/bird.conf

protocol kernel {
    scan time 60;
    import none;
}

protocol device {
    scan time 60;
}

# Generate static route inside bird
protocol static {
    route 192.0.2.0/24 via 10.0.1.1;
}

# BGP peer with faucet
# Import all routes and export our static route
protocol bgp faucet {
    local as 65001;
    neighbor 10.0.1.3 port 9179 as 65000;
    export all;
    import all;
}
```

We can now start BIRD inside the bgp namespace:

```
as_ns bgp bird -P /run/bird-bgp.pid
```

We’ll configure Faucet to talk to BIRD by adding BGP configuration to `/etc/faucet/faucet.yaml`. Add the following to the routers section.

```
Listing 24: /etc/faucet/faucet.yaml

routers:
    ...
    bird:
        bgp:
            vlan: servers # The VLAN faucet use for BGP
            as: 65000 # Faucet’s AS number
            port: 9179 # BGP port for Faucet to listen on.
```

(continues on next page)
And finally add the port configuration for the Faucet data plane interface (veth-faucet0).

Listing 25: /etc/faucet/facuet.yaml

```yaml
dps:
  br0:
    ... interfaces:
    ... 4:
      name: "bgp"
      description: "BIRD BGP router"
      native_vlan: servers
  5:
    name: "faucet"
    description: "faucet dataplane connection"
    native_vlan: servers
```

Now reload Faucet.

```
sudo systemctl reload faucet
```

We can use the command line tool `birdc` to query the status of our peering connection, we should see that it is now established:

```
$ as_ns bgp birdc show protocols all faucet
name    proto   table  state       since     info          Preference: 100
faucet  BGP     master  up     13:25:38   Established
Input filter: ACCEPT
Output filter: ACCEPT
Routes: 1 imported, 1 exported, 1 preferred
Route change stats: received rejected filtered ignored accepted
Import updates: 1 0 0 0 0 1
Import withdraws: 0 0 --- 0 0
Export updates: 2 1 0 --- 1
Export withdraws: 0 --- --- --- 0
BGP state: Established
Neighbor address: 10.0.1.3
Neighbor AS: 65000
Neighbor ID: 10.0.1.3
Neighbor caps: AS4
Session: external AS4
Source address: 10.0.1.2
Hold timer: 185/240
Keepalive timer: 57/80
```

Using `birdc` we can also check what routes are being exported to faucet:
Faucet Documentation

```
as_ns bgp birdc show route export faucet
192.0.2.0/24 via 10.0.1.1 on veth0 [static1 13:25:34] * (200)
```

And which routes bird receives from faucet:

```
as_ns bgp birdc show route protocol faucet
10.0.1.0/24 via 10.0.1.254 on veth0 [faucet 13:25:38 from 10.0.1.3] * (100) [i]
```

In `/var/log/faucet/faucet.log` we should now see log messages relating to BGP:

```
Listing 26: /var/log/faucet/faucet.log
Jan 16 13:25:17 faucet INFO Reloading configuration
Jan 16 13:25:17 faucet INFO configuration /etc/faucet/faucet.yaml changed, analyzing differences
Jan 16 13:25:17 faucet INFO Add new datapath DPID 1 (0x1)
Jan 16 13:25:17 faucet INFO Adding BGP speaker key DP ID: 1, VLAN VID: 200, IP version: 4 for VLAN servers vid:200 untagged: Port 3,Port 4,Port 5
Jan 16 13:25:38 faucet INFO BGP peer router ID 10.0.1.2 AS 65001 up
Jan 16 13:25:38 faucet INFO BGP add 192.0.2.0/24 nexthop 10.0.1.1
Jan 16 13:25:42 faucet.valve INFO DPID 1 (0x1) br0 resolving 10.0.1.1 (1 flows) on VLAN 200
Jan 16 13:25:42 faucet.valve INFO DPID 1 (0x1) br0 Adding new route 192.0.2.0/24 via 10.0.1.1 (aa:97:cd:33:74:a9) on VLAN 200
```

Once confirming the BGP connection is up between BIRD and faucet and the correct routes are being advertised, we should now be able to ping the IP alias on the server namespace again:

```
as_ns host1 ping 192.0.2.1
```

### 1.2.5 Stacking tutorial

Faucet has two primary modes of operation: independent switching and distributed switching.

In independent mode each decision about the network (learning, routing, etc) is made in the context of each individual switch.

This tutorial will cover Faucet’s distributed switching (a.k.a stacking) mode. Stacking allows decisions such as switching and routing to be made in the context of the whole network. This has great benefits for building resilient network topologies that can automatically recover from switch and port/cable failures. In this tutorial we will cover some of the new features and demonstrate how they work.

#### Prerequisites

- Knowledge of the VLAN and routing tutorial topics ([VLAN tutorial](#), [Routing tutorial](#))
- Install Faucet - *Package installation* steps 1 & 2
- Install Open vSwitch - *Connect your first datapath* steps 1 & 2
- Useful Bash Functions - Copy and paste the following definitions into your bash terminal, or to make them persistent between sessions add them to the bottom of your `.bashrc` and run `source .bashrc`.  

---

Chapter 1. User Documentation
# Create network namespace

```
create_ns () {
    NAME=$1
    IP=$2
    NETNS=faucet-$NAME
    sudo ip netns add $NETNS
    sudo ip link add dev veth-$NAME type veth peer name veth0 netns $NETNS
    sudo ip link set dev veth-$NAME up
    as_ns $NAME ip link set dev lo up
    [ -n "$IP" ] && as_ns $NAME ip addr add dev veth0 $IP
    as_ns $NAME ip link set dev veth0 up
}
```

# Run command inside network namespace

```
as_ns () {
    NAME=$1
    NETNS=faucet-$NAME
    shift
    sudo ip netns exec $NETNS @
}
```

# Add inter-switch link between two switches

```
inter_switch_link () {
    SW_A_NAME=$(echo $1 | cut -d ':' -f 1)
    SW_A_PORT=$(echo $1 | cut -d ':' -f 2)
    SW_B_NAME=$(echo $2 | cut -d ':' -f 1)
    SW_B_PORT=$(echo $2 | cut -d ':' -f 2)
    VETH_A=l-$(SW_A_NAME)_$(SW_A_PORT)-$(SW_B_NAME)_$(SW_B_PORT)
    VETH_B=l-$(SW_B_NAME)_$(SW_B_PORT)-$(SW_A_NAME)_$(SW_A_PORT)
    VETH_A=$(VETH_A:0:15)
    VETH_B=$(VETH_B:0:15)
    sudo ip link add dev $VETH_A type veth peer name $VETH_B
    sudo ip link set dev $VETH_A up
    sudo ip link set dev $VETH_B up
    sudo ovs-vsctl add-port $(SW_A_NAME) $VETH_A \-- set interface $VETH_A ofport_request=$(SW_A_PORT)
    sudo ovs-vsctl add-port $(SW_B_NAME) $VETH_B \-- set interface $VETH_B ofport_request=$(SW_B_PORT)
}
```

# Clean up namespaces, bridges and processes created during faucet tutorial

```
cleanup () {
    for NETNS in $(sudo ip netns list | grep "faucet-" | awk '{print $1}'); do
        [ -n "$NETNS" ] || continue
        NAME=$NETNS
        if [ -f "/run/dhclient-$NAME.pid" ]; then
            # Stop dhclient
            sudo pkill -F "/run/dhclient-$NAME.pid"
        fi
        if [ -f "/run/iperf3-$NAME.pid" ]; then
            # Stop iperf3
            sudo pkill -F "/run/iperf3-$NAME.pid"
        fi
    done
}
```

(continues on next page)
if [ -f "/run/bird-${NAME}.pid" ]; then
    # Stop bird
    sudo pkill -F "/run/bird-${NAME}.pid"
fi
# Remove netns and veth pair
sudo ip link delete veth-${NAME}
 sudo ip netns delete ${NETNS}
done
for isl in $(ip -o link show | awk -F': ' '{print $2}' | grep -oE "^l-br[0-9](_[0-9]*)?-br[0-9](_[0-9]*).*$"); do
    # Delete inter-switch links
    sudo ip link delete dev $isl 2>/dev/null || true
done
for DNSMASQ in /run/dnsmasq-vlan*.pid; do
    [ -e "$DNSMASQ" ] || continue
    # Stop dnsmasq
    sudo pkill -F "$DNSMASQ"
done
# Remove faucet dataplane connection
sudo ip link delete veth-faucet 2>/dev/null || true
# Remove openvswitch bridges
sudo ovs-vsctl --if-exists del-br br0
sudo ovs-vsctl --if-exists del-br br1
sudo ovs-vsctl --if-exists del-br br2
sudo ovs-vsctl --if-exists del-br br3}

• Run the cleanup script to remove old namespaces and switches:

    cleanup

Basic stacking

We can start by considering two switches with one host on each switch on the same VLAN.

Let's define a simple base faucet.yaml to get started:
Faucet Documentation

Listing 27: /etc/faucet/faucet.yaml

```yaml
vlans:
  hosts:
    vid: 100
dps:
  br0:
    dp_id: 0x1
    hardware: "Open vSwitch"
    interfaces:
      1:
        description: "host1 network namespace"
        native_vlan: hosts
  br1:
    dp_id: 0x2
    hardware: "Open vSwitch"
    interfaces:
      1:
        description: "host2 network namespace"
        native_vlan: hosts
```

Now let's signal faucet to reload the configuration file.

```
sudo systemctl reload faucet
```

We need to create our two hosts, host1 and host2.

```
create_ns host1 10.0.1.1/24
create_ns host2 10.0.1.2/24
```

To setup multiple switches in Open vSwitch we can define two bridges with different datapath-ids and names. We’ll be using br0 and br1.

```
sudo ovs-vsctl add-br br0 \
  -- set bridge br0 other-config:datapath-id=0000000000000001 \
  -- set bridge br0 other-config:disable-in-band=true \
  -- set bridge br0 fail_mode=secure \
  -- add-port br0 veth-host1 -- set interface veth-host1 ofport_request=1 \
  -- set-controller br0 tcp:127.0.0.1:6653 tcp:127.0.0.1:6654

sudo ovs-vsctl add-br br1 \
  -- set bridge br1 other-config:datapath-id=0000000000000002 \
  -- set bridge br1 other-config:disable-in-band=true \
  -- set bridge br1 fail_mode=secure \
  -- add-port br1 veth-host2 -- set interface veth-host2 ofport_request=1 \
  -- set-controller br1 tcp:127.0.0.1:6653 tcp:127.0.0.1:6654
```

Since the switches are not connected it will be impossible to ping between the two hosts.

```
as_ns host1 ping 10.0.1.2
```

To connect the switches we can use the Faucet switch stacking feature. First, we need to define a root switch for our stack by setting a stack priority value for br0, the datapath with the lowest priority will be root. Second, we need to add stack interfaces connecting each datapath, we do this by defining the stack parameter on an interface. When defining a stack interface we say which datapath (dp) and port the other end of the cable is connected to.

Replace your base faucet.yaml from earlier with this version with stacking enabled:

```
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```
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Listing 28: /etc/faucet/faucet.yaml

```yaml
vlans:
  hosts:
    vid: 100
dps:
  br0:
    dp_id: 0x1
    hardware: "Open vSwitch"
    stack:
      priority: 1
      interfaces:
        1:
          description: "host1 network namespace"
          native_vlan: hosts
        2:
          description: "br0 stack link to br1"
          stack:
            dp: br0
            port: 2
  br1:
    dp_id: 0x2
    hardware: "Open vSwitch"
    interfaces:
      1:
        description: "host2 network namespace"
        native_vlan: hosts
      2:
        description: "br1 stack link to br0"
        stack:
          dp: br0
          port: 2
```

To connect two Open vSwitch bridges we can use a veth interface pair. We will use the `inter_switch_link` function we defined earlier to connect br0 port 2 to br1 port 2:

```
inter_switch_link br0:2 br1:2
```

Let’s reload Faucet and see what happens.

```
sudo systemctl reload faucet
```

Faucet will start sending out LLDP beacons to connect up the stack ports. We can see this happening in the log file when the switches report that port 2 (the stack port) is UP.

Listing 29: /var/log/faucet/faucet.log

```
DPID 2 (0x2) br1 LLDP on 0e:00:00:00:00:01, Port 2 from 0e:00:00:00:00:01 (remote_,
  └DPID 1 (0x1), port 2) state 2
DPID 2 (0x2) br1 Stack Port 2 INIT
DPID 1 (0x1) br0 LLDP on 0e:00:00:00:00:01, Port 2 from 0e:00:00:00:00:01 (remote_,
  └DPID 2 (0x2), port 2) state 2
DPID 1 (0x1) br0 Stack Port 2 INIT
DPID 2 (0x2) br1 LLDP on 0e:00:00:00:00:01, Port 2 from 0e:00:00:00:00:01 (remote_,
  └DPID 1 (0x1), port 2) state 1
DPID 2 (0x2) br1 Stack Port 2 UP
DPID 2 (0x2) br1 1 stack ports changed state
```
Now that the two switches are connected and our stack is up, we can ping between the two hosts.

```
as_ns host1 ping 10.0.1.2
```

**Inter-VLAN routing with stacking**

For this task we will see that inter-VLAN routing can work between hosts on different switches.

First run the cleanup.

```
cleanup
```

We can accomplish inter-VLAN routing between different switches by using the stacking feature. To do this we will be combining the methods from the Basic stacking and the Routing between VLANs tutorials. However, we need to set `drop_spoofed_faucet_mac` to false on each DP. Doing this will prevent a packet that has been routed and come from a stack port from being dropped.

Here is a full faucet.yaml you can copy and paste that sets up our stack topology and enables all the features we need.

```
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Listing 30: /etc/faucet/faucet.yaml

```

```yaml
vlans:
  hosts:
    vid: 100
    faucet_vips: ["10.0.1.254/24"]
    faucet_mac: "00:00:00:00:00:11"
  servers:
    vid: 200
    faucet_vips: ["10.0.2.254/24"]
```

(continues on next page)
faucet_mac: "00:00:00:00:00:22"

routers:
  router-1:
    vlans: [hosts, servers]
dps:
  br0:
    dp_id: 0x1
    hardware: "Open vSwitch"
    stack:
      priority: 1
    drop_spoofed_faucet_mac: False
    interfaces:
      1:
        description: "host1 network namespace"
        native_vlan: hosts
      2:
        description: "br0 stack link to br1"
        stack:
          dp: br1
          port: 2
      3:
        description: "server1 network namespace"
        native_vlan: servers

br1:
  dp_id: 0x2
  hardware: "Open vSwitch"
  drop_spoofed_faucet_mac: False
  interfaces:
    1:
      description: "host2 network namespace"
      native_vlan: hosts
    2:
      description: "br1 stack link to br0"
      stack:
        dp: br0
        port: 2
    3:
      description: "server2 network namespace"
      native_vlan: servers

Reload faucet to enable inter-VLAN routing.

```
sudo systemctl reload faucet
```

As we have learnt previously. First, set up the hosts:

```
create_ns host1 10.0.1.1/24
create_ns host2 10.0.1.2/24
create_ns server1 10.0.2.1/24
create_ns server2 10.0.2.2/24
```

Now we can set up the default routes for each host.

```
as_ns host1 ip route add default via 10.0.1.254
as_ns host2 ip route add default via 10.0.1.254
```

(continues on next page)
Next, we can create the bridges.

```
sudo ovs-vsctl add-br br0 \
   -- set bridge br0 other-config:datapath-id=0000000000000001 \
   -- set bridge br0 other-config:disable-in-band=true \
   -- set bridge br0 fail_mode=secure \
   -- add-port br0 veth-host1 -- set interface veth-host1 ofport_request=1 \
   -- add-port br0 veth-server1 -- set interface veth-server1 ofport_request=3 \
   -- set-controller br0 tcp:127.0.0.1:6653 tcp:127.0.0.1:6654
```

```
sudo ovs-vsctl add-br br1 \
   -- set bridge br1 other-config:datapath-id=0000000000000002 \
   -- set bridge br1 other-config:disable-in-band=true \
   -- set bridge br1 fail_mode=secure \
   -- add-port br1 veth-host2 -- set interface veth-host2 ofport_request=1 \
   -- add-port br1 veth-server2 -- set interface veth-server2 ofport_request=3 \
   -- set-controller br1 tcp:127.0.0.1:6653 tcp:127.0.0.1:6654
```

And finally, we can create the inter-switch links to connect the bridges to each other.

```
inter_switch_link br0:2 br1:2
```

Now it should be possible to ping between any combination of hosts on any VLAN after the LLDP has configured the stack ports as UP. For example host1 can ping to server1 on the same switch as well as server2 on the other switch via the use of the stack link.

```
as_ns host1 ping 10.0.2.1
as_ns host1 ping 10.0.2.2
```

### Tunneling over a stack

Faucet has a feature that allows us to tunnel packets from one datapath to another without having to think about the underlying network topology. In this example we have three switches and two hosts. We will create a tunnel that runs over top of this topology connecting host1 and host2 together.

```
VLAN 100
  10.0.1.1/24
  host1
```

```
VLAN 200
  10.0.1.24
  host2
```

```
Open vSwitch Bridge
br0
  veth link
  l-br0_2-br1_1
  10.0.1.1/24
  host1

Open vSwitch Bridge
br1
  veth link
  l-br1_1-br0_2
  l-br1.1-br0_2

Open vSwitch Bridge
br2
  veth link
  l-br2_2-br1_2
  l-br2.2-br1_2
```

First run the cleanup.

```
cleanup
```

Now let’s define our faucet.yaml that will make this network work. The configuration file below defines our faucet stack topology and ports for our host1 and host2. An important thing to note is that we define our two hosts on separate VLANs so they should not be able to communicate.
The other thing to notice is the two ACLs we define, `tunnel-to-host1` and `tunnel-to-host2`. At the moment these ACLs match all traffic (though we could easily add a match here to only tunnel a subset of traffic, see *ACL tutorial* for more details). Each tunnel sets the destination datapath and port for traffic matching the ACL, we currently support one type of tunnel, VLAN, and must reserve a tunnel VLAN here using the `tunnel_id` parameter (in future we could support different types of tunnels).

The two ACLs are then applied to the ports host1 and host2 are connected to.

```
Listing 31: /etc/faucet/faucet.yaml

```

Faucet Documentation

---

The other thing to notice is the two ACLs we define, `tunnel-to-host1` and `tunnel-to-host2`. At the moment these ACLs match all traffic (though we could easily add a match here to only tunnel a subset of traffic, see *ACL tutorial* for more details). Each tunnel sets the destination datapath and port for traffic matching the ACL, we currently support one type of tunnel, VLAN, and must reserve a tunnel VLAN here using the `tunnel_id` parameter (in future we could support different types of tunnels).

The two ACLs are then applied to the ports host1 and host2 are connected to.

```
Listing 31: /etc/faucet/faucet.yaml

```

The other thing to notice is the two ACLs we define, `tunnel-to-host1` and `tunnel-to-host2`. At the moment these ACLs match all traffic (though we could easily add a match here to only tunnel a subset of traffic, see *ACL tutorial* for more details). Each tunnel sets the destination datapath and port for traffic matching the ACL, we currently support one type of tunnel, VLAN, and must reserve a tunnel VLAN here using the `tunnel_id` parameter (in future we could support different types of tunnels).

The two ACLs are then applied to the ports host1 and host2 are connected to.

```
Listing 31: /etc/faucet/faucet.yaml

```

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The other thing to notice is the two ACLs we define, `tunnel-to-host1` and `tunnel-to-host2`. At the moment these ACLs match all traffic (though we could easily add a match here to only tunnel a subset of traffic, see *ACL tutorial* for more details). Each tunnel sets the destination datapath and port for traffic matching the ACL, we currently support one type of tunnel, VLAN, and must reserve a tunnel VLAN here using the `tunnel_id` parameter (in future we could support different types of tunnels).

The two ACLs are then applied to the ports host1 and host2 are connected to.

```
Listing 31: /etc/faucet/faucet.yaml

```

The other thing to notice is the two ACLs we define, `tunnel-to-host1` and `tunnel-to-host2`. At the moment these ACLs match all traffic (though we could easily add a match here to only tunnel a subset of traffic, see *ACL tutorial* for more details). Each tunnel sets the destination datapath and port for traffic matching the ACL, we currently support one type of tunnel, VLAN, and must reserve a tunnel VLAN here using the `tunnel_id` parameter (in future we could support different types of tunnels).

The two ACLs are then applied to the ports host1 and host2 are connected to.

```
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The two ACLs are then applied to the ports host1 and host2 are connected to.

```
Listing 31: /etc/faucet/faucet.yaml

```
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(continued from previous page)

When we have updated our configuration to match above, signal to faucet to reload the configuration file.

```
sudo systemctl reload faucet
```

Then we can set up the hosts:

```
create_ns host1 10.0.1.1/24
create_ns host2 10.0.1.2/24
```

Next, we can create the bridges.

```
sudo ovs-vsctl add-br br0 \  
-- set bridge br0 other-config:datapath-id=0000000000000001 \  
-- set bridge br0 other-config:disable-in-band=true \  
-- set bridge br0 fail_mode=secure \  
-- add-port br0 veth-host1 -- set interface veth-host1 ofport_request=1 \  
-- set-controller br0 tcp:127.0.0.1:6653 tcp:127.0.0.1:6654

sudo ovs-vsctl add-br br1 \  
-- set bridge br1 other-config:datapath-id=0000000000000002 \  
-- set bridge br1 other-config:disable-in-band=true \  
-- set bridge br1 fail_mode=secure \  
-- set-controller br1 tcp:127.0.0.1:6653 tcp:127.0.0.1:6654

sudo ovs-vsctl add-br br2 \  
-- set bridge br2 other-config:datapath-id=0000000000000003 \  
-- set bridge br2 other-config:disable-in-band=true \  
-- set bridge br2 fail_mode=secure \  
-- add-port br2 veth-host2 -- set interface veth-host2 ofport_request=1 \  
-- set-controller br2 tcp:127.0.0.1:6653 tcp:127.0.0.1:6654
```

We also need to define inter-switch links that connect br0 and b1 as well as br1 and br2.

```
inter_switch_link br0:2 br1:1
inter_switch_link br1:2 br2:2
```

We should now be able to ping between host1 and host2 despite them being on different VLANs and datapaths because
The reason the hosts can now communicate is that faucet is using the stack topology to find a path between the two hosts and automatically stitching up a tunnel. If we had a more complicated topology with multiple valid paths between the hosts, faucet will pick one and if the topology changes faucet will ensure the tunnel still goes over a valid path.

If we were to disable the ACLs on the port we would notice the hosts would no longer be able to ping.

**Redundant stack links**

Faucet is able to handle stack topologies with loops in them. This is because when faucet brings up a stack topology for the first time (or when it detects the network topology has changed), it has enough knowledge of the network to calculate a spanning tree for the network without the need for running a spanning tree protocol. Faucet uses this spanning tree to ensure broadcast packets aren’t looped around the network.

This feature enables us to build fault-tolerant network architectures that can survive switch/port failures, a simple example is a ring topology:

![Ring Topology Diagram]

To build this network, let’s first cleanup from previous exercises.

```
cleanup
```

We should be quite familiar with configuring faucet for stacks now, let’s define a faucet.yaml that matches our ring topology.

```
Listing 32: /etc/faucet/faucet.yaml

vlans:
  hosts:
    vid: 100
dps:
  br0:
    dp_id: 0x1
```

(continues on next page)
Reload faucet to enable the ring topology.

```
sudo systemctl reload faucet
```

We will define three hosts, one on each switch.

```yaml
hardware: "Open vSwitch"
stack:
  priority: 1
interfaces:
  1:
    description: "host1 network namespace"
    native_vlan: hosts
  2:
    description: "br0 stack link to br1"
    stack:
      dp: br1
      port: 2
  3:
    description: "br0 stack link to br2"
    stack:
      dp: br2
      port: 2

br1:
  dp_id: 0x2
  hardware: "Open vSwitch"
  interfaces:
    1:
      description: "host2 network namespace"
      native_vlan: hosts
    2:
      description: "br1 stack link to br0"
      stack:
        dp: br0
        port: 2
    3:
      description: "br1 stack link to br2"
      stack:
        dp: br2
        port: 2

br2:
  dp_id: 0x3
  hardware: "Open vSwitch"
  interfaces:
    1:
      description: "host3 network namespace"
      native_vlan: hosts
    2:
      description: "br2 stack link to br0"
      stack:
        dp: br0
        port: 3
    3:
      description: "br2 stack link to br1"
      stack:
        dp: br1
        port: 3
```
create_ns host1 10.0.1.1/24
create_ns host2 10.0.1.2/24
create_ns host3 10.0.1.3/24

Now let’s define the three switches.

```bash
sudo ovs-vsctl add-br br0 \
  -- set bridge br0 other-config:datapath-id=0000000000000001 \
  -- set bridge br0 other-config:disable-in-band=true \
  -- set bridge br0 fail_mode=secure \
  -- add-port br0 veth-host1 -- set interface veth-host1 ofport_request=1 \
  -- set-controller br0 tcp:127.0.0.1:6653 tcp:127.0.0.1:6654

sudo ovs-vsctl add-br br1 \
  -- set bridge br1 other-config:datapath-id=0000000000000002 \
  -- set bridge br1 other-config:disable-in-band=true \
  -- set bridge br1 fail_mode=secure \
  -- add-port br1 veth-host2 -- set interface veth-host2 ofport_request=1 \
  -- set-controller br1 tcp:127.0.0.1:6653 tcp:127.0.0.1:6654

sudo ovs-vsctl add-br br2 \
  -- set bridge br2 other-config:datapath-id=0000000000000003 \
  -- set bridge br2 other-config:disable-in-band=true \
  -- set bridge br2 fail_mode=secure \
  -- add-port br2 veth-host3 -- set interface veth-host3 ofport_request=1 \
  -- set-controller br2 tcp:127.0.0.1:6653 tcp:127.0.0.1:6654
```

We also need to create the inter-switch links forming our ring network.

```bash
inter_switch_link br0:2 br1:2
inter_switch_link br0:3 br2:2
inter_switch_link br1:3 br2:3
```

Once the network is up we should be able to ping from all hosts to all other hosts.

```bash
as_ns host1 ping 10.0.1.2
as_ns host1 ping 10.0.1.3
```

Now let us intentionally introduce a fault into the network, our network should be able to survive a single cable failure and still have all devices reachable.

To test this we will manually disable the link between br0 and br2.

```bash
sudo ip link set down l-br0_3-br2_2
sudo ip link set down l-br2_2-br0_3
```

Which will force traffic between br0 and br2 to now go via br1, we can test this by ensuring host1 can still ping host3.

```bash
as_ns host1 ping 10.0.1.3
```
Multi-root stack

The previous exercise introduced the ability to survive cable failures, but you might have noticed in each exercise so far we have defined only a single root switch. If we were to lose this root switch the network would no longer function.

In this exercise we will introduce multi-root stacked networks which give us the ability to tolerate switch failures.

This example topology will allow us to survive any single cable failure or either of br0 or br1 failing.

Before we begin, let’s do another cleanup.

cleanup

Our faucet.yaml will look familiar here, except for one difference, we now have two switches defined as stack priority 1. This signals to faucet that it has two equal priority root candidates it can use when selecting a root for the network.

Listing 33: /etc/faucet/faucet.yaml

```yaml
vlans:
    hosts:
        vid: 100
dps:
    br0:
        dp_id: 0x1
        hardware: "Open vSwitch"
        stack:
            priority: 1
        interfaces:
            1:
                description: "br0 stack link to br2"
                stack:
                    dp: br2
                    port: 2
```

(continues on next page)
When we have this new faucet.yaml loaded we will do a full restart this time instead of reloading to force a root
We will create some hosts to let us test the failure scenarios of this topology.

create_ns host1 10.0.1.1/24
create_ns host2 10.0.1.2/24

We also need to define our four switches.

```
sudo ovs-vsctl add-br br0 \
-- set bridge br0 other-config:datapath-id=0000000000000001 \
-- set bridge br0 other-config:disable-in-band=true \
-- set bridge br0 fail_mode=secure \
-- set-controller br0 tcp:127.0.0.1:6653 tcp:127.0.0.1:6654

sudo ovs-vsctl add-br br1 \
-- set bridge br1 other-config:datapath-id=0000000000000002 \
-- set bridge br1 other-config:disable-in-band=true \
-- set bridge br1 fail_mode=secure \
-- set-controller br1 tcp:127.0.0.1:6653 tcp:127.0.0.1:6654

sudo ovs-vsctl add-br br2 \
-- set bridge br2 other-config:datapath-id=0000000000000003 \
-- set bridge br2 other-config:disable-in-band=true \
-- set bridge br2 fail_mode=secure \
-- add-port br2 veth-host1 -- set interface veth-host1 ofport_request=1 \
-- set-controller br2 tcp:127.0.0.1:6653 tcp:127.0.0.1:6654

sudo ovs-vsctl add-br br3 \
-- set bridge br3 other-config:datapath-id=0000000000000004 \
-- set bridge br3 other-config:disable-in-band=true \
-- set bridge br3 fail_mode=secure \
-- add-port br3 veth-host2 -- set interface veth-host2 ofport_request=1 \
-- set-controller br3 tcp:127.0.0.1:6653 tcp:127.0.0.1:6654
```

We need to fully mesh br0, br1, br2 and br3 to match our topology diagram above.

```
# Inter-switch links for br0
inter_switch_link br0:1 br2:2
inter_switch_link br0:2 br3:3

# Inter-switch links for br1
inter_switch_link br1:1 br3:2
inter_switch_link br1:2 br2:3
```

When everything is setup we should be able to ping between host1 and host2.

```
as_ns host1 ping 10.0.1.2
```

Now let’s inspect the log file to find out which switch is currently our root.

```
$ grep -ai "stack root changed" /var/log/faucet/faucet.log | tail -n 1
Oct 08 04:19:24 faucet INFO stack root changed from None to br0
```

Since br0 is the switch which is currently root, let’s delete it to simulate a switch failure.
sudo ovs-vsctl del-br br0

If we look into the log file we should see faucet detects the switch is down and br1 takes over as the new root.

Listing 34: /var/log/faucet/faucet.yaml

Oct 08 04:22:52 faucet.valve WARNING DPID 1 (0x1) br0 datapath down
Oct 08 04:23:03 faucet.valve INFO DPID 1 (0x1) br0 LLDP for Port 1 inactive after 17s
Oct 08 04:23:03 faucet.valve INFO DPID 1 (0x1) br0 LLDP for Port 2 inactive after 17s
Oct 08 04:23:03 faucet.valve ERROR DPID 1 (0x1) br0 Stack Port 1 DOWN, too many packets lost, last received 17s ago
Oct 08 04:23:03 faucet.valve INFO DPID 2 (0x2) br1 shortest path to root is via Port 1
Oct 08 04:23:03 faucet.valve INFO DPID 3 (0x3) br2 shortest path to root is via Port 2
Oct 08 04:23:03 faucet.valve INFO DPID 3 (0x3) br2 shortest path to root is via Port 3
Oct 08 04:23:03 faucet.valve ERROR DPID 1 (0x1) br0 Stack Port 2 DOWN, too many packets lost, last received 17s ago
Oct 08 04:23:03 faucet.valve INFO DPID 2 (0x2) br1 shortest path to root is via Port 1
Oct 08 04:23:03 faucet.valve INFO DPID 2 (0x2) br1 shortest path to root is via Port 2
Oct 08 04:23:03 faucet.valve INFO DPID 4 (0x4) br3 shortest path to root is via Port 3
Oct 08 04:23:03 faucet.valve INFO DPID 4 (0x4) br3 shortest path to root is via Port 3
Oct 08 04:23:03 faucet.valve ERROR DPID 1 (0x1) br0 Stack Port 3 DOWN, too many packets lost, last received 17s ago
Oct 08 04:23:03 faucet.valve INFO DPID 2 (0x2) br1 shortest path to root is via Port 1
Oct 08 04:23:03 faucet.valve INFO DPID 2 (0x2) br1 shortest path to root is via Port 2
Oct 08 04:23:03 faucet.valve INFO DPID 4 (0x4) br3 shortest path to root is via Port 3
Oct 08 04:23:03 faucet.valve INFO DPID 4 (0x4) br3 shortest path to root is via Port 3
Oct 08 04:23:03 faucet.valve INFO DPID 3 (0x3) br2 1 stack ports changed state
Oct 08 04:23:03 faucet.valve INFO DPID 3 (0x3) br2 1 stack ports changed state
Oct 08 04:23:03 faucet.valve ERROR DPID 4 (0x4) br3 Stack Port 3 DOWN, too many packets lost, last received 17s ago
Oct 08 04:23:03 faucet.valve INFO DPID 2 (0x2) br1 shortest path to root is via Port 1
Oct 08 04:23:03 faucet.valve INFO DPID 2 (0x2) br1 shortest path to root is via Port 2
Oct 08 04:23:03 faucet.valve INFO DPID 4 (0x4) br3 shortest path to root is via Port 3
Oct 08 04:23:03 faucet.valve INFO DPID 4 (0x4) br3 shortest path to root is via Port 3
Oct 08 04:23:03 faucet.valve INFO DPID 4 (0x4) br3 1 stack ports changed state
Oct 08 04:23:03 faucet.valve INFO DPID 4 (0x4) br3 1 stack ports changed state
Oct 08 04:23:15 faucet INFO stack root changed from br0 to br1
Oct 08 04:23:15 faucet INFO root now br1 (all candidates ('br0', 'br1'), healthy ['br1'])

We should also still be able to ping between host1 and host2 after the stack has recalculated.

as_ns host1 ping 10.0.1.2
1.2.6 NFV services tutorial

This tutorial will cover using faucet with Network Function Virtualisation (NFV) style services.
NFV services that will be demonstrated in this tutorial are:

- DHCP/DNS server
- Zeek (formerly known as Bro) Intrusion Detection System (IDS)

This tutorial demonstrates how the previous topics in this tutorial series can be combined to run real world services on our network.

Prerequisites

- A good understanding of the previous tutorial topics (ACL tutorial, VLAN tutorial, Routing tutorial)
- Install Faucet - Package installation steps 1 & 2
- Install Open vSwitch - Connect your first datapath steps 1 & 2
- Useful Bash Functions - Copy and paste the following definitions into your bash terminal, or to make them persistent between sessions add them to the bottom of your .bashrc and run ‘source .bashrc’.

```bash
# Run command inside network namespace
as_ns () { 
  NAME=$1
  NETNS=faucet-$NAME
  shift
  sudo ip netns exec $NETNS @
}

# Create network namespace
create_ns () { 
  NAME=$1
  IP=$2
  NETNS=faucet-$NAME
  sudo ip netns add $NETNS
  sudo ip link add dev veth-$NAME type veth peer name veth0 netns $NETNS
  sudo ip link set dev veth-$NAME up
  as_ns $NAME ip link set dev lo up
  [ -n "$IP" ] && as_ns $NAME ip addr add dev veth0 $IP
  as_ns $NAME ip link set dev veth0 up
}

# Clean up namespaces, bridges and processes created during faucet tutorial
cleanup () { 
  for NETNS in $(sudo ip netns list | grep "faucet-" | awk '{print $1}'); do 
    [ -n "$NETNS" ] || continue 
    NAME=$NETNS#faucet-
    if [ -f "/run/dhclient-$NAME.pid" ]; then 
      # Stop dhclient
      sudo pkill -F "/run/dhclient-$NAME.pid"
    fi
    if [ -f "/run/iperf3-$NAME.pid" ]; then 
      # Stop iperf3
      fi
    fi
  done
}
```

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```bash
# Stop iperf3
sudo pkill -F "/run/iperf3-$(NAME).pid"
fi
if [ -f "/run/bird-$(NAME).pid" ]; then
  # Stop bird
  sudo pkill -F "/run/bird-$(NAME).pid"
fi
# Remove netns and veth pair
sudo ip link delete veth-$(NAME)
sudo ip netns delete $(NETNS)
done
for isl in $(ip -o link show | awk -F: '{print $2}' | grep -oE "^l-br[0-9](_[0-9]*)?-br[0-9](_[0-9]*)?"); do
  # Delete inter-switch links
  sudo ip link delete dev $isl 2>/dev/null || true
done
for DNSSMASQ in /run/dnsmasq-vlan*.pid; do
  [ -e "$DNNSMASQ" ] || continue
  # Stop dnsmasq
  sudo pkill -F "$DNNSMASQ"
done
# Remove faucet dataplane connection
sudo ip link delete veth-faucet 2>/dev/null || true
# Remove openvswitch bridges
sudo ovs-vsctl --if-exists del-br br0
sudo ovs-vsctl --if-exists del-br br1
sudo ovs-vsctl --if-exists del-br br2
sudo ovs-vsctl --if-exists del-br br3
}

# Add tagged VLAN interface to network namespace
add_tagged_interface () {
    NAME=$1
    VLAN=$2
    IP=$3
    NETNS=faucet-$(NAME)
    as_ns $NAME ip link add link veth0 name veth0.$VLAN type vlan id
    [ -n "$IP" ] && as_ns $NAME ip addr add dev veth0.$VLAN $IP
    as_ns $NAME ip link set dev veth0.$VLAN up
    as_ns $NAME ip addr flush dev veth0
}

• Run the cleanup script to remove old namespaces and switches:

```
Network setup

The network will be divided into three VLANs, two of which are client VLANs (200 & 300), with two clients in each and a DHCP/DNS server. There is also a separate VLAN 100 for the Zeek server which we will mirror traffic two from the other two VLANs.

To start, let’s create our hosts and dnsmasq namespaces.

```
# DHCP/DNS server
create_ns dnsmasq 0.0.0.0
add_tagged_interface dnsmasq 200 192.168.2.1/24 # to serve VLAN 200
add_tagged_interface dnsmasq 300 192.168.3.1/24 # to serve VLAN 300

# VLAN 200 hosts
create_ns host1 0.0.0.0
create_ns host2 0.0.0.0
# VLAN 300 hosts
create_ns host3 0.0.0.0
create_ns host4 0.0.0.0
```

Then create an Open vSwitch bridge and connect all hosts to it.

```
sudo ovs-vsctl add-br br0 \
   -- set bridge br0 other-config:datapath-id=0000000000000001 \ 
   -- set bridge br0 other-config:disable-in-band=true \ 
   -- set bridge br0 fail_mode=secure \ 
   -- add-port br0 veth-host1 -- set interface veth-host1 ofport_request=1 \ 
   -- add-port br0 veth-host2 -- set interface veth-host2 ofport_request=2 \ 
   -- add-port br0 veth-host3 -- set interface veth-host3 ofport_request=3 \ 
   -- add-port br0 veth-host4 -- set interface veth-host4 ofport_request=4 \ 
   -- add-port br0 veth-dnsmasq -- set interface veth-dnsmasq ofport_request=5 \ 
   -- set-controller br0 tcp:127.0.0.1:6653 tcp:127.0.0.1:6654
```
Dnsmasq setup

We will use dnsmasq to assign IP addresses to our host namespaces via the DHCP protocol. It will also serve as our DNS resolver for the hosts.

First install dnsmasq:

```
sudo apt-get install dnsmasq
sudo systemctl stop dnsmasq
```

Run the following two commands to start two dnsmasq instances inside the dnsmasq namespace. One instance will serve hosts on VLAN 200 and the other VLAN 300. We will be providing DHCP leases in the supplied ranges, the lease will set the gateway for each host to point at faucet’s virtual IP and set dnsmasq as the DNS resolver. We also provide a fake `does.it.work` DNS name which we will later use to demonstrate DNS is working as expected.

```
# 192.168.2.0/24 for VLAN 200
as_ns dnsmasq dnsmasq \
  --dhcp-range=192.168.2.10,192.168.2.20 \
  --dhcp-sequential-ip \
  --dhcp-option=option:router,192.168.2.254 \
  --no-resolv \
  --txt-record=does.it.work,yes \
  --bind-interfaces \
  --except-interface=lo --interface=veth0.200 \
  --dhcp-leasefile=/tmp/nfv-dhcp-vlan200.leases \
  --log-facility=/tmp/nfv-dhcp-vlan200.log \
  --pid-file=/run/dnsmasq-vlan200.pid \
  --conf-file=

# 192.168.3.0/24 for VLAN 300
as_ns dnsmasq dnsmasq \
  --dhcp-range=192.168.3.10,192.168.3.20 \
  --dhcp-sequential-ip \
  --dhcp-option=option:router,192.168.3.254 \
  --no-resolv \
  --txt-record=does.it.work,yes \
  --bind-interfaces \
  --except-interface=lo --interface=veth0.300 \
  --dhcp-leasefile=/tmp/nfv-dhcp-vlan300.leases \
  --log-facility=/tmp/nfv-dhcp-vlan300.log \
  --pid-file=/run/dnsmasq-vlan300.pid \
  --conf-file=
```

Now let’s configure faucet.yaml.

Listing 35: /etc/faucet/faucet.yaml

```
vlans:
  vlan200:
    vid: 200
    description: "192.168.2.0/24 network"
    faucet_vips: ["192.168.2.254/24"]
    faucet_mac: "00:00:00:00:00:22"
  vlan300:
    vid: 300
    description: "192.168.3.0/24 network"
    faucet_vips: ["192.168.3.254/24"]
    faucet_mac: "00:00:00:00:00:33"
```

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Now reload faucet configuration file.

```
sudo systemctl reload faucet
```

Use dhclient to configure host1 to host4 using DHCP (it may take a few seconds, but should return when successful).

```
as_ns host1 dhclient -v -pf /run/dhclient-host1.pid -lf /run/dhclient-host1.leases
   -veth0
as_ns host2 dhclient -v -pf /run/dhclient-host2.pid -lf /run/dhclient-host2.leases
   -veth0
as_ns host3 dhclient -v -pf /run/dhclient-host3.pid -lf /run/dhclient-host3.leases
   -veth0
as_ns host4 dhclient -v -pf /run/dhclient-host4.pid -lf /run/dhclient-host4.leases
   -veth0
```

If dhclient is unable to obtain an address you can check `/tmp/nfv-dhcp-vlan<vlanid>.log` (e.g. `/tmp/nfv-dhcp-vlan300.leases`) to check the log messages from dnsmasq.

To look up the address for each namespace we can run the following commands:

```
as_ns host1 ip address show dev veth0
as_ns host2 ip address show dev veth0
as_ns host3 ip address show dev veth0
as_ns host4 ip address show dev veth0
```

If the hosts have IPs then great our DHCP server works.

At the moment we should be able to ping inside VLAN 200 and VLAN 300:

```
as_ns host1 ping <ip of host2> # both in VLAN 200 should work
as_ns host3 ping <ip of host4> # both in VLAN 300 should work
```
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Pinging between VLANs will not currently work as we didn’t turn on inter-VLAN routing in our faucet configuration.

DNS

We can use faucet to enforce where protocols such as DNS go on the network. In this section we will use a faucet ACL to rewrite DNS packets to allow our dnsmasq namespace to answer DNS queries for any IP address.

Firstly, we can see that our dnsmasq server is correctly responding to DNS requests by manually querying them:

```
as_ns host1 host -t txt does.it.work 192.168.2.1
as_ns host3 host -t txt does.it.work 192.168.3.1
```

Both commands should return:

```
does.it.work descriptive text "yes"
```

But if we tried to query say 8.8.8.8 we would see this fail:

```
as_ns host1 host -t txt does.it.work 8.8.8.8
```

To make this work we first need the MAC address of the dnsmasq container:

```
as_ns dnsmasq cat /sys/class/net/veth0/address
```

```
00:11:22:33:44:55
```

We now replace our previous faucet configuration with the configuration below which adds an ACL that rewrites the MAC address of all DNS packets from the host namespaces and sends these to our dnsmasq namespace. Make sure to update the example MAC address of 00:11:22:33:44:55 with the one you get from running the previous command.

```
Listing 36: /etc/faucet/faucet.yaml
```

```
vls:
  vlan200:
    vid: 200
    description: "192.168.2.0/24 network"
    faucet_vips: ["192.168.2.254/24"]
    faucet_mac: "00:00:00:00:00:22"
  vlan300:
    vid: 300
    description: "192.168.3.0/24 network"
    faucet_vips: ["192.168.3.254/24"]
    faucet_mac: "00:00:00:00:00:33"
dps:
  sw1:
    dp_id: 0x1
    hardware: "Open vSwitch"
    interfaces:
      1:
        name: "host1"
        description: "host1 network namespace"
        native_vlan: vlan200
        acls_in: [nfv-dns, allow-all]
      2:
        name: "host2"
        description: "host2 network namespace"
```

(continues on next page)
native_vlan: vlan200
acls_in: [nfv-dns, allow-all]

3:
  name: "host3"
  description: "host3 network namespace"
  native_vlan: vlan300
  acls_in: [nfv-dns, allow-all]

4:
  name: "host4"
  description: "host4 network namespace"
  native_vlan: vlan300
  acls_in: [nfv-dns, allow-all]

5:
  name: "dnsmasq"
  description: "dnsmasq server network namespace"
  tagged_vlans: [vlan200, vlan300]

acls:

  nfv-dns:
    # Force UDP DNS to our DNS server
    - rule:
      dl_type: 0x800  # ipv4
      nw_proto: 17  # udp
      udp_dst: 53  # dns
      actions:
        output:
          set_fields:
            - eth_dst: "00:11:22:33:44:55"  # MAC address of dnsmasq
          →
          namespace
          allow: True
          # Force TCP DNS to our DNS server
          - rule:
            dl_type: 0x800  # ipv4
            nw_proto: 6  # tcp
            tcp_dst: 53  # dns
            actions:
              output:
                set_fields:
                  - eth_dst: "00:11:22:33:44:55"  # MAC address of dnsmasq
                  →
                  namespace
                  allow: True
  allow-all:
  - rule:
    actions:
      allow: True

As usual reload faucet configuration file.

```
sudo systemctl reload faucet
```

The next step is to configure the namespace to be able to handle incoming DNS packets with any IP, this can be done by adding some rules to iptables that will NAT all DNS traffic to the IP address of the VLAN interface:

```
as_ns dnsmasq iptables -t nat -A PREROUTING -i veth0.200 -p udp --dport 53 -j DNAT --to-destination 192.168.2.1
as_ns dnsmasq iptables -t nat -A PREROUTING -i veth0.200 -p tcp --dport 53 -j DNAT --to-destination 192.168.2.1
```

(continues on next page)
Now we should be able to query any IP address from the hosts and get a valid DNS response:

```
as_ns host1 host -t txt does.it.work 8.8.8.8
as_ns host2 host -t txt does.it.work 8.8.4.4
```
as_ns zeek broctl install

Then start Zeek instant

as_ns zeek broctl start

Check Zeek status

as_ns zeek broctl status

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>Host</th>
<th>Status</th>
<th>Pid</th>
<th>Started</th>
</tr>
</thead>
<tbody>
<tr>
<td>bro</td>
<td>standalone</td>
<td>localhost</td>
<td>running</td>
<td>15052</td>
<td>07 May 09:03:59</td>
</tr>
</tbody>
</table>

Now let's add a mirror ACL so all VLAN 200 & VLAN 300 traffic is sent to Zeek.

We will use a VLAN ACLs similar to the previous VLAN tutorial. Copy and paste the entire configuration below into faucet.yaml.

```
Listing 39: /etc/faucet/faucet.yaml

acls:
  mirror-acl:
    - rule:
        actions:
          allow: true
          mirror: zeek

vlans:
  zeek-vlan:
    vid: 100
    description: "Zeek IDS network"
  vlan200:
    vid: 200
    description: "192.168.2.0/24 network"
    faucet_vips: ["192.168.2.254/24"]
    faucet_mac: "00:00:00:00:00:22"
    acls_in: [mirror-acl]
  vlan300:
    vid: 300
    description: "192.168.3.0/24 network"
    faucet_vips: ["192.168.3.254/24"]
    faucet_mac: "00:00:00:00:00:33"
    acls_in: [mirror-acl]

dps:
  sw1:
    dp_id: 0x1
    hardware: "Open vSwitch"
    interfaces:
      1:
        name: "host1"
        description: "host1 network namespace"
        native_vlan: vlan200
      2:
        name: "host2"
        description: "host2 network namespace"
        native_vlan: vlan200
      3:
        name: "host3"
        description: "host3 network namespace"
```

(continues on next page)
As usual reload faucet configuration file.

```
sudo systemctl reload faucet
```

If we generate some DNS traffic on either of the hosts VLANs

```
as_ns host4 host -t txt does.it.work 192.168.3.1
```

Then if we inspect the Zeek logs for DNS /var/log/bro/current/dns.log, we should see that Zeek has seen the DNS queries and logged these.

```
#separator \x09
#set_separator ,
#empty_field   (empty)
#unset_field   -
#path dns
#open 2019-01-17-17-43-56
#fields ts uid id.orig_h id.orig_p id.resp_h id.resp_p ->
  proto trans_id rtt query qclass qclass_name qtype qtype_
  name rcode rcode_name AA TC RD RA Z answers_
-TTLs rejected
#types time string addr port addr port enum count interval -->
  string count string count string count string bool bool bool
  bool count vector[string] vector[interval] bool
1547700236.794299 CsulWM1Px7fIyPpCVi 192.168.3.10 43428 192.168.3.1
  53 udp 14288 0.006973does.it.work 1 C_INTERNET 16 TXT
  0 NOERROR T F T T 2 TXT 3 yes 0.
  000000 F
1547700379.311319 CZa11oBd3CgWBmgS8 192.168.3.11 45089 192.168.3.1
  53 udp 64001 0.000336does.it.work 1 C_INTERNET 16 TXT
  0 NOERROR T F T T 0 TXT 3 yes 0.
  000000 F
```

You can also check if the traffic is being mirrored as expected using `tcpdump` in the zeek network namespace:

```
as_ns zeek sudo tcpdump -i veth0 -n -l
```

in one window, and then generating some more DNS traffic, eg:

```
as_ns host4 host -t txt does.it.work 192.168.3.1
```
then you should see something like:

```
Listing 41: zeek namespace tcpdump output

tcpdump: verbose output suppressed, use -v or -vv for full protocol decode
listening on veth0, link-type EN10MB (Ethernet), capture size 262144 bytes
12:19:24.625109 IP 192.168.3.1.53 > 192.168.3.13.38174: 64571* 1/0/0 TXT "yes" (46)
```

### 1.3 Installation

We recommend installing faucet with apt for first time users and provide a *Installing faucet for the first time* tutorial which walks you through all the required steps for setting up faucet and gauge for the first time.

Once installed, see *Configuration* for documentation on how to configure faucet. Also, see *Vendor-specific Documentation* for documentation on how to configure your switch.

More advanced methods of installing faucet are also available here:

1. **Installation using APT**
2. **Installation with Docker**
3. **Installation with Pip**
4. **Installing on Raspberry Pi**
5. **Installing with Virtual Machine image**

#### 1.3.1 Installation using APT

We maintain a apt repo for installing faucet and its dependencies on Debian-based Linux distributions.

Here is a list of packages we supply:

<table>
<thead>
<tr>
<th>Package</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>python3-faucet</td>
<td>Install standalone faucet/gauge python3 library</td>
</tr>
<tr>
<td>faucet</td>
<td>Install python3 library, systemd service and default config files</td>
</tr>
<tr>
<td>gauge</td>
<td>Install python3 library, systemd service and default config files</td>
</tr>
<tr>
<td>faucet-all-in-one</td>
<td>Install faucet, gauge, prometheus and grafana. Easy to use and good for testing faucet for the first time.</td>
</tr>
</tbody>
</table>

**Installation on Debian/Raspbian 9+ and Ubuntu 16.04+**

```
sudo apt-get install curl gnupg apt-transport-https lsb-release
echo "deb https://packagecloud.io/faucetsdn/faucet/$(lsb_release -si | awk '{print tolower($0)})')/ $(lsb_release -sc) main" | sudo tee /etc/apt/sources.list.d/faucet.list
curl -L https://packagecloud.io/faucetsdn/faucet/gpgkey | sudo apt-key add -
sudo apt-get update
```

Then to install all components for a fully functioning system on a single machine:

```
sudo apt-get install faucet-all-in-one
```
or you can install the individual components:

```
sudo apt-get install faucet
gsudo apt-get install gauge
```

### 1.3.2 Installation with Docker

We provide official automated builds on Docker Hub so that you can easily run Faucet and its components in a self-contained environment without installing on the main host system.

#### Installing docker

We recommend installing Docker Community Edition (CE) according to the official docker engine installation guide.

#### Configuring dockers

First, we need to create some configuration files on our host to mount inside the docker containers to configure faucet and gauge:

```
sudo mkdir -p /etc/faucet
sudo vi /etc/faucet/faucet.yaml
sudo vi /etc/faucet/gauge.yaml
```

See the [Configuration](#) section for configuration options.

#### Starting dockers

We use Docker tags to differentiate between versions of Faucet. The latest tag will always point to the latest stable release of Faucet. All tagged versions of Faucet in git are also available to use, for example using the `faucet/faucet:1.8.0` Docker will run the released version 1.8.0 of Faucet.

By default the Faucet and Gauge images are run as the `faucet` user under UID 0, GID 0. If you need to change that it can be overridden at runtime with the Docker flags: `-e LOCAL_USER_ID` and `-e LOCAL_GROUP_ID`.

To pull and run the latest version of Faucet:

```
mkdir -p /var/log/faucet/
docker pull faucet/faucet:latest
docker run -d --name faucet --restart=always -v /etc/faucet:/etc/faucet/ -v /var/log/faucet:/var/log/faucet/ -p 6653:6653 -p 9302:9302 faucet/faucet
```

Port 6653 is used for OpenFlow, port 9302 is used for Prometheus - port 9302 may be omitted if you do not need Prometheus.

To pull and run the latest version of Gauge:
mkdir -p /var/log/faucet/gauge/
docker pull faucet/gauge:latest
docker run -d \n  --name gauge \n  --restart=always \n  -v /etc/faucet/:/etc/faucet/ \n  -v /var/log/faucet/:/var/log/faucet/ \n  -p 6654:6653 \n  -p 9303:9303 \n  faucet/gauge
Port 6654 is used for OpenFlow, port 9303 is used for Prometheus - port 9303 may be omitted if you do not need Prometheus.

**Additional arguments**

You may wish to run faucet under docker with additional arguments, for example: setting certificates for an encrypted control channel. This can be done by overriding the docker entrypoint like so:

docker run -d \n  --name faucet \n  --restart=always \n  -v /etc/faucet/:/etc/faucet/ \n  -v /etc/ryu/ssl/:/etc/ryu/ssl/ \n  -v /var/log/faucet/:/var/log/faucet/ \n  -p 6653:6653 \n  -p 9302:9302 \n  faucet/faucet \n  --ctl-privkey /etc/ryu/ssl/ctrlr.key \n  --ctl-cert /etc/ryu/ssl/ctrlr.cert \n  --ca-certs /etc/ryu/ssl/sw.cert
You can get a list of all additional arguments faucet supports by running:

docker run -it faucet/faucet faucet --help

**Docker compose**

This is an example docker-compose file that can be used to set up gauge to talk to Prometheus and InfluxDB with a Grafana instance for dashboards and visualisations.

It can be run with:

docker-compose pull
docker-compose up

The time-series databases with the default settings will write to /opt/prometheus/ /opt/influxdb/shared/data/db you can edit these locations by modifying the docker-compose.yaml file.

On OSX, some of the default shared paths are not accessible, so to overwrite the location that volumes are written to on your host, export an environment variable name FAUCET_PREFIX and it will get prepended to the host paths. For example:
When all the docker containers are running we will need to configure Grafana to talk to Prometheus and InfluxDB. First login to the Grafana web interface on port 3000 (e.g. http://localhost:3000) using the default credentials of admin:admin.

Then add two data sources. Use the following settings for Prometheus:

Name: Prometheus
Type: Prometheus
Url: http://prometheus:9090

And the following settings for InfluxDB:

Name: InfluxDB
Type: InfluxDB
Url: http://influxdb:8086
With Credentials: true
Database: faucet
User: faucet
Password: faucet

Check the connection using test connection.

From here you can add a new dashboard and a graphs for pulling data from the data sources. Hover over the + button on the left sidebar in the web interface and click Import.

We will import the following dashboards, just download the following links and upload them through the grafana dashboard import screen:

- Instrumentation
- Inventory
- Port Statistics

### 1.3.3 Installation with Pip

You can install the latest pip package, or you can install directly from git via pip.

**Installing faucet**

First, install some python dependencies:

```bash
apt-get install python3-dev python3-pip
pip3 install setuptools
pip3 install wheel
```

Then install the latest stable release of faucet from pypi, via pip:

```bash
pip3 install faucet
```

Or, install the latest development code from git, via pip:

```bash
pip3 install git+https://github.com/faucetsdn/faucet.git
```
**Starting faucet manually**

Faucet includes a start up script for starting Faucet and Gauge easily from the command line.

To run Faucet manually:

```bashfaishet --verbose
```

To run Gauge manually:

```bash
gauge --verbose
```

There are a number of options that you can supply the start up script for changing various options such as OpenFlow port and setting up an encrypted control channel. You can find a list of the additional arguments by running:

```bash
faucet --help
```

**Starting faucet With systemd**

Systemd can be used to start Faucet and Gauge at boot automatically:

```bash
EDITOR /etc/systemd/system/faucet.service
EDITOR /etc/systemd/system/gauge.service
systemctl daemon-reload
systemctl enable faucet.service
systemctl enable gauge.service
systemctl restart faucet
systemctl restart gauge
```

/`etc/systemd/system/faucet.service` should contain:

```
[Unit]
Description="Faucet OpenFlow switch controller"
After=network-online.target
Wants=network-online.target

[Service]
EnvironmentFile=/etc/default/faucet
User=faucet
Group=faucet
ExecStart=/usr/local/bin/faucet --ryu-config-file=${FAUCET_RYU_CONF} --ryu-ofp-tcp-listen-port=${FAUCET_LISTEN_PORT}
ExecReload=/bin/kill -HUP $MAINPID
Restart=always

[Install]
WantedBy=multi-user.target
```

/`etc/systemd/system/gauge.service` should contain:

```
[Unit]
Description="Gauge OpenFlow statistics controller"
```

(continues on next page)
1.3.4 Installing on Raspberry Pi

We provide a Raspberry Pi image running FAUCET which can be retrieved from the latest faucet release page on GitHub. Download the faucet_VERSION_raspbian-lite.zip file.

The image can then be copied onto an SD card following the same steps from the official Raspberry Pi installation guide.

Once you have booted up the Raspberry Pi and logged in using the default credentials you can follow through the Installing faucet for the first time tutorial starting from Configure prometheus to properly configure each component.

Note: It is strongly recommended to use a Raspberry Pi 3 or better.

1.3.5 Installing with Virtual Machine image

We provide a VM image for running FAUCET for development and learning purposes. The VM comes pre-installed with FAUCET, GAUGE, prometheus and grafana.

Openstack’s diskimage-builder (DIB) is used to build the VM images in many formats (qcow2,tgz,squashfs,vhd,raw).

Downloading pre-built images

Pre-built images are available on github, see the latest faucet release page on GitHub and download the faucet-amd64-VERSION.qcow2 file.

Building the images

If you don’t want to use our pre-built images, you can build them yourself:

1. Install the latest disk-image-builder
2. Install a patched vhd-util
3. Run build-faucet-vm.sh
Security considerations

This VM is not secure by default, it includes no firewall and has a number of network services listening on all interfaces with weak passwords. It also includes a backdoor user (faucet) with weak credentials.

Services

The VM exposes a number of ports listening on all interfaces by default:

<table>
<thead>
<tr>
<th>Service</th>
<th>Port</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSH</td>
<td>22</td>
</tr>
<tr>
<td>Faucet OpenFlow Channel</td>
<td>6653</td>
</tr>
<tr>
<td>Gauge OpenFlow Channel</td>
<td>6654</td>
</tr>
<tr>
<td>Grafana Web Interface</td>
<td>3000</td>
</tr>
<tr>
<td>Prometheus Web Interface</td>
<td>9090</td>
</tr>
</tbody>
</table>

Default Credentials

<table>
<thead>
<tr>
<th>Service</th>
<th>Username</th>
<th>Password</th>
</tr>
</thead>
<tbody>
<tr>
<td>VM TTY Console</td>
<td>faucet</td>
<td>faucet</td>
</tr>
<tr>
<td>SSH</td>
<td>faucet</td>
<td>faucet</td>
</tr>
<tr>
<td>Grafana Web Interface</td>
<td>admin</td>
<td>admin</td>
</tr>
</tbody>
</table>

Post-install steps

Grafana comes installed but unconfigured, you will need to login to the grafana web interface at http://VM_IP:3000 and configure a data source and some dashboards.

After logging in with the default credentials shown above, the first step is to add a prometheus data source, use the following settings then click Save & Test:

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>URL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prometheus</td>
<td>Prometheus</td>
<td><a href="http://localhost:9090">http://localhost:9090</a></td>
</tr>
</tbody>
</table>

Next we want to add some dashboards so that we can later view the metrics from faucet.

Hover over the + button on the left sidebar in the web interface and click Import.

We will import the following dashboards, just download the following links and upload them through the grafana dashboard import screen:

- Instrumentation
- Inventory
- Port Statistics

You will need to supply your own faucet.yaml and gauge.yaml configuration in the VM. There are samples provided at /etc/faucet/faucet.yaml and /etc/faucet/gauge.yaml.

Finally you will need to point one of the supported OpenFlow vendors at the controller VM, port 6653 is the Faucet OpenFlow control channel and 6654 is the Gauge OpenFlow control channel for monitoring.
1.4 Configuration

1.4.1 Faucet configuration

Faucet is configured with a YAML-based configuration file, `faucet.yaml`. The following is an example demonstrating a few common features:

Listing 44: faucet.yaml

```yaml
include:
  - acls.yaml

vlans:
  office:
    vid: 100
    description: "office network"
    acls_in: ["office-vlan-protect"]
    faucet_mac: "0e:00:00:00:10:01"
    faucet_vips: ['10.0.100.254/24', '2001:100::1/64', 'fe80::c00:00ff:fe00:1001/64']

  guest:
    vid: 200
    description: "guest network"
    faucet_mac: "0e:00:00:00:20:01"
    faucet_vips: ['10.0.200.254/24', '2001:200::1/64', 'fe80::c00:00ff:fe00:2001/64']

routes:
  - route:
      ip_dst: '192.168.0.0/24'
      ip_gw: '10.0.100.2'

routers:
  router-office-guest:
    vlans: ["office", "guest"]

dps:
  sw1:
    dp_id: 0x1
    hardware: "Open vSwitch"
    interfaces:
      1:
        name: "h1"
        description: "host1 container"
        native_vlan: office
        acls_in: ["access-port-protect"]
      2:
        name: "h2"
        description: "host2 container"
        native_vlan: office
        acls_in: ["access-port-protect"]
      3:
        name: "g1"
        description: "guest1 container"
        native_vlan: guest
        acls_in: ["access-port-protect"]
      4:
        name: "s1"
```

(continues on next page)
description: "services container"
native_vlan: office
acls_in: [service-port-protect]

5:
  name: "trunk"
description: "VLAN trunk to sw2"
tagged_vlans: [office]
acls_in: [access-port-protect]

sw2:
  dp_id: 0x2
  hardware: "Allied-Telesis"
  interfaces:
    1:
      name: "pi"
description: "raspberry pi"
native_vlan: office
acls_in: [access-port-protect]

2:
  name: "laptop"
description: "guest laptop"
native_vlan: guest
acls_in: [access-port-protect]

4:
  name: "s1"
description: "services Laptop"
native_vlan: guest
acls_in: [access-port-protect]

24:
  name: "trunk"
description: "VLAN trunk to sw1"
tagged_vlans: [office, guest]

Listing 45: acls.yaml

```yaml
acls:

  office-vlan-protect:
    # Prevent IPv4 communication between Office/Guest networks
    - rule:
        dl_type: 0x800  # ipv4
        ipv4_src: 10.0.100.0/24
        ipv4_dst: 10.0.200.0/24
        actions:
          allow: 0  # drop
    - rule:
        actions:
          allow: 1  # allow

  access-port-protect:
    # Drop dhcp servers
    - rule:
        dl_type: 0x800  # ipv4
        nw_proto: 17    # udp
        udp_src: 67     # bootps
        udp_dst: 68     # bootpc
        actions:
          allow: 0  # drop
```

(continues on next page)
# Drop dhcpv6 servers
- rule:
  dl_type: 0x86dd  # ipv6
  nw_proto: 17    # udp
  udp_src: 547    # dhcpv6-server
  udp_dst: 546    # dhcpv6-client
  actions:
    allow: 0      # drop

# Drop icmpv6 RAs
- rule:
  dl_type: 0x86dd  # ipv6
  nw_proto: 58    # icmpv6
  icmpv6_type: 134 # router advertisement
  actions:
    allow: 0      # drop

# Drop SMTP
- rule:
  dl_type: 0x800  # ipv4
  nw_proto: 6     # tcp
  tcp_dst: 25     # smtp
  actions:
    allow: 0      # drop

# Force DNS to our DNS server
- rule:
  dl_type: 0x800  # ipv4
  nw_proto: 17    # udp
  udp_dst: 53     # dns
  actions:
    output:
      set_fields:
        - eth_dst: "72:b8:3c:4c:dc:4d"
        port: "s1"  # s1 container

- rule:
  dl_type: 0x800  # ipv4
  nw_proto: 6     # tcp
  tcp_dst: 53     # dns
  actions:
    output:
      set_fields:
        - eth_dst: "72:b8:3c:4c:dc:4d"
        port: "s1"  # s1 container
    allow: 1        # allow

service-port-protect:
  # Drop icmpv6 RAs
- rule:
  dl_type: 0x86dd  # ipv6
  nw_proto: 58     # icmpv6
  icmpv6_type: 134 # router advertisement
  actions:
    allow: 0      # drop

# Drop SMTP
- rule:
  dl_type: 0x800  # ipv4
  nw_proto: 6     # tcp
nw_proto: 6  # tcp
tcp_dst: 25  # smtp
actions:
  allow: 0  # drop

- rule:
  actions:
  allow: 1  # allow

The datapath ID may be specified as an integer or hex string (beginning with 0x).
A port not explicitly defined in the YAML configuration file will be left down and will drop all packets.

Configuration options

Top Level

Table 1: Faucet.yaml

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Type</th>
<th>Default</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>acls</td>
<td>dictionary</td>
<td>{}</td>
<td>Configuration specific to acls. The keys are names of each acl, and the values are config dictionaries holding the acl’s configuration (see below).</td>
</tr>
<tr>
<td>dps</td>
<td>dictionary</td>
<td>{}</td>
<td>Configuration specific to datapaths. The keys are names or dp_ids of each datapath, and the values are config dictionaries holding the datapath’s configuration (see below).</td>
</tr>
<tr>
<td>meters</td>
<td>dictionary</td>
<td>{}</td>
<td>Configuration specific to meters. The keys are names of each meter, and the values are config dictionaries holding the meter’s configuration (see below).</td>
</tr>
<tr>
<td>routers</td>
<td>dictionary</td>
<td>{}</td>
<td>Configuration specific to routers. The keys are names of each router, and the values are config dictionaries holding the router’s configuration (see below).</td>
</tr>
<tr>
<td>version</td>
<td>integer</td>
<td>2</td>
<td>The config version. 2 is the only supported version.</td>
</tr>
<tr>
<td>vlans</td>
<td>dictionary</td>
<td>{}</td>
<td>Configuration specific to vlans. The keys are names or vids of each vlan, and the values are config dictionaries holding the vlan’s configuration (see below).</td>
</tr>
</tbody>
</table>

DP

DP configuration is entered in the ‘dps’ configuration block. The ‘dps’ configuration contains a dictionary of configuration blocks each containing the configuration for one datapath. The keys can either be string names given to the datapath, or the OFP datapath id.

Table 2: dps: <dp name or id>: {}

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Type</th>
<th>Default</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>advertise_interval</td>
<td>integer</td>
<td>30</td>
<td>How often to advertise (eg. IPv6 RAs)</td>
</tr>
<tr>
<td>arp_neighbor_timeout</td>
<td>integer</td>
<td>250</td>
<td>ARP and neighbour timeout in seconds</td>
</tr>
<tr>
<td>description</td>
<td>string</td>
<td>name</td>
<td>Description of this datapath, strictly informational</td>
</tr>
<tr>
<td>dot1x</td>
<td>dictionary</td>
<td>{}</td>
<td>802.1X configuration (see below)</td>
</tr>
</tbody>
</table>

Continued on next page
<table>
<thead>
<tr>
<th>Attribute</th>
<th>Type</th>
<th>Default</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>dp_id</td>
<td>integer</td>
<td></td>
<td>The OFP datapath-id of this datapath</td>
</tr>
<tr>
<td>drop_bpdu</td>
<td>boolean</td>
<td>True</td>
<td>If True, Faucet will drop all STP BPDUs arriving at the datapath. NB: Faucet does not handle BPDUs itself, if you disable this then you either need to configure an ACL to catch BDPUs or Faucet will forward them as though they were normal traffic.</td>
</tr>
<tr>
<td>drop_broadcast_source_address</td>
<td>boolean</td>
<td>True</td>
<td>If True, Faucet will drop any packet from a broadcast source address</td>
</tr>
<tr>
<td>drop_spoofed_faucet_mac</td>
<td>boolean</td>
<td>True</td>
<td>If True, Faucet will drop any packet it receives with an ethernet source address equal to a MAC address that Faucet is using.</td>
</tr>
<tr>
<td>group_table</td>
<td>boolean</td>
<td>False</td>
<td>If True, Faucet will use the OpenFlow Group tables to flood packets. This is an experimental feature that is not fully supported by all devices and may not interoperate with all features of faucet.</td>
</tr>
<tr>
<td>hardware</td>
<td>string</td>
<td>&quot;Open vSwitch&quot;</td>
<td>The hardware model of the datapath. Defaults to “Open vSwitch”. Other options can be seen in the documentation for valve.py</td>
</tr>
<tr>
<td>high_priority</td>
<td>integer</td>
<td>low_priority + 1 (9001)</td>
<td>The high priority value.</td>
</tr>
<tr>
<td>highest_priority</td>
<td>integer</td>
<td>high_priority + 98 (9099)</td>
<td>The highest priority number to use.</td>
</tr>
<tr>
<td>ignore_learn_ins</td>
<td>integer</td>
<td>10</td>
<td>Ignore every approx nth packet for learning. 2 will ignore 1 out of 2 packets; 3 will ignore 1 out of 3 packets. This limits control plane activity when learning new hosts rapidly. Flooding will still be done by the dataplane even with a packet is ignored for learning purposes.</td>
</tr>
<tr>
<td>interfaces</td>
<td>dictionary</td>
<td>{}</td>
<td>Configuration block for interface specific config (see below)</td>
</tr>
<tr>
<td>interface_ranges</td>
<td>dictionary</td>
<td>{}</td>
<td>Contains the config blocks for sets of multiple interfaces. The configuration entered here will be used as the defaults for these interfaces. The defaults can be overwritten by configuring the interfaces individually, which will also inherit all defaults not specifically configured. For example, if the range specifies tagged_vlans: [1, 2, 3], and the individual interface specifies tagged_vlans: [4], the result will be tagged_vlans: [4]. The format for the configuration key is a comma separated string. The elements can either be the name or number of an interface or a range of port numbers eg: “1-6,8,port9”.</td>
</tr>
</tbody>
</table>

Continued on next page
<table>
<thead>
<tr>
<th>Attribute</th>
<th>Type</th>
<th>Default</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>learn_ban_timeout</td>
<td>integer</td>
<td>10</td>
<td>When a host is rapidly moving between ports Faucet will stop learning mac addresses on one of the ports for this number of seconds.</td>
</tr>
<tr>
<td>learn_jitter</td>
<td>integer</td>
<td>10</td>
<td>In order to reduce load on the controller Faucet will randomly vary the timeout for learnt mac addresses by up to this number of seconds.</td>
</tr>
<tr>
<td>lldp_beacon</td>
<td>dictionary</td>
<td>{}</td>
<td>Configuration block for LLDP beacons</td>
</tr>
<tr>
<td>low_priority</td>
<td>integer</td>
<td>low_priority + 9000 (9000)</td>
<td>The low priority value.</td>
</tr>
<tr>
<td>lowest_priority</td>
<td>integer</td>
<td>priority_offset (0)</td>
<td>The lowest priority number to use.</td>
</tr>
<tr>
<td>max_host_fib_retry_count</td>
<td>integer</td>
<td>10</td>
<td>Limit the number of times Faucet will attempt to resolve a next-hop’s l2 address.</td>
</tr>
<tr>
<td>max_hosts_per_resolve_cycle</td>
<td>integer</td>
<td>5</td>
<td>Limit the number of hosts resolved per cycle.</td>
</tr>
<tr>
<td>max_resolve_backoff_time</td>
<td>integer</td>
<td>32</td>
<td>When resolving next hop l2 addresses, Faucet will back off exponentially until it reaches this value.</td>
</tr>
<tr>
<td>metrics_rate_limit_sec</td>
<td>integer</td>
<td>0</td>
<td>Rate limit metric updates - don’t update metrics if last update was less than this many seconds ago.</td>
</tr>
<tr>
<td>name</td>
<td>string</td>
<td></td>
<td>A name to reference the datapath by.</td>
</tr>
<tr>
<td>ofchannel_log</td>
<td>string</td>
<td>None</td>
<td>Name of logfile for openflow logs</td>
</tr>
<tr>
<td>packetin_pps</td>
<td>integer</td>
<td>None</td>
<td>Ask switch to rate limit packetin in pps.</td>
</tr>
<tr>
<td>slowpath_pps</td>
<td>integer</td>
<td>None</td>
<td>Ask switch to rate limit slowpath in pps.</td>
</tr>
<tr>
<td>priority_offset</td>
<td>integer</td>
<td>0</td>
<td>Shift all priority values by this number.</td>
</tr>
<tr>
<td>proactive_learn_v4</td>
<td>boolean</td>
<td>True</td>
<td>Whether proactive learning is enabled for IPv4 nexthops</td>
</tr>
<tr>
<td>proactive_learn_v6</td>
<td>boolean</td>
<td>True</td>
<td>Whether proactive learning is enabled for IPv6 nexthops</td>
</tr>
<tr>
<td>stack</td>
<td>dictionary</td>
<td>{}</td>
<td>Configuration block for stacking config, for loop protection (see below)</td>
</tr>
<tr>
<td>timeout</td>
<td>integer</td>
<td>300</td>
<td>Timeout for MAC address learning</td>
</tr>
<tr>
<td>use_idle_timeout</td>
<td>boolean</td>
<td>False</td>
<td>Turn on/off the use of idle timeout for src_table, default OFF.</td>
</tr>
<tr>
<td>table_sizes</td>
<td>dictionary</td>
<td>{}</td>
<td>For TFM based switches, size of each FAUCET table (any may be specified)</td>
</tr>
<tr>
<td>port_table_scale_factor</td>
<td>float</td>
<td>1.0</td>
<td>For TFM based switches, and for tables that are sized by number of ports, scale size estimate.</td>
</tr>
<tr>
<td>global_vlan</td>
<td>int</td>
<td>2**11-1</td>
<td>When global routing is enabled, FIB VID used internally</td>
</tr>
</tbody>
</table>
Stacking (DP)

Stacking is configured in the dp configuration block and in the interface configuration block. At the dp level the following attributes can be configured within the configuration block ‘stack’:

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Type</th>
<th>Default</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>priority</td>
<td>integer</td>
<td>0</td>
<td>Setting any value for stack priority indicates that this datapath should be the root for the stacking topology.</td>
</tr>
</tbody>
</table>

LLDP (DP)

LLDP beacons are configured in the dp and interface configuration blocks.

LLDP beacons can be used to, among other things, facilitate physical troubleshooting (e.g. so that a standard cable tester can display port information), verify FAUCET stacking topology, and cue a phone to use the right voice VLAN.

**Note:** While FAUCET can receive and log LLDP from other devices, FAUCET does not do spanning tree. Those LLDP packets will have no influence on FAUCET’s forwarding decisions.

The following attributes can be configured within the ‘lldp_beacon’ configuration block at the dp level:

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Type</th>
<th>Default</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>system_name</td>
<td>string</td>
<td></td>
<td>The datapath name inside LLDP packet</td>
</tr>
<tr>
<td>send_interval</td>
<td>integer</td>
<td>None</td>
<td>Seconds between sending beacons</td>
</tr>
<tr>
<td>max_per_interval</td>
<td>integer</td>
<td>None</td>
<td>The maximum number of beacons, across all ports to send each interval</td>
</tr>
</tbody>
</table>

**Note:** When stack ports are enabled FAUCET automatically configures LLDP with the default values for send_interval and max_per_interval to 5.

802.1X (DP)

**Note:** 802.1X support is experimental, and there may be incomplete features or bugs. If you find an issue please email the mailing list or create a Github issue.

Faucet implements 802.1X by forwarding EAPOL packets on the dataplane to a socket it is listening on. These packets are then passed through to a RADIUS server which performs the authentication and generates the reply message.

For each instance of Faucet there is only one 802.1X speaker. This 802.1X speaker is configured by the options below. Except for the ‘nfv_sw_port’ option, the configuration for the speaker is configured using the first dp’s dot1x config dictionary. For all other dps only the ‘nfv_sw_port’ option is required with the others ignored.

A basic network and configuration with two hosts may look like:
1.4. Configuration

dps:
  dp1:
    nfv_intf: eth1
    nfv_sw_port: 4
    ...

Faucet

dp1

Controlplane

Dataplane

H1

H2
A brief overview of the current state of the implementation:

Implemented:

- EAP Types: MD5, PEAP, TLS, TTLS.
- Authentication session expiry default 3600 seconds. (configurable (per authentication) via returning the Session-Timeout attribute in the RADIUS Access-Accept message).
- Faucet connects to a single RADIUS server, and passes through all EAP messages.
- Client can end session with EAP-Logoff.
- Dynamic assignment of the native VLAN. Use RADIUS attribute Private-Group-Tunnel-ID in Radius Access-Accept with the name of the faucet VLAN.

Not Supported (yet):

- RADIUS Accounting.
- Multiple RADIUS Servers.
- Other EAP types. E.g. FAST, …
- Dynamic assignment of ACL.

802.1X port authentication is configured in the dp configuration block and in the interface configuration block. At the dp level the following attributes can be configured with the configuration block ‘dot1x’:
Table 5: dps: <dp name or id>: dot1x: {}

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Type</th>
<th>Default</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>nfv_intf</td>
<td>str</td>
<td></td>
<td>The interface for Faucet to listen for EAP packets from the dataplane. - NOTE: Faucet will only use the config from the first dp</td>
</tr>
<tr>
<td>nfv_sw_port</td>
<td>int</td>
<td></td>
<td>Switch port number that connects to the Faucet server’s nfv_intf</td>
</tr>
<tr>
<td>radius_ip</td>
<td>str</td>
<td></td>
<td>IP address of RADIUS Server the 802.1X speaker will authenticate with. - NOTE: Faucet will only use the config from the first dp</td>
</tr>
<tr>
<td>radius_port</td>
<td>int</td>
<td>1812</td>
<td>UDP port of RADIUS Server the 802.1X speaker will authenticate with. - NOTE: Faucet will only use the config from the first dp</td>
</tr>
<tr>
<td>radius_secret</td>
<td>str</td>
<td></td>
<td>Shared secret used by the RADIUS server and the 802.1X speaker. - NOTE: Faucet will only use the config from the first dp</td>
</tr>
<tr>
<td>noauth_acl</td>
<td>str</td>
<td>None</td>
<td>The name of the defined ACL [refer to acls.yaml for more information] that will be set to all 802.1X ports by default, that is before any user is authenticated. - NOTE: Faucet will only use the config from the first dp</td>
</tr>
<tr>
<td>auth_acl</td>
<td>str</td>
<td>None</td>
<td>The name of the defined ACL [refer to acls.yaml for more information] that will be set to an 802.1X port when a user authenticates. - NOTE: Faucet will only use the config from the first dp</td>
</tr>
<tr>
<td>dot1x_assigned</td>
<td>boolean</td>
<td>False</td>
<td>True, if this ACL can be dynamically assigned by a RADIUS server during 802.1X authentication.</td>
</tr>
</tbody>
</table>

**Interfaces**

Configuration for each interface is entered in the ‘interfaces’ configuration block within the config for the datapath. Each interface configuration block is a dictionary keyed by the interface name.

Defaults for groups of interfaces can also be configured under the ‘interface-ranges’ attribute within the datapath configuration block. These provide default values for a number of interfaces which can be overwritten with the config block for an individual interface. These are keyed with a string containing a comma separated list of OFP port numbers, interface names or with OFP port number ranges (eg. 1-6).
# Table 6: dps: <dp name or id>: interfaces: <interface name or OFP port number>: {}

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Type</th>
<th>Default</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>acl_in</td>
<td>integer or string</td>
<td>None</td>
<td>Deprecated, replaced by acls_in which accepts a list. The acl that should be applied to all packets arriving on this port. referenced by name or list index</td>
</tr>
<tr>
<td>acls_in</td>
<td>a list of ACLs, as integers or strings</td>
<td>None</td>
<td>A list of ACLs that should be applied to all packets arriving on this port. referenced by name or list index. ACLs listed first take priority over those later in the list.</td>
</tr>
<tr>
<td>description</td>
<td>string</td>
<td>Name (which defaults to the configuration key)</td>
<td>Description, purely informational</td>
</tr>
<tr>
<td>dot1x</td>
<td>boolean</td>
<td>False</td>
<td>Enable 802.1X port authentication (NOTE: Requires ACL with dot1x_assigned attribute, for 802.1X Per User ACLs)</td>
</tr>
<tr>
<td>dot1x_acl</td>
<td>boolean</td>
<td>False</td>
<td>Enable 802.1X ACL functionality on port (NOTE: Requires dot1x attribute)</td>
</tr>
<tr>
<td>dot1x_mab</td>
<td>boolean</td>
<td>False</td>
<td>Enable 802.1X Mac Authentication Bypass on port (NOTE: Requires dot1x attribute)</td>
</tr>
<tr>
<td>enabled</td>
<td>boolean</td>
<td>True</td>
<td>Allow packets to be forwarded through this port.</td>
</tr>
<tr>
<td>hairpin</td>
<td>boolean</td>
<td>False</td>
<td>If True it allows packets arriving on this port to be output to this port. This is necessary to allow routing between two vlans on this port, or for use with a WIFI radio port.</td>
</tr>
<tr>
<td>lldp_beacon</td>
<td>dictionary</td>
<td>{}</td>
<td>Configuration block for lldp configuration</td>
</tr>
<tr>
<td>loop_protect</td>
<td>boolean</td>
<td>False</td>
<td>if True, do simple (host/access port) loop protection on this port.</td>
</tr>
<tr>
<td>loop_protect_external</td>
<td>boolean</td>
<td>False</td>
<td>if True, do external (other switch) loop protection on this port.</td>
</tr>
<tr>
<td>max_hosts</td>
<td>integer</td>
<td>255</td>
<td>the maximum number of mac addresses that can be learnt on this port.</td>
</tr>
<tr>
<td>mirror</td>
<td>a list of integers or strings</td>
<td>None</td>
<td>Mirror all allowed packets received from (subject to ACLs), and all packets transmitted to, the ports specified (by name or by port number), to this port. If mirroring of denied by ACL packets is desired, use the ACL rule mirror option. The mirrored packets are from the perspective of hosts on the mirrored port (for example, a packet with a VLAN tag, transmitted to a host on a mirrored and untagged port, will be mirrored without its original VLAN tag). NOTE: If packets are exchanged between two ports that are both mirrored, depending on the OpenFlow switch, only one copy of the mirrored traffic may be sent (when a port sends a packet, not when the other receives it). This is because some implementations cannot send a packet more than once to the same port.</td>
</tr>
<tr>
<td>name</td>
<td>string</td>
<td>The configuration key.</td>
<td></td>
</tr>
<tr>
<td>native_vlan</td>
<td>integer</td>
<td>None</td>
<td>The vlan associated with untagged packets arriving and leaving this interface.</td>
</tr>
</tbody>
</table>
Stacking (Interfaces)

Stacking port configuration indicates how datapaths are connected when using stacking. The configuration is found under the ‘stack’ attribute of an interface configuration block. The following attributes can be configured:

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Type</th>
<th>Default</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>dp</td>
<td>integer or string</td>
<td>None</td>
<td>The name or dp_id of the dp connected to this port</td>
</tr>
<tr>
<td>port</td>
<td>integer or string</td>
<td>None</td>
<td>The name or OFP port number of the interface on the remote dp connected to this interface.</td>
</tr>
</tbody>
</table>

LLDP (Interfaces)

Interface specific configuration for LLDP.

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Type</th>
<th>Default</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>enable</td>
<td>boolean</td>
<td>False</td>
<td>Enable sending lldp beacons from this interface</td>
</tr>
<tr>
<td>org_tlvs</td>
<td>list</td>
<td>[]</td>
<td>Definitions of Organisational TLVs to add to LLDP beacons</td>
</tr>
<tr>
<td>port_descr</td>
<td>string</td>
<td>Interface description</td>
<td>Port description to use in beacons from this interface</td>
</tr>
<tr>
<td>system_name</td>
<td>string</td>
<td>lldp_beacon (dp) system name</td>
<td>The System Name to use in beacons from this interface</td>
</tr>
</tbody>
</table>

LLDP Organisational TLVs (Interfaces)

Faucet allows defining organisational TLVs for LLDP beacons. These are configured in a list under lldp_beacons/org_tlvs at the interfaces level of configuration.

Each list element contains a dictionary with the following elements:

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Type</th>
<th>Default</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>info</td>
<td>string</td>
<td>None</td>
<td>The info field of the tlv, as a hex string</td>
</tr>
<tr>
<td>oui</td>
<td>integer</td>
<td>None</td>
<td>The Organisationally Unique Identifier</td>
</tr>
<tr>
<td>subtype</td>
<td>integer</td>
<td>None</td>
<td>The organizationally defined subtype</td>
</tr>
</tbody>
</table>
Router

Routers config is used to allow routing between VLANs, and optionally BGP. Routers configuration is entered in the ‘routers’ configuration block at the top level of the faucet configuration file. Configuration for each router is an entry in the routers dictionary and is keyed by a name for the router. The following attributes can be configured:

Table 10: routers: <router name>: {}

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Type</th>
<th>Default</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>vlans</td>
<td>list of integers or strings</td>
<td>None</td>
<td>Enables inter-vlan routing on the given VLANs.</td>
</tr>
<tr>
<td>bgp</td>
<td>BGP configuration.</td>
<td>None</td>
<td>See below for BGP configuration.</td>
</tr>
</tbody>
</table>

BGP

Routers config to enable BGP routing.

Table 11: routers: <router name>: {}

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Type</th>
<th>Default</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>as</td>
<td>integer</td>
<td>None</td>
<td>The local AS number to used when speaking BGP</td>
</tr>
<tr>
<td>connect_mode</td>
<td>string</td>
<td>“passive”</td>
<td>Must be “passive”</td>
</tr>
<tr>
<td>neighbor_addresses</td>
<td>list of strings (IP addresses)</td>
<td>None</td>
<td>The list of BGP neighbours</td>
</tr>
<tr>
<td>neighbor_as</td>
<td>integer</td>
<td>None</td>
<td>The AS Number for the BGP neighbours</td>
</tr>
<tr>
<td>routerid</td>
<td>string (IP address)</td>
<td>None</td>
<td>BGP router ID.</td>
</tr>
<tr>
<td>server_addresses</td>
<td>list of strings (IP addresses)</td>
<td>None</td>
<td>IP addresses for FAUCET to listen for in-coming BGP addresses.</td>
</tr>
<tr>
<td>port</td>
<td>integer</td>
<td>None</td>
<td>Port to use for BGP sessions</td>
</tr>
<tr>
<td>vlan</td>
<td>string</td>
<td>None</td>
<td>The VLAN to add/remove BGP routes from.</td>
</tr>
</tbody>
</table>

VLAN

VLANs are configured in the ‘vlans’ configuration block at the top level of the faucet config file. The config for each vlan is an entry keyed by its vid or a name. The following attributes can be configured:
### Table 12: vlans: `<vlan name or vid>`: `{ }`

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Type</th>
<th>Default</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>acl_in</td>
<td>string or integer</td>
<td>None</td>
<td>Deprecated, replaced by acls_in which accepts a list. The acl to be applied to all packets arriving on this vlan.</td>
</tr>
<tr>
<td>acls_in</td>
<td>a list of ACLs, as integers or strings</td>
<td>None</td>
<td>The acl to be applied to all packets arriving on this vlan. ACLs listed first take priority over those later in the list.</td>
</tr>
<tr>
<td>description</td>
<td>string</td>
<td>None</td>
<td>Strictly informational</td>
</tr>
<tr>
<td>dot1x_assigned</td>
<td>bool</td>
<td>False</td>
<td>True, if this VLAN can be dynamically assigned by a RADIUS server during 802.1X authentication. Otherwise False</td>
</tr>
<tr>
<td>faucet_vips</td>
<td>list of strings (IP address prefixes)</td>
<td>None</td>
<td>The IP Address for Faucet’s routing interface on this vlan</td>
</tr>
<tr>
<td>faucet_mac</td>
<td>string (MAC address)</td>
<td>None</td>
<td>Set MAC for FAUCET VIPs on this VLAN</td>
</tr>
<tr>
<td>max_hosts</td>
<td>integer</td>
<td>255</td>
<td>The maximum number of hosts that can be learnt on this vlan.</td>
</tr>
<tr>
<td>minimum_ip_size_check</td>
<td>boolean</td>
<td>True</td>
<td>If False, don’t check that IP packets have a payload (must be False for OVS trace/tutorial to work)</td>
</tr>
<tr>
<td>name</td>
<td>string</td>
<td>the configuration key</td>
<td>A name that can be used to refer to this vlan.</td>
</tr>
<tr>
<td>proactive_arp_limit</td>
<td>integer</td>
<td>2052</td>
<td>Do not proactively ARP for hosts once this value has been reached (set to None for unlimited)</td>
</tr>
<tr>
<td>proactive_nd_limit</td>
<td>integer</td>
<td>2052</td>
<td>Don’t proactively discover IPv6 hosts once this value has been reached (set to None for unlimited)</td>
</tr>
<tr>
<td>routes</td>
<td>list of routes</td>
<td>None</td>
<td>Static routes configured on this vlan (see below)</td>
</tr>
<tr>
<td>targeted_gw_resolution</td>
<td>boolean</td>
<td>False</td>
<td>If True, and a gateway has been resolved, target the first re-resolution attempt to the same port rather than flooding.</td>
</tr>
<tr>
<td>unicast_flood</td>
<td>boolean</td>
<td>True</td>
<td>If False packets to unknown ethernet destination MAC addresses will be dropped rather than flooded.</td>
</tr>
<tr>
<td>vid</td>
<td>integer</td>
<td>the configuration key</td>
<td>The vid for the vlan.</td>
</tr>
</tbody>
</table>
Static Routes

Static routes are given as a list. Each entry in the list contains a dictionary keyed with the keyword ‘route’ and contains a dictionary configuration block as follows:

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Type</th>
<th>Default</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ip_dst</td>
<td>string (IP subnet)</td>
<td>None</td>
<td>The destination subnet.</td>
</tr>
<tr>
<td>ip_gw</td>
<td>string (IP address)</td>
<td>None</td>
<td>The next hop for this route</td>
</tr>
</tbody>
</table>

Meters

**Note**: Meters are platform dependent and not all functions may be available.

Meters are configured under the ‘meters’ configuration block. The meters block contains a dictionary of individual meters each keyed by its name.

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Type</th>
<th>Default</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>meter_id</td>
<td>int</td>
<td></td>
<td>Unique identifier.</td>
</tr>
<tr>
<td>entry</td>
<td>dictionary</td>
<td></td>
<td>Defines the meter actions. Details Below.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Type</th>
<th>Default</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>flags</td>
<td>string or list of strings</td>
<td>KBPS</td>
<td>Possible values are ‘KBPS’ (Rate value in kb/s (kilo-bit per second).), ‘PKTPS’ (Rate value in packet/sec.), ‘BURST’ (Do burst size), ‘STATS’ (Collect statistics)</td>
</tr>
<tr>
<td>bands</td>
<td>list of bands (which are dictionaries, see below)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 16: <meter name>: entry: bands:

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Type</th>
<th>Default</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>type</td>
<td>string</td>
<td>‘DROP’</td>
<td>‘DROP’ - drop packets when the band rate is exceeded, or ‘DSCP_REMARK’ - use a simple DiffServ policer to remark the DSCP field in the IP header of packets that exceed the band rate.</td>
</tr>
<tr>
<td>rate</td>
<td>int</td>
<td></td>
<td>Rate for dropping or remarking packets, depending on the above type. Value is in KBPS or PKTPS flag depending on the flag set.</td>
</tr>
<tr>
<td>burst_size</td>
<td>int</td>
<td></td>
<td>Only used if flags include BURST. Indicates the length of packet or byte burst to consider for applying the meter.</td>
</tr>
<tr>
<td>prec_level</td>
<td>int</td>
<td></td>
<td>Only used if type is DSCP_REMARK. The amount by which the drop precedence should be increased.</td>
</tr>
</tbody>
</table>

**ACLs**

ACLs are configured under the ‘acls’ configuration block. The acls block contains a dictionary of individual acls each keyed by its name.

Each acl contains a list of rules: a packet will have the first matching rule applied to it.

Each rule is a dictionary containing the single key ‘rule’ with matches and actions. Matches are key/values based on the ryu RESTful API. Actions is a dictionary of actions to apply upon match.

Table 17: <acl name>: - rule: actions: {}

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Type</th>
<th>Default</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>allow</td>
<td>boolean</td>
<td>False</td>
<td>If True allow the packet to continue through the Faucet pipeline, if False drop the packet.</td>
</tr>
<tr>
<td>force_port_vlan</td>
<td>boolean</td>
<td>False</td>
<td>If True, don’t verify VLAN/port association.</td>
</tr>
<tr>
<td>cookie</td>
<td>int, 0-2**16</td>
<td>defaults to datapath cookie value</td>
<td>If set, cookie on this flow will be set to this value.</td>
</tr>
<tr>
<td>meter</td>
<td>string</td>
<td>None</td>
<td>Meter to apply to the packet</td>
</tr>
<tr>
<td>mirror</td>
<td>string or integer</td>
<td>None</td>
<td>Copy the packet, before any modifications, to the specified port (NOTE: ACL mirroring is done in input direction only)</td>
</tr>
<tr>
<td>output</td>
<td>dictionary</td>
<td>None</td>
<td>Used to output a packet directly. Details below.</td>
</tr>
</tbody>
</table>

The output action contains a dictionary with the following elements:
Table 18: : acls: <acl name>: - rule: actions: output: {} 

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Type</th>
<th>Default</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>set_fields</td>
<td>list of dictionaries</td>
<td>None</td>
<td>A list of fields to set with values, eg. eth_dst: “1:2:3:4:5:6”</td>
</tr>
<tr>
<td>port</td>
<td>integer or string</td>
<td>None</td>
<td>The port to output the packet to.</td>
</tr>
<tr>
<td>ports</td>
<td>list of [ integer or string ]</td>
<td>None</td>
<td>The list of ports the packet will be output through.</td>
</tr>
<tr>
<td>pop_vlans</td>
<td>boolean</td>
<td>False</td>
<td>Pop vlan tag before output.</td>
</tr>
<tr>
<td>vlan_vid</td>
<td>integer</td>
<td>False</td>
<td>Push vlan tag before output.</td>
</tr>
<tr>
<td>swap_vid</td>
<td>integer</td>
<td>None</td>
<td>Rewrite the vlan vid of the packet when outputting</td>
</tr>
<tr>
<td>vlan_vids</td>
<td>list of [ integer or {vid: integer, eth_type: integer} ]</td>
<td>None</td>
<td>Push vlan tags on output, with optional eth_type.</td>
</tr>
<tr>
<td>failover</td>
<td>dictionary</td>
<td>None</td>
<td>Output with a failover port (see below).</td>
</tr>
</tbody>
</table>

Failover is an experimental option, but can be configured as follows:


<table>
<thead>
<tr>
<th>Attribute</th>
<th>Type</th>
<th>Default</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>group_id</td>
<td>integer</td>
<td>None</td>
<td>The OFP group id to use for the failover group</td>
</tr>
<tr>
<td>ports</td>
<td>list</td>
<td>None</td>
<td>The list of ports the packet can be output through.</td>
</tr>
</tbody>
</table>

1.4.2 Gauge configuration

Gauge is configured similarly with, gauge.yaml. The following is an example demonstrating a few common features:

Listing 46: gauge.yaml

```yaml
# Recommended configuration is Prometheus for all monitoring, with all_dps: True
faucet_configs:
  - '/etc/faucet/faucet.yaml'

watchers:
  port_status_poller:
    type: 'port_state'
    all_dps: True
    #dps: ['sw1', 'sw2']
    db: 'prometheus'
  port_stats_poller:
    type: 'port_stats'
    all_dps: True
    #dps: ['sw1', 'sw2']
    interval: 10
    db: 'prometheus'
    #db: 'influx'
  flow_table_poller:
    type: 'flow_table'
```

(continues on next page)
1.4.3 Verifying configuration

You can verify that your configuration is correct with the `check_faucet_config` script:

```
check_faucet_config /etc/faucet/faucet.yaml
```

1.4.4 Configuration examples

For complete working examples of configuration features, see the unit tests, `tests/faucet_mininet_test.py`. For example, `FaucetUntaggedACLTest` shows how to configure an ACL to block a TCP port, `FaucetTaggedIPv4RouteTest` shows how to configure static IPv4 routing.

1.4.5 Applying configuration updates

You can update FAUCET’s configuration by sending it a HUP signal. This will cause it to apply the minimum number of flow changes to the switch(es), to implement the change.

```
pkill -HUP -f faucet.faucet
```

1.4.6 Configuration in separate files

Extra DP, VLAN or ACL data can also be separated into different files and included into the main configuration file, as shown below. The `include` field is used for configuration files which are required to be loaded, and Faucet will log an error if there was a problem while loading a file. Files listed on `include-optional` will simply be skipped and a warning will be logged instead.

Files are parsed in order, and both absolute and relative (to the configuration file) paths are allowed. DPs, VLANs or ACLs defined in subsequent files overwrite previously defined ones with the same name.

```
faucet.yaml
```
Faucet Documentation

include:
- /etc/faucet/dps.yaml
- /etc/faucet/vlans.yaml

include-optional:
- acls.yaml


dps.yaml

# Recursive include is allowed, if needed.
# Again, relative paths are relative to this configuration file.
include-optional:
- override.yaml

dps:
  test-switch-1:
  ...
  test-switch-2:
  ...

1.4.7 Environment variables

You can use environment variables to override default behaviour of faucet such as paths for configuration files and port numbers.
<table>
<thead>
<tr>
<th>Environment Variable</th>
<th>Type</th>
<th>Default</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>FAUCET_CONFIG</td>
<td>Colon-separated list of file paths</td>
<td>/etc/faucet/faucet.yml; /etc/ryu/faucet/faucet.yml</td>
<td>Faucet will load its configuration from the first valid file in list</td>
</tr>
<tr>
<td>FAUCET_CONFIG_AUTO_REVERT</td>
<td>boolean</td>
<td>False</td>
<td>If true, Faucet will attempt to revert a bad config file back to the last known good version.</td>
</tr>
<tr>
<td>FAUCET_CONFIG_STAT_RELOAD</td>
<td>boolean</td>
<td>False</td>
<td>If true, faucet will automatically reload itself and apply new configuration when FAUCET_CONFIG changes</td>
</tr>
<tr>
<td>FAUCET_LOG_LEVEL</td>
<td>Python log level</td>
<td>INFO</td>
<td>Log verbosity</td>
</tr>
<tr>
<td>FAUCET_LOG</td>
<td>File path or STDOUT or STDERR</td>
<td>/var/log/faucet/faucet.log</td>
<td>Location for faucet to log messages to, can be special values STDOUT or STDERR</td>
</tr>
<tr>
<td>FAUCET_EXCEPTION_LOG</td>
<td>File path or STDOUT or STDERR</td>
<td>/var/log/faucet/faucet_exception.log</td>
<td>Location for faucet log to log exceptions to, can be special values STDOUT or STDERR</td>
</tr>
<tr>
<td>FAUCET_EVENT_SOCK</td>
<td>Socket path</td>
<td></td>
<td>Location to a UNIX socket where faucet will write events to, or empty to disable events</td>
</tr>
<tr>
<td>FAUCET_EVENT_SOCK_HEARTBEAT</td>
<td>Seconds</td>
<td>0</td>
<td>If set to a value greater than 0, it emits a dummy event every n seconds so that faucet knows if the event socket connection is broken and closes the connection on it’s side.</td>
</tr>
<tr>
<td>FAUCET_PROMETHEUS_PORT</td>
<td>Port</td>
<td>9302</td>
<td>TCP port to listen on for faucet prometheus client</td>
</tr>
<tr>
<td>FAUCET_PROMETHEUS_ADDR</td>
<td>IP address</td>
<td>0.0.0.0</td>
<td>IP address to listen on for faucet prometheus client</td>
</tr>
<tr>
<td>GAUGE_CONFIG</td>
<td>Colon-separated list of file paths</td>
<td>/etc/faucet/gauge.yml; /etc/ryu/faucet/gauge.yml</td>
<td>Gauge will load it’s configuration from the first valid file in list</td>
</tr>
<tr>
<td>GAUGE_CONFIG_STAT_RELOAD</td>
<td>boolean</td>
<td>False</td>
<td>If true, gauge will automatically reload itself and apply new configuration when GAUGE_CONFIG changes</td>
</tr>
<tr>
<td>GAUGE_LOG_LEVEL</td>
<td>Python log level</td>
<td>INFO</td>
<td>Log verbosity</td>
</tr>
<tr>
<td>GAUGE_LOG</td>
<td>File path or STDOUT or STDERR</td>
<td>/var/log/faucet/gauge.log</td>
<td>Location for gauge to log messages to, can be special values STDOUT or STDERR</td>
</tr>
<tr>
<td>GAUGE_EXCEPTION_LOG</td>
<td>File path or STDOUT or STDERR</td>
<td>/var/log/faucet/gauge_exception.log</td>
<td>Location for faucet log to log exceptions to, can be special values STDOUT or STDERR</td>
</tr>
</tbody>
</table>
1.5 Monitoring

Faucet can be monitored in a number of ways. Both the faucet and gauge services export instrumentation data via a built-in Prometheus exporter which can be consumed by Prometheus. By default the Prometheus exporter is available on port 9302, this can be changed with Environment variables (FAUCET_PROMETHEUS_PORT and FAUCET_PROMETHEUS_ADDR).

Gauge also collects conventional switch statistics (port counters, port state, etc) and can export these to a number of different databases (including Prometheus). For information on configuring gauge see the Gauge configuration section.

1.5.1 Prometheus metrics

Below is a list of the metrics exported by faucet and gauge.

Exported by faucet

---

Table 20: Faucet prometheus metrics

<table>
<thead>
<tr>
<th>Metric</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>faucet_pbr_version</td>
<td>gauge</td>
<td>Faucet PBR version</td>
</tr>
<tr>
<td>faucet_stack_root_dpid</td>
<td>gauge</td>
<td>set to current stack root DPID</td>
</tr>
<tr>
<td>faucet_config_reload_requests_total</td>
<td>counter</td>
<td>number of config reload requests</td>
</tr>
<tr>
<td>faucet_config_load_error</td>
<td>gauge</td>
<td>1 if last attempt to re/load config failed</td>
</tr>
<tr>
<td>faucet_config_hash</td>
<td>info</td>
<td>file hashes for last successful config</td>
</tr>
<tr>
<td>faucet_config_hash_func</td>
<td>gauge</td>
<td>algorithm used to compute config hashes</td>
</tr>
<tr>
<td>faucet_config_applied</td>
<td>gauge</td>
<td>fraction of DPs that we have tried to apply config to</td>
</tr>
<tr>
<td>faucet_event_id</td>
<td>gauge</td>
<td>highest/most recent event ID to be sent</td>
</tr>
<tr>
<td>faucet_config_reload_warm_total</td>
<td>counter</td>
<td>number of warm, differences only config reloads executed</td>
</tr>
<tr>
<td>faucet_config_reload_cold_total</td>
<td>counter</td>
<td>number of cold, complete reprovision config reloads executed</td>
</tr>
<tr>
<td>of_ignored_packet_ins_total</td>
<td>counter</td>
<td>number of OF packet_ins received but ignored from DP (due to rate limiting)</td>
</tr>
<tr>
<td>of_unexpected_packet_ins_total</td>
<td>counter</td>
<td>number of OF packet_ins received that are unexpected from DP (e.g. for unknown VLAN)</td>
</tr>
<tr>
<td>of_packet_ins_total</td>
<td>counter</td>
<td>number of OF packet_ins received from DP</td>
</tr>
<tr>
<td>of_non_vlan_packet_ins_total</td>
<td>counter</td>
<td>number of OF packet_ins received from DP, not associated with a FAUCET VLAN</td>
</tr>
<tr>
<td>of_vlan_packet_ins_total</td>
<td>counter</td>
<td>number of OF packet_ins received from DP, associated with a FAUCET VLAN</td>
</tr>
<tr>
<td>of_flowmsgs_sent_total</td>
<td>counter</td>
<td>number of OF flow messages (and packet outs) sent to DP</td>
</tr>
<tr>
<td>of_errors_total</td>
<td>counter</td>
<td>number of OF errors received from DP</td>
</tr>
<tr>
<td>of_dp_connections_total</td>
<td>counter</td>
<td>number of OF connections from a DP</td>
</tr>
<tr>
<td>of_dp_disconnections_total</td>
<td>counter</td>
<td>number of OF connections from a DP</td>
</tr>
<tr>
<td>vlan_hosts_learned</td>
<td>gauge</td>
<td>number of hosts learned on a VLAN</td>
</tr>
<tr>
<td>port_vlan_hosts_learned</td>
<td>gauge</td>
<td>number of hosts learned on a port and VLAN</td>
</tr>
<tr>
<td>vlan_neighbors</td>
<td>gauge</td>
<td>number of L3 neighbors on a VLAN (whether resolved to L2 addresses, or not)</td>
</tr>
<tr>
<td>vlan_learn_bans</td>
<td>gauge</td>
<td>number of times learning was banned on a VLAN</td>
</tr>
<tr>
<td>faucet_config_table_names</td>
<td>gauge</td>
<td>number to names map of FAUCET pipeline tables</td>
</tr>
</tbody>
</table>

Continued on next page
### Table 20 – continued from previous page

<table>
<thead>
<tr>
<th>Metric</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>faucet_packet_in_secs</td>
<td>histogram</td>
<td>FAUCET packet in processing time</td>
</tr>
<tr>
<td>faucet_valve_service_secs</td>
<td>histogram</td>
<td>FAUCET valve service processing time</td>
</tr>
<tr>
<td>bgp_neighbor_uptime</td>
<td>gauge</td>
<td>BGP neighbor uptime in seconds</td>
</tr>
<tr>
<td>bgp_neighbor_routes</td>
<td>gauge</td>
<td>BGP neighbor route count</td>
</tr>
<tr>
<td>learned_macs</td>
<td>gauge</td>
<td>MAC address stored as 64bit number to DP ID, port, VLAN, and n (discrete index)</td>
</tr>
<tr>
<td>port_status</td>
<td>gauge</td>
<td>status of switch ports</td>
</tr>
<tr>
<td>port_stack_state</td>
<td>gauge</td>
<td>state of stacking on a port</td>
</tr>
<tr>
<td>port_learn_bans</td>
<td>gauge</td>
<td>number of times learning was banned on a port</td>
</tr>
<tr>
<td>learned_l2_port</td>
<td>gauge</td>
<td>learned port of l2 entries</td>
</tr>
<tr>
<td>port_lacp_state</td>
<td>gauge</td>
<td>state of LACP on a port</td>
</tr>
<tr>
<td>dp_status</td>
<td>gauge</td>
<td>status of datapaths</td>
</tr>
<tr>
<td>dp_root_hop_port</td>
<td>gauge</td>
<td>port that leads to stack root DP</td>
</tr>
<tr>
<td>of_dp_desc_stats</td>
<td>gauge</td>
<td>DP description (OFPDescStatsReply)</td>
</tr>
<tr>
<td>stack_cabling_errors_total</td>
<td>counter</td>
<td>number of cabling errors detected in all FAUCET stacks</td>
</tr>
<tr>
<td>stack_probes_received_total</td>
<td>counter</td>
<td>number of stacking messages received</td>
</tr>
<tr>
<td>dp_dot1x_success_total</td>
<td>counter</td>
<td>number of successful authentications on dp</td>
</tr>
<tr>
<td>dp_dot1x_failure_total</td>
<td>counter</td>
<td>number of authentications attempts failed on dp</td>
</tr>
<tr>
<td>dp_dot1x_logoff_total</td>
<td>counter</td>
<td>number of eap-logoff events on dp</td>
</tr>
<tr>
<td>port_dot1x_success_total</td>
<td>counter</td>
<td>number of successful authentications on port</td>
</tr>
<tr>
<td>port_dot1x_failure_total</td>
<td>counter</td>
<td>number of authentications attempts failed on port</td>
</tr>
<tr>
<td>port_dot1x_logoff_total</td>
<td>counter</td>
<td>number of eap-logoff events on port</td>
</tr>
</tbody>
</table>

### Exported by gauge

### Table 21: Gauge prometheus metrics

<table>
<thead>
<tr>
<th>Metric</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>faucet_pbr_version</td>
<td>gauge</td>
<td>Faucet PBR version</td>
</tr>
<tr>
<td>dp_status</td>
<td>gauge</td>
<td>status of datapaths</td>
</tr>
<tr>
<td>of_port_tx_packets</td>
<td>gauge</td>
<td></td>
</tr>
<tr>
<td>of_port_rx_packets</td>
<td>gauge</td>
<td></td>
</tr>
<tr>
<td>of_port_tx_bytes</td>
<td>gauge</td>
<td></td>
</tr>
<tr>
<td>of_port_rx_bytes</td>
<td>gauge</td>
<td></td>
</tr>
<tr>
<td>of_port_tx_dropped</td>
<td>gauge</td>
<td></td>
</tr>
<tr>
<td>of_port_rx_dropped</td>
<td>gauge</td>
<td></td>
</tr>
<tr>
<td>of_port_tx_errors</td>
<td>gauge</td>
<td></td>
</tr>
<tr>
<td>of_port_rx_errors</td>
<td>gauge</td>
<td></td>
</tr>
<tr>
<td>of_port_reason</td>
<td>gauge</td>
<td></td>
</tr>
<tr>
<td>of_port_state</td>
<td>gauge</td>
<td></td>
</tr>
<tr>
<td>of_portCurr_speed</td>
<td>gauge</td>
<td></td>
</tr>
<tr>
<td>of_port_max_speed</td>
<td>gauge</td>
<td></td>
</tr>
<tr>
<td>of_meter_flow_count</td>
<td>gauge</td>
<td></td>
</tr>
<tr>
<td>of_meter_byte_in_count</td>
<td>gauge</td>
<td></td>
</tr>
<tr>
<td>of_meter_packet_in_count</td>
<td>gauge</td>
<td></td>
</tr>
<tr>
<td>of_meter_byte_band_count</td>
<td>gauge</td>
<td></td>
</tr>
<tr>
<td>of_meter_packet_band_count</td>
<td>gauge</td>
<td></td>
</tr>
</tbody>
</table>
1.6 Configuration Recipe Book

In this section we will cover some common network configurations and how you would configure these with the Faucet YAML configuration format.

1.6.1 Forwarding

1.6.2 Routing

1.6.3 Policy

1.7 Vendor-specific Documentation

1.7.1 Faucet on Allied Telesis products

Introduction

Allied Telesis has a wide portfolio of OpenFlow enabled switches that all support the Faucet pipeline. These OpenFlow enabled switches come in various port configurations of 10/18/28/52/96 with POE+ models as well. Here is a list of some of our most popular switches:

- AT-x930
- SBx908Gen2
- AT-x950
- AT-x510
- AT-x230

Setup

Switch

OpenFlow supported Firmware

OpenFlow has been supported since AlliedWarePlus version 5.4.6 onwards. To inquire more about compatibility of versions, you can contact our customer support team.

OpenFlow configuration

For a Pure OpenFlow deployment, we recommend the following configurations on the switch. Most of these configuration steps will be shown with an example.

/* Create an OpenFlow native VLAN */
awplus (config)# vlan database
awplus (config-vlan)# vlan 4090

/* Set an IP address for Control Plane (CP) */
* Here we will use vlan1 for Management/Control Plane */
awplus (config)# interface vlan1
awplus (config-if)# ip address 192.168.1.1/24

(continues on next page)
/* Configure the FAUCET controller */
awplus (config)# openflow controller tcp 192.168.1.10 6653

/* (OPTIONAL) Configure GAUGE controller */
awplus (config)# openflow controller tcp 192.168.1.10 6654

/* NOTE - Starting from AlliedWarePlus version 5.4.8-2, we have added support for controller name. */
* You can specify a controller name with the optional <name> parameter.
* Users can still use the previous controller commands (without the name parameter) and the switch will auto-generate
  a suitable name (starting with "oc") in that case.
* Here is an example to add a controller with name 'faucet' using TCP port 6653 */
awplus (config)# openflow controller faucet tcp 192.168.1.10 6653

/* User must set a dedicated native VLAN for OpenFlow ports */
awplus (config)# openflow native vlan 4090

/* Enable OpenFlow on desired ports */
awplus (config)# interface port1.0.1-1.0.46
awplus (config-if)# openflow

/* Disable Spanning Tree Globally */
awplus (config)# no spanning-tree rstp enable

/* Disable Loop protection detection Globally */
awplus (config)# no loop-protection loop-detect

/* OpenFlow requires that ports under its control do not send any control traffic */
* So it is better to disable RSTP and IGMP Snooping TCN Query Solicitation.
* Disable IGMP Snooping TCN Query Solicitation on the OpenFlow native VLAN */
awplus (config)# interface vlan4090
awplus (config-if)# no ip igmp snooping tcn query solicit

Once OpenFlow is up and running and connected to Faucet/Gauge controller, you should be able to verify the operation using some of our show commands.

/* To check contents of the DP flows */
awplus# show openflow flows

/* To check the actual rules as pushed by the controller */
awplus# show openflow rules

/* To check the OpenFlow configuration and other parameters */
awplus# show openflow status
awplus# show openflow config
awplus# show openflow coverage

Some other OPTIONAL configuration commands, that may be useful to modify some parameters, if needed.

/* Set the OpenFlow version other than default version (v1.3) */
Faucet Documentation

awplus (config)# openflow version 1.0

/* Set IPv6 hardware filter size
   * User needs to configure the following command if a packet needs to be forwarded by IPv6 address matching */
awplus (config)# platform hwfilter-size ipv4-full-ipv6

/* Set the datapath ID(DPID)
   * By default, we use the switch MAC address for datapath-ID.
   * To change the DPID to a hex value 0x1, use the following */
awplus (config)# openflow datapath-id 1

/* NOTE - For all software versions prior to 5.4.7, all data VLAN(s) must be included in the vlan database config
   * on the switch before they can be used by OpenFlow.
   * Here is an example to create DP VLANs 2-100 */
awplus (config)# vlan database
awplus (config-vlan)# vlan 2-100

/* NOTE - Starting from software version 5.4.8-2, in order to negate a controller, you need to specify the controller name.
   * In case you add the controller the legacy way (without the name), the newer software will auto-generate a name which can be used to delete the controller.
   * Here is an example to delete a controller with auto-generated name ocl */
awplus (config)# no openflow controller ocl

Useful Switch related configurations

Note: If the Openflow controller is located in a different VLAN or Network segment, routing needs to be configured so that the switch can talk to the controller.

/* To set Timezone: Codes - https://www.timeanddate.com/time/zones/ */
/* For US Pacific Time zone */
awplus (config)# clock timezone NAPST minus 8

/* To set DNS, say a local Gateway also acting as a DNS forwarder 10.20.0.1 */
awplus (config)# ip name-server 10.20.0.1

/* To make sure that DNS and routing correctly work, Gateway address needs to be set.
   * Here, Gateway is set only to the management VLAN, vlan1; 255 is the max depth allowed */
awplus (config)# ip route 0.0.0.0/0 vlan1 255
awplus (config)# ip route 0.0.0.0/0 10.20.0.1

/* To see the configured Route database */
awplus# show ip route database

/* To test routing, ping Google.com - note the name to ip resolution */
awplus# ping google.com

Setting up PKI Certs for secure connectivity between Switch and Openflow Controller

Note: There are many ways to get the keys and certificates into the box. Here, both private key (unencrypted PEM formatted) and corresponding Certificate (PEM) as trusted by the Openflow Controller is provided to the Switch Admin
Getting keys into the Switch flash partition

```bash
/* Here SCP is used to copy. TFTP, USB, etc are other supported methods */
awplus# copy scp://user@10.20.5.5/home/user/switch-cert.pem switch-cert.pem
awplus# copy scp://user@10.20.5.5/home/user/switch-key_nopass.pem switch-key_nopass.pem

/* Showing only relevant files */
awplus# dir
    1679 -rw- Dec 20 2017 09:04:35  switch-key_nopass.pem
    11993 -rw- Dec 20 2017 09:04:03  switch-cert.pem
```

Setting up Trustpoint for SSL connectivity to Openflow Controller

```bash
/* Create a local trustpoint */
awplus (config)# crypto pki trustpoint local

/* Point the switch to the OF controller */
awplus (config)# openflow controller ssl 192.168.1.10 6653

/* Allow OpenFlow to use local trustpoint */
awplus (config)# openflow ssl trustpoint local

/* Copy the new key and pvt keys to local trustpoint directory */
awplus# copy switch-key_nopass.pem .certs/pki/local/cakey.pem
Overwrite flash:/.certs/pki/local/cakey.pem (y/n)[n]:y
Copying...
Successful operation

awplus# copy switch-cert.pem .certs/pki/local/cacert.pem
Overwrite flash:/.certs/pki/local/cacert.pem (y/n)[n]:y
Copying...
Successful operation
```

Enabling SNMP for monitoring Management/Control Plane Port

Openflow enabled ports are monitored via Openflow Stats request/response protocol. This means that Management port (and if Openflow control channel port is separate), are not monitored on the switch. Hence, SNMP is used to monitor the same. SNMP v2 is the most widely used. As an example below, let us assume NMS is @ 10.20.30.71

```bash
/* Check contents of existing access-list */
awplus# show access-list

/* Enable the SNMP agent and enable the generation of authenticate failure traps to monitor unauthorized SNMP access. */
awplus (config)# snmp-server enable trap auth

/* Creating a write access community called sfractalonprem1rw for use by the central network management station at 10.20.30.71 */
awplus (config)# access-list 96 permit 10.20.30.71
awplus (config)# snmp-server community sfractalonprem1rw rw view atview 96

/* Enable link traps on VLANs or specific interfaces (in our case management port) */
```
Faucet Documentation

awplus (config)# interface port1.0.1
awplus (config-if)# snmp trap link-status

/* Configuring Trap Hosts */
awplus (config)# snmp-server host 10.20.30.71 version 2c sfractalonpremlrw

/* Confirm all SNMP settings */
awplus# show snmp-server
SNMP Server ......................... Enabled
IP Protocol ......................... IPv4, IPv6
SNMP Startup Trap Delay .......... 30 Seconds
SNMPv3 Engine ID (configured name) ... Not set
SNMPv3 Engine ID (actual) .......... 0x80001f8880a2977c410e3bb658

awplus# show snmp-server community
SNMP community information:
Community Name ............. sfractalonpremlrw
Access ...................... Read-write
View ....................... atview

awplus# show run snmp
snmp-server
snmp-server enable trap auth
snmp-server community sfractalonpremlrw rw view atview 96
snmp-server host 10.20.30.71 version 2c sfractalonpremlrw

/* Check if the interface is configured for SNMP */
awplus# show interface port1.0.1
Interface port1.0.1
Scope: both
Link is UP, administrative state is UP
Thrash-limiting
Status Not Detected, Action learn-disable, Timeout 1(s)
Hardware is Ethernet, address is 001a.eb96.6ef2
index 5001 metric 1 mru 1500
current duplex full, current speed 1000, current polarity mdi
collapsed duplex auto, configured speed auto, configured polarity auto
<UP,BROADCAST,RUNNING,MULTICAST>
SNMP link-status traps: Sending (suppressed after 20 traps in 60 sec)
  Link-status trap delay: 0 sec
  input packets 14327037, bytes 3727488153, dropped 0, multicast packets 440768
  output packets 11172202, bytes 2028940085, multicast packets 233192 broadcast,
  packets 1889
  Time since last state change: 40 days 00:48:38

awplus# show access-list
Standard IP access list 96
  10 permit 10.20.30.71

---

Enabling sFlow for monitoring Management/Control Port

Openflow enabled ports are monitored via Openflow Stats request/response protocol. This means that Management port (and if Openflow control channel port is separate), are not monitored on the switch. Hence, sFlow is used to monitor the same. At this time, no TLS/SSL support is seen on the sFlow Controller channel.
/* Check for any existing sFlow configuration */
awplus# show running-config sflow

/* Enable sFlow globally */
awplus (config)# sflow enable
% INFO: sFlow will not function until collector address is non-zero
% INFO: sFlow will not function until agent address is set
awplus# show running-config sflow

sflow enable

/* Confirm the new sFlow settings */
awplus# show sflow

sFlow Agent Configuration: Default Values
sFlow Admin Status ........ Enabled [Disabled]
sFlow Agent Address ........ [not set] [not set]
Collector Address .......... 0.0.0.0 [0.0.0.0]
Collector UDP Port ........ 6343 [6343]
Tx Max Datagram Size ...... 1400 [1400]

sFlow Agent Status:
Polling/sampling/Tx ........ Inactive because:
  - Agent Addr is not set
  - Collector Addr is 0.0.0.0
  - Polling & sampling disabled on all ports

/* Agent IP MUST be the IP address of the management port of this switch */
awplus (config)# sflow agent ip 192.0.2.23

/* Default sFlow UDP collector port is 6343 */
awplus (config)# sflow collector ip 192.0.2.25 port 6343
awplus (config)# interface port1.0.1
awplus (config-if)# sflow polling-interval 120
awplus (config-if)# sflow sampling-rate 512

awplus# show running-config sflow

sflow agent ip 192.0.2.23
sflow collector ip 192.0.2.25
sflow enable

! interface port1.0.1
  sflow polling-interval 120
  sflow sampling-rate 512

! awplus#
Faucet Documentation

Faucet

Edit the faucet configuration file (/etc/faucet/faucet.yaml) to add the datapath of the switch you wish to be managed by faucet. This yaml file also contains the interfaces that need to be seen by Faucet as openflow ports. The device type (hardware) should be set to Allied-Telesis in the configuration file.

```yaml
:dps: 
  allied-telesis: 
    dp_id: 0x0000eccd6d123456 
    hardware: "Allied-Telesis" 
    interfaces: 
      1: 
        native_vlan: 100 
        name: "port1.0.1" 
      2: 
        name: "port1.0.2" 
        description: "windscale"
```

References

- Allied Telesis x930
- OpenFlow Configuration Guide
- Chapter 61 (SNMP)
- SNMP Feature Guide

1.7.2 Faucet on HPE-Aruba Switches

Introduction

All the Aruba’s v3 generation of wired switches support the FAUCET pipeline. These switches include:

- 5400R
- 3810
- 2930F

The FAUCET pipeline is only supported from 16.03 release of the firmware onwards. HPE Aruba recommends use of the latest available firmware, which can be downloaded from HPE Support.

For any queries, please post your question on HPE’s SDN forum.
**Caveats**

- IPv6 management of the switch, together OpenFlow is not supported.
- The `OFPAT_DEC_NW_TTL` action is not supported (when FAUCET is configured as a router, IP TTL will not be decremented).

**Setup**

In all configuration examples following, substitute 10.0.0.1 for your controller IP address, and 10.0.0.2 for your switch IP address, as appropriate. VLAN 2048 is used for the control plane - you can substitute this for another VID. In any case, the control plane VLAN VID you reserve cannot be used in FAUCET’s configuration file (ie. it cannot be controlled by OpenFlow).

**Switch**

**Chassis configuration (5400R only)**

Skip this step if you have a fixed configuration system (2930 or 3810).

On a chassis system with insertable cards, new cards are configured to work in a backwards-compatible way (with reduced functionality) unless older cards are disabled in the chassis. To disable older (V2) cards and enable all functionality necessary to operate FAUCET, put the chassis into a mode where only V3 cards are allowed.

```
// Disable backwards compatibility, enable full Openflow flexibility
switch (config)# no allow-v2-modules
```

**VLAN/port configuration**

Aruba switches require the reservation of each VLAN VID you wish to use in FAUCET, on the switch. Some Aruba switches will allow you to reserve a large range of VIDs at once. If your switch has limited resources, then reserve just the VIDs you need.

The reservation of a VID is accomplished by defining a tagged VLAN. Note even you are using that VLAN VID untagged on a port in FAUCET, it must be reserved as tagged on the switch.

- **Using OOBM control-plane (3810, 5400R)**

```
// Increase the maximum number of allowed VLANs on the box and save the configuration.
// If the switch cannot reserve the full range, reserve only the maximum you need.
switch (config)# max-vlans 4094
switch (config)# write mem

// Reboot the box for the new max-vlan configuration to take affect.
switch (config)# boot system

// Configure the control-plane IP address
switch (config)# oobm ip address 10.0.0.2/24

// Create maximum number of VLANs and tag every dataplane port available to each vlan. Takes up to 30 minutes.
// If the switch cannot reserve the full range, reserve only the VLANs needed individually.
switch (config)# vlan 2-4094 tagged all
```

- **Using VLAN control-plane (2930)**
// Increase the maximum number of allowed VLANs on the box and save the configuration.  
// If the switch cannot reserve the full range, reserve only the maximum you need.  
switch (config)# max-vlans 2048  
switch (config)# write mem  

// Reboot the box for the new max-vlan configuration to take affect.  
switch (config)# boot system  

// Create a control-plane vlan and add a single control-plane port (port 48)  
switch (config)# vlan 2048 untagged 48  
switch (config)# vlan 2048 ip address 10.0.0.2/24  

// Create maximum number of VLANs and tag every dataplane port available to each vlan,  
// except for the control-plane vlan (above). Note that the command below assumes it  
// is run on a 52-port switch, with port 48 as the control-plane. Takes up to 20 minutes.  
// If the switch cannot reserve the full range, reserve only the VLANs needed individually.  
switch (config)# vlan 2-2047 tagged 1-47,49-52

OpenFlow configuration

Aruba switches reference a controller by ID, so first configure the controllers which will be used. The controller-interface matches the control-plane configuration above.

- **Using OOBM control-plane (3810, 5400R)**

   // Enter OpenFlow context  
   switch (config)# openflow  

   // Configure an OpenFlow controller connection for FAUCET over tcp-port 6653  
   switch(openflow)# controller-id 1 ip 10.0.0.1 port 6653 controller-interface oobm  

   // Configure an OpenFlow controller connection for Gauge over tcp-port 6654  
   switch(openflow)# controller-id 2 ip 10.0.0.1 port 6654 controller-interface oobm

- **Using VLAN control-plane (2930)**

   // Enter OpenFlow context  
   switch (config)# openflow  

   // Configure an OpenFlow controller connection for FAUCET over tcp-port 6653  
   switch(openflow)# controller-id 1 ip 10.0.0.1 port 6653 controller-interface vlan 2048  

   // Configure an OpenFlow controller connection for Gauge over tcp-port 6654  
   switch(openflow)# controller-id 2 ip 10.0.0.1 port 6654 controller-interface vlan 2048  

   // Enter the OpenFlow instance context  
   switch(openflow)# instance aggregate  

   // Associate the controllers to the instance  
   switch(of-inst-aggregate)# controller-id 1  
   switch(of-inst-aggregate)# controller-id 2  

   // Associate the controllers in secure mode to the instance  
   switch(of-inst-aggregate)# controller-id 1 secure  
   switch(of-inst-aggregate)# controller-id 2 secure

(continues on next page)
// Configure the OpenFlow version to be 1.3
switch(of-inst-aggregate)# version 1.3 only

// Configure the pipeline model type of the instance. It is a must to set it to custom.
switch(of-inst-aggregate)# pipeline-model custom

// Configure the payload in the packet-ins message to be sent in its original form.
switch(of-inst-aggregate)# packet-in vlan-tagging input-form

// Ensure the switch re-attempts an OpenFlow connection at least once every 10 seconds when connection is dropped/inactive.
switch(of-inst-aggregate)# max-backoff-interval 10

// Allow OpenFlow to override some protocols which are otherwise excluded from OpenFlow processing in switch CPU.
switch(of-inst-aggregate)# override-protocol all
WARNING: Overriding the protocol can also potentially lead to control packets of the protocol to bypass any of the security policies like ACL(s).
Continue (y/n)? y

// Enable the instance
switch(of-inst-aggregate)# enable
switch(of-inst-aggregate)# exit

// Enable OpenFlow globally
switch(openflow)# enable
switch(openflow)# exit

// To save the Configuration
switch# save
switch# write mem

// Show running Configuration
switch# show running-config

// Check the OpenFlow instance configuration (includes Datapath ID associated)
switch# show openflow instance aggregate
...

// Easier way to get the Datapath ID associated with the OpenFlow instance
switch# show openflow instance aggregate | include Datapath ID
Datapath ID : 00013863bbc41800

At this point, OpenFlow is enabled and running on the switch. If the FAUCET controller is running and has connected to the switch successfully, you should see the FAUCET pipeline programmed on the switch.

NOTE: following is an example only, and may look different depending on FAUCET version and which FAUCET features have been enabled.

switch# show openflow instance aggregate flow-table

OpenFlow Instance Flow Table Information

<table>
<thead>
<tr>
<th>Table ID</th>
<th>Table Name</th>
<th>Flow Count</th>
<th>Miss Count</th>
<th>Goto Table</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(continues on next page)
0 Port ACL 5 0 1, 2, 3, 4...
1 VLAN 10 0 2, 3, 4, 5...
2 VLAN ACL 1 0 3, 4, 5, 6...
3 Ethernet Source 2 0 4, 5, 6, 7, 8
4 IPv4 FIB 1 0 5, 6, 7, 8
5 IPv6 FIB 1 0 6, 7, 8
6 VIP 1 0 7, 8
7 Ethernet Destination 2 0 8
8 Flood 21 0 *

Table
<table>
<thead>
<tr>
<th>ID</th>
<th>Table Name</th>
<th>Available Free Flow Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Port ACL Ports</td>
<td>1-52: 46</td>
</tr>
<tr>
<td>1</td>
<td>VLAN Ports</td>
<td>1-52: 91</td>
</tr>
<tr>
<td>2</td>
<td>VLAN ACL Ports</td>
<td>1-52: 50</td>
</tr>
<tr>
<td>3</td>
<td>Ethernet Source</td>
<td>1-52: 99</td>
</tr>
<tr>
<td>4</td>
<td>IPv4 FIB Ports</td>
<td>1-52: 100</td>
</tr>
<tr>
<td>5</td>
<td>IPv6 FIB Ports</td>
<td>1-52: 100</td>
</tr>
<tr>
<td>6</td>
<td>VIP Ports</td>
<td>1-52: 20</td>
</tr>
<tr>
<td>7</td>
<td>Ethernet Destination</td>
<td>1-52: 99</td>
</tr>
<tr>
<td>8</td>
<td>Flood Ports</td>
<td>1-52: 280</td>
</tr>
</tbody>
</table>

* Denotes that the pipeline could end here.

switch# show openflow instance aggregate
Configured OF Version : 1.3 only
Negotiated OF Version : 1.3
Instance Name : aggregate
Data-path Description : aggregate
Administrator Status : Enabled
Member List : VLAN 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, ...

// To just get openflow controllers
switch (openflow)# show openflow controllers

Controller Information

<table>
<thead>
<tr>
<th>Controller Id</th>
<th>IP Address</th>
<th>Hostname</th>
<th>Port</th>
<th>Interface</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.0.0.0</td>
<td>controller-1.t...</td>
<td>6653</td>
<td>VLAN 2048</td>
</tr>
<tr>
<td>2</td>
<td>0.0.0.0</td>
<td>controller-1.t...</td>
<td>6654</td>
<td>VLAN 2048</td>
</tr>
</tbody>
</table>

// Copy Running Config to a TFTP Server
// (first enable TFTP client)
switch (config)# tftp client
Faucet

On the FAUCET configuration file (/etc/faucet/faucet.yaml), add the datapath of the switch you wish to be managed by FAUCET. The device type (hardware) MUST be set to Aruba in the configuration file.

Listing 47: /etc/faucet/faucet.yaml

```
dps:
  aruba-3810:
    dp_id: <DP ID from *show openflow instance aggregate | include Datapath ID>
    hardware: "Aruba"
    interfaces:
      1:
        native_vlan: 100
      2:
        native_vlan: 100
```

Debug

If you encounter a failure or unexpected behavior, it may help to enable debug output on Aruba switches. Debug output displays information about what OpenFlow is doing on the switch at message-level granularity.

```
switch# debug openflow
switch# debug destination session
switch# show debug

Debug Logging

Source IP Selection: Outgoing Interface
Origin identifier: Outgoing Interface IP
Destination:
  Session

Enabled debug types:
  openflow
  openflow packets
  openflow events
  openflow errors
  openflow packets tx
  openflow packets rx
  openflow packets tx pkt_in
  openflow packets rx pkt_out
  openflow packets rx flow_mod
```
PKI setup on switch (OPTIONAL)

Only complete this section if you wish to secure the OpenFlow connection between switch and FAUCET with certificates.

**Note:** The root certificate container supports only one root certificate not a chain. So, install the one that the CSR (Certificate Signing Request) is signed with.

// Configure DNS. Here DNS is set to a local LAN DNS server
switch (config)# ip dns server-address priority 1 10.0.0.1

switch# show crypto pki application

Certificate Extension Validation :

<table>
<thead>
<tr>
<th>Application</th>
<th>SAN/CN</th>
</tr>
</thead>
<tbody>
<tr>
<td>openflow</td>
<td>Disabled</td>
</tr>
<tr>
<td>syslog</td>
<td>Disabled</td>
</tr>
</tbody>
</table>

// Here, we create CA profile
switch (config)# crypto pki ta-profile EXAMPLE_CA

// Copy the root certificate for the EXAMPLE_CA from a tftp server
switch# copy tftp ta-certificate EXAMPLE_CA 10.0.0.1 myswitch.cert.pem

switch# show crypto pki ta-profile EXAMPLE_CA

<table>
<thead>
<tr>
<th>Profile Name</th>
<th>Profile Status</th>
<th>CRL Configured</th>
<th>OCSP Configured</th>
</tr>
</thead>
<tbody>
<tr>
<td>EXAMPLE_CA</td>
<td>1 certificate installed</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

Trust Anchor:
Version: 3 (0x2)
Serial Number: 4096 (0x1000)
Signature Algorithm: sha256withRSAEncryption
...
......

// Now we are ready to create a CSR so that a switch identity certificate that is accepted by the controller can be set up.

switch (config)# crypto pki identity-profile hpe_sf_switch1 subject common-name myswitch org MyOrgName org-unit MyOrgUnit locality MyCity state CA country US

switch (config)# show crypto pki identity-profile

Switch Identity:
  ID Profile Name : hpe_sf_switch1
  Common Name (CN) : myswitch
  Org Unit (OU) : MyOrgUnit
  Org Name (O) : MyOrgName
  Locality (L) : MyCity
  State (ST) : CA
  Country (C) : US

// Generate CSR
switch (config)# crypto pki create-csr certificate-name hpeswt_switch1_crt ta-profile EXAMPLE_CA usage openflow

(continues on next page)
// Copy the printed CSR request and send it to "EXAMPLE_CA"

switch (config)# show crypto pki local-certificate summary
Name                             Usage   Expiration    Parent / Profile
-----------------------------------------------------------------------------------
hpeswt_switch1_crt               Openflow   CSR           EXAMPLE_CA

// Once the signed certificate is received, copy the same to switch.

switch (config)# copy tftp local-certificate 10.0.0.1 myswitch.cert.pem
000M Transfer is successful

switch (config)# show crypto pki local-certificate summary
Name                             Usage   Expiration    Parent / Profile
-----------------------------------------------------------------------------------
hpeswt_switch1_crt               Openflow 2019/01/02 EXAMPLE_CA

References

- Aruba OpenFlow Administrator Guide (16.03)
- Aruba OS version as of Dec 2017 is 16.05
- Aruba Switches
- FAUCET
- Model 2390F Product Site
- 2930F top level documentation
- Password settings
- PKI Setup

1.7.3 Faucet on Lagopus

Introduction

Lagopus is a software OpenFlow 1.3 switch, that also supports DPDK.
FAUCET is supported as of Lagopus 0.2.11 (https://github.com/lagopus/lagopus/issues/107).

Setup

Lagopus install on a supported Linux distribution

Install Lagopus according to the quickstart guide. You don’t need to install Ryu since we will be using FAUCET and FAUCET’s installation takes care of that dependency.

These instructions are for Ubuntu 16.0.4 (without DPDK). In theory any distribution, with or without DPDK, that Lagopus supports will work with FAUCET.
Create lagopus.dsl configuration file

In this example, Lagopus is controlling two ports, enp1s0f0 and enp1s0f1, which will be known as OpenFlow ports 1 and 2 on DPID 0x1. FAUCET and Lagopus are running on the same host (though of course, they don’t need to be).

Listing 48: /usr/local/etc/lagopus/lagopus.dsl

```
channel channel01 create -dst-addr 127.0.0.1 -protocol tcp
controller controller01 create -channel channel01 -role equal -connection-type main
interface interface01 create -type ethernet-rawsock -device enp1s0f0
interface interface02 create -type ethernet-rawsock -device enp1s0f1
port port01 create -interface interface01
port port02 create -interface interface02
bridge bridge01 create -controller controller01 -port port01 1 -port port02 2 -dpid 0x1
bridge bridge01 enable
```

Create faucet.yaml

Listing 49: /etc/faucet/faucet.yaml

```
vlans:
  100:
    name: "test"
dps:
  lagopus-1:
    dp_id: 0x1
    hardware: "Lagopus"
    interfaces:
      1:
        native_vlan: 100
      2:
        native_vlan: 100
```
Start Lagopus

Start in debug mode, in a dedicated terminal.

```
lagopus -d
```

Run FAUCET

```
faucet --verbose --ryu-ofp-listen-host=127.0.0.1
```

Test connectivity

Host(s) on enp1s0f0 and enp1s0f1 in the same IP subnet, should now be able to communicate, and FAUCET’s log file should indicate learning is occurring:

```
Listing 50: /var/log/faucet/faucet.log
```

```
May 11 13:04:57 faucet.valve INFO DPID 1 (0x1) Configuring DP
May 11 13:04:57 faucet.valve INFO DPID 1 (0x1) Delete VLAN vid:100 ports:1,2
May 11 13:04:57 faucet.valve INFO DPID 1 (0x1) VLANs changed/added: [100]
May 11 13:04:57 faucet.valve INFO DPID 1 (0x1) Configuring VLAN vid:100 ports:1,→
→2
May 11 13:04:57 faucet.valve INFO DPID 1 (0x1) Port 1 added
May 11 13:04:57 faucet.valve INFO DPID 1 (0x1) Sending config for port 1
May 11 13:04:57 faucet.valve INFO DPID 1 (0x1) Port 2 added
May 11 13:04:57 faucet.valve INFO DPID 1 (0x1) Sending config for port 2
May 11 13:04:57 faucet.valve INFO DPID 1 (0x1) Packet_in src:00:16:41:6d:87:28
→in_port:1 vid:100
May 11 13:04:57 faucet.valve INFO learned 1 hosts on vlan 100
May 11 13:04:57 faucet.valve INFO DPID 1 (0x1) Packet_in src:00:16:41:32:87:e0
→in_port:2 vid:100
May 11 13:04:57 faucet.valve INFO learned 2 hosts on vlan 100
```
1.7.4 Faucet on ZodiacFX

Introduction

ZodiacFX is a small 4 port multi table OF1.3 switch from Northbound Networks.

Caveats

- ZodiacFX allows only one controller (so you cannot run Gauge).
- The default OF port is 6633; it is recommended to use 6653.
- It is recommended to enable ether type filtering to minimize corrupt packets.

Applying recommended config

You can use the following expect script to program the recommended configuration:

```bash
Listing 51: conf-zodiac.sh

#!/usr/bin/expect
#
## configure ZodiacFX with recommended settings.
#
# Serial port assigned to ZodiacFX
set port /dev/ttyACM0

# ZodiacFX network settings
set configip "10.0.1.99"
set confignetmask "255.255.255.0"
set configgateway "10.0.1.1"

# OpenFlow controller network settings
set configofcontroller "10.0.1.8"
set configofport 6653

set timeout 5
set prompt {Zodiac_FX
#
}
set configprompt {Zodiac_FX\(config\)\#
}
set spawned [spawn -open [open $port w+]]

send_user "get initial prompt\n"
send "\r"
send "\r"
expect -re $prompt
send_user "found initial prompt\n"
send "config\r"
expect -re $configprompt
send_user "setting ethertype-filter\n"
send "set ethertype-filter enable\r"
expect -re $configprompt
send_user "setting IP address\n"
send "set ip-address $configip\r"
expect -re $configprompt
```

(continues on next page)
send "set netmask $confignetmask\r"
expect -re $configprompt
send "set gateway $configgateway\r"
expect -re $configprompt
send_user "setting OF controller\n"
set of-controller $configofcontroller\r
expect -re $configprompt
send "set of-port $configofport\r"
expect -re $configprompt
send_user "save configuration\n"
send "show config\r"
expect -re $configprompt
send "save\r"
expect -re $configprompt
send "exit\r"
expect -re $prompt
send "restart\r"
expect -re "Restarting"

Example of running the script:

$ sudo ./conf-zodiac.sh
spawn [open ...]
get initial prompt

Zodiac_FX#
Zodiac_FX# found initial prompt
config
Zodiac_FX(config)# setting ethertype-filter
set ethertype-filter enable
EtherType Filtering Enabled
Zodiac_FX(config)# setting of-port set of-port 6653
OpenFlow Port set to 6653
Zodiac_FX(config)# save
Writing Configuration to EEPROM (197 bytes)
Zodiac_FX(config)# exit
Zodiac_FX# restart
Restarting the Zodiac FX, please reopen your terminal application.
1.7.5 Faucet on ZodiacGX

Introduction

ZodiacGX is a small 5 port multi table OF1.3 switch from Northbound Networks. Please see the documentation for configuring OpenFlow on the switch, and use ZodiacGX as the FAUCET hardware type.

Caveats

- The default OF port is 6633; it is recommended to use 6653.
- Minimum firmware required is v1.01

1.7.6 Faucet on NoviFlow

Introduction

NoviFlow provide a range of switches known to work with FAUCET.

These instructions have been tested on NS1248, NS1132, NS2116, NS2128, NS2122, NS2150, NS21100 switches, using NoviWare versions starting from NW400.5.4, running with FAUCET v1.8.14.

Compared to older versions of NoviWare and Faucet, where manual pipeline configuration was required, it is possible to use the GenericTFM Hardware type to make Faucet automatically program the tables based on the needs of its current configuration.

Setup

Configure the CPN on the switch

The only configuration required in the switch is the definition of the IP and ports on which the Faucet controller must be reached. Optionally it is also possible to change the switch DPID. In this example, the server running FAUCET is 10.0.1.8; configuration for CPN interfaces is not shown.

```
set config controller controllergroup faucet controllerid 1 priority 1 ipaddr 10.0.1.8 port 6653 security none
set config controller controllergroup gauge controllerid 1 priority 1 ipaddr 10.0.1.8 port 6654 security none
set config switch dpid 0x1
```

Create faucet.yaml

In order to exploit the automatic pipeline configuration, the hardware specified in faucet.yaml must be GenericTFM

```
vlangs:
  100:
    name: "test"
dps:
  noviflow-1:
    dp_id: 0x1
    hardware: "GenericTFM"
```
interfaces:
1:
    native_vlan: 100
2:
    native_vlan: 100
etc...

Run FAUCET

```bash
ciau --verbose
```

Using Older Faucet and NoviWare versions

Before the introduction of GenericTFM, Faucet used a static pipeline which needed to be configured in the switch before connecting to the controller. The following match configuration is known to pass the unit tests using NW400.4.3 with FAUCET 1.6.18, but take care to adjust ACL tables matches based on the type of ACL rules defined in the configuration file. Different FAUCET releases may also use different match fields in the other tables.

```ini
set config pipeline tablesizes 1524 1024 1024 5000 3000 1024 1024 5000 3000
→tablewidths 80 40 40 80 40 40 40 40 40
set config table tableid 0 matchfields 0 3 4 5 6 10 11 12 13 14 23 29 31
set config table tableid 1 matchfields 0 3 4 5 6
set config table tableid 2 matchfields 0 5 6 10 11 12 14
set config table tableid 3 matchfields 0 3 4 5 6 10
set config table tableid 4 matchfields 5 6 12
set config table tableid 5 matchfields 5 6 27
set config table tableid 6 matchfields 3 5 10 23 29
set config table tableid 7 matchfields 3 6
set config table tableid 8 matchfields 0 3 6
```

Note that this table configuration will allow most of the automated test cases to pass, except FaucetIPv6TupleTest (which requires IPv6 Src and Dst matching in the ACL table). In order to run this test, table 0 must be configured as follows:

```ini
set config table tableid 0 matchfields 0 5 6 10 26 27 13 14
```

1.7.7 Faucet on Cisco Switches

Introduction

Cisco supports Openflow with faucet pipeline on the Catalyst 9000 Series switches.

Cisco IOS XE first introduced faucet support in version 16.9.1, however since faucet support is being continually improved on Cisco platforms we recommend running the latest stable release. Currently we would recommend running 16.12.1c or later.

For official Cisco documentation on OpenFlow and faucet support see the following configuration guide:

- Programmability Configuration Guide, Cisco IOS XE Gibraltar 16.12.x
Setup

Boot up in Openflow Mode

The Catalyst 9K will be in traditional switching mode by default. The below command will enable Openflow mode on the switch.

```
Switch-C9300# configure terminal
Switch-C9300(config)#boot mode 
openflow openflow forwarding mode

Switch-C9300(config)#boot mode openflow
Changes to the boot mode preferences have been stored, but it cannot take effect until the next reload. Use "show boot mode" to check the boot mode currently active.
Switch-C9300(config)#end

Switch-C9300#show boot mode
System initialized in normal switching mode
System configured to boot in openflow forwarding mode

Reload required to boot switch in configured boot mode.
Switch-C9300#reload
```

Configure Openflow

** Configure the Management interface communicate with controller. **

```
Switch-C9300# configure terminal
Switch-C9300#configure terminal
Switch-C9300(config)#interface GigabitEthernet0/0
Switch-C9300(config-if)#vrf forwarding Mgmt-vrf
Switch-C9300(config-if)#ip address 192.168.0.41 255.255.255.0
Switch-C9300(config-if)#negotiation auto
Switch-C9300(config-if)#end

Switch-C9300#
```

** Configure the Openflow feature and controller connectivity. **

```
Switch-C9300# configure terminal
Switch-C9300(config)#feature openflow
Switch-C9300(config)#openflow
Switch-C9300(config-openflow)#switch 1 pipeline 1
Switch-C9300(config-openflow-switch)#controller ipv4 192.168.0.91 port 6653 vrf Mgmt-vrf security none
Switch-C9300(config-openflow-switch)#controller ipv4 192.168.0.91 port 6654 vrf Mgmt-vrf security none
Switch-C9300(config-openflow-switch)#datapath-id 0xABCDEF1234
Switch-C9300(config-openflow-switch)#end

Switch-C9300#
```

** Disable DTP/keepalive on OpenFlow ports which may interfere with FAUCET. **
The following example will disable DTP and keepalives for TenGigabitEthernet1/0/1-24; adjust the range as necessary.

```
Switch-C9300(config)#interface range TenGigabitEthernet1/0/1-24
Switch-C9300(config-if-range)#switchport mode trunk
Switch-C9300(config-if-range)#switchport nonegotiate
Switch-C9300(config-if-range)#spanning-tree bpdufilter enable
Switch-C9300(config-if-range)#no keepalive
Switch-C9300(config-if-range)#exit
```

**Faucet**

On the FAUCET configuration file (/etc/faucet/faucet.yaml), add the datapath of the switch you wish to be managed by FAUCET. The device type (hardware) should be set to CiscoC9K in the configuration file.

```
:dps:
  Cisco-C9K:
    dp_id: 0xABCDEF1234
    hardware: "CiscoC9K"
    interfaces:
      1:
        native_vlan: 100
        name: "port1"
      2:
        native_vlan: 100
        name: "port2"
```

**Troubleshooting**

Command to check overall openflow configuration

```
Switch-C9300#
Switch-C9300#show openflow switch 1
Logical Switch Context
  Id: 1
  Switch type: Forwarding
  Pipeline id: 1
  Data plane: secure
  Table-Miss default: drop
  Configured protocol version: Negotiate
  Config state: no-shutdown
  Working state: enabled
  Rate limit (packet per second): 0
  Burst limit: 0
  Max backoff (sec): 8
  Probe interval (sec): 5
  TLS local trustpoint name: not configured
  TLS remote trustpoint name: not configured
  Logging flow changes: Disabled
  Stats collect interval (sec): 5
  Stats collect Max flows: 9216
```
Stats collect period (sec): 1
Minimum flow idle timeout (sec): 10

OFA Description:
- Manufacturer: Cisco Systems, Inc.
- Hardware: C9300-48P
- Software: Cisco IOS Software [Fuji], Catalyst L3 Switch Software (CAT9K_NONIOSXE), Version 16.8.1GO3, RELEASE SOFTWARE (fc1)| openvswitch 2.1
- Serial Num: FCW2145L0FP

DP Description: Faucet-C9300:sw1

OF Features:
- DPID: 0x000000ABCDEF1234
- Number of tables: 9
- Number of buffers: 256
- Capabilities: FLOW_STATS TABLE_STATS PORT_STATS

Controllers:
- 192.168.0.91:6653, Protocol: TCP, VRF: Mgmt-vrf
- 192.168.0.91:6654, Protocol: TCP, VRF: Mgmt-vrf

Interfaces:
- GigabitEthernet1/0/1
- GigabitEthernet1/0/2

Command to check the openflow flows installed

Switch-C9300#
Switch-C9300#show openflow switch 1 flow list
Logical Switch Id: 1
Total flows: 9

Flow: 1 Match: any Actions: drop, Priority: 0, Table: 0, Cookie: 0x0, Duration: 33812.029s, Packets: 46853, Bytes: 3636857

Command to check the state of the port status

Switch-C9300#
Switch-C9300#show openflow switch 1 ports
Logical Switch Id: 1

<table>
<thead>
<tr>
<th>Port</th>
<th>Interface Name</th>
<th>Config-State</th>
<th>Link-State</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>G1/0/1</td>
<td>PORT_UP</td>
<td>LINK_UP</td>
<td>1GB-HD</td>
</tr>
<tr>
<td>2</td>
<td>G1/0/2</td>
<td>PORT_UP</td>
<td>LINK_DOWN</td>
<td>1GB-HD</td>
</tr>
<tr>
<td>3</td>
<td>G1/0/3</td>
<td>PORT_UP</td>
<td>LINK_DOWN</td>
<td>1GB-HD</td>
</tr>
<tr>
<td>4</td>
<td>G1/0/4</td>
<td>PORT_UP</td>
<td>LINK_DOWN</td>
<td>1GB-HD</td>
</tr>
</tbody>
</table>

Command to check the status of the controller

Switch-C9300#
Switch-C9300#show openflow switch 1 controller
Logical Switch Id: 1
Total Controllers: 2

Controller: 1
- 192.168.0.91:6653
- Protocol: tcp
- VRF: Mgmt-vrf
- Connected: Yes
- Role: Equal
Negotiated Protocol Version: OpenFlow 1.3
Last Alive Ping: 2018-10-03 18:43:07 NZST
state: ACTIVE
sec_since_connect: 13150

Controller: 2
192.16.0.91:6654
Protocol: tcp
VRF: Mgmt-vrf
Connected: Yes
Role: Equal
Negotiated Protocol Version: OpenFlow 1.3
Last Alive Ping: 2018-10-03 18:43:07 NZST
state: ACTIVE
sec_since_connect: 12960

Command to check controller statistics

Switch-C9300#
Switch-C9300#show openflow switch 1 controller stats
Logical Switch Id: 1
Total Controllers: 2

Controller: 1
  address : tcp:192.168.0.91:6653%Mgmt-vrf
  connection attempts : 165
  successful connection attempts : 61
  flow adds : 1286700
  flow mods : 645
  flow deletes : 909564
  flow removals : 0
  flow errors : 45499
  flow unencodable errors : 0
  total errors : 45499
  echo requests : rx: 842945, tx:205
  echo reply : rx: 140, tx:842945
  flow stats : rx: 0, tx:0
  barrier : rx: 8324752, tx:8324737
  packet-in/packet-out : rx: 29931732, tx:8772758

Controller: 2
  address : tcp:192.168.0.91:6654%Mgmt-vrf
  connection attempts : 11004
  successful connection attempts : 3668
  flow adds : 0
  flow mods : 0
  flow deletes : 0
  flow removals : 0
  flow errors : 0
  flow unencodable errors : 0
  total errors : 0
  echo requests : rx: 946257, tx:1420
  echo reply : rx: 1420, tx:946257
  flow stats : rx: 47330, tx:57870
  barrier : rx: 0, tx:0
  packet-in/packet-out : rx: 377, tx:0
1.7.8 Faucet on OVS with DPDK

Introduction

Open vSwitch is a software OpenFlow switch, that supports DPDK. It is also the reference switching platform for FAUCET.

Setup

Install OVS on a supported Linux distribution

Install OVS and DPDK per the official OVS instructions, including enabling DPDK at compile time and in OVS’s initial configuration.

These instructions are known to work for Ubuntu 16.0.4, with OVS 2.7.0 and DPDK 16.11.1, kernel 4.4.0-77. In theory later versions of these components should work without changes. A multiport NIC was used, based on the Intel 82580 chipset.

Bind NIC ports to DPDK

Note: If you have a multiport NIC, you must bind all the ports on the NIC to DPDK, even if you do not use them all.

From the DPDK source directory, determine the relationship between the interfaces you want to use with DPDK and their PCI IDs:

```bash
export DPDK_DIR=`pwd`
$DPDK_DIR/tools/dpdk-devbind.py --status
```

In this example, we want to use enp1s0f0 and enp1s0f1.

```bash
$ ./tools/dpdk-devbind.py --status
```

Network devices using DPDK-compatible driver

```
  Network devices using kernel driver
  0000:01:00.0 '82580 Gigabit Network Connection' if=enp1s0f0 drv=igb unused=
  0000:01:00.1 '82580 Gigabit Network Connection' if=enp1s0f1 drv=igb unused=
  0000:01:00.2 '82580 Gigabit Network Connection' if=enp1s0f2 drv=igb unused=
  0000:01:00.3 '82580 Gigabit Network Connection' if=enp1s0f3 drv=igb unused=
```

Still from the DPDK source directory:
export DPDK_DIR=`pwd`
modprobe vfio-pci
chmod a+x /dev/vfio
chmod 0666 /dev/vfio/*

$ export DPDK_DIR=tools/dpdk-devbind.py --bind=vfio-pci 0000:01:00.0 0000:01:00.1 0000:01:00.2 0000:01:00.3
$ export DPDK_DIR=tools/dpdk-devbind.py --status

Confirm OVS has been configured to use DPDK

$ sudo /usr/local/share/openvswitch/scripts/ovs-ctl stop
$ Exiting ovs-vswitchd (20510)
$ Exiting ovsdb-server (20496)
$ sudo /usr/local/share/openvswitch/scripts/ovs-ctl start
$ Starting ovsdb-server
$ system ID not configured, please use --system-id
$ Configuring Open vSwitch system IDs
EAL: Detected 4 lcore(s)
EAL: Probing VFIO support...
EAL: VFIO support initialized
EAL: PCI device 0000:01:00.0 on NUMA socket -1
EAL: probe driver: 8086:150e net_e1000_igb
EAL: using IOMMU type 1 (Type 1)
EAL: PCI device 0000:01:00.1 on NUMA socket -1
EAL: probe driver: 8086:150e net_e1000_igb
EAL: PCI device 0000:01:00.2 on NUMA socket -1
EAL: probe driver: 8086:150e net_e1000_igb
EAL: PCI device 0000:01:00.3 on NUMA socket -1
EAL: probe driver: 8086:150e net_e1000_igb
EAL: PCI device 0000:02:00.0 on NUMA socket -1
EAL: probe driver: 8086:150e net_e1000_igb
EAL: PCI device 0000:02:00.1 on NUMA socket -1
EAL: probe driver: 8086:150e net_e1000_igb
EAL: PCI device 0000:02:00.2 on NUMA socket -1
EAL: probe driver: 8086:150e net_e1000_igb
EAL: PCI device 0000:02:00.3 on NUMA socket -1
EAL: probe driver: 8086:150e net_e1000_igb
EAL: PCI device 0000:02:00.0 on NUMA socket -1
EAL: probe driver: 8086:150e net_e1000_igb
EAL: PCI device 0000:02:00.1 on NUMA socket -1
EAL: probe driver: 8086:150e net_e1000_igb
EAL: PCI device 0000:02:00.2 on NUMA socket -1
EAL: probe driver: 8086:150e net_e1000_igb
EAL: PCI device 0000:02:00.3 on NUMA socket -1
EAL: probe driver: 8086:150e net_e1000_igb
Zone 0: name:<rte_eth_dev_data>, phys:0x7ffced40, len:0x30100, virt:0x7f843ffced40,
    --socket_id:0, flags:0
    Starting ovs-vswitchd
    Enabling remote OVSDB managers

Configure an OVS bridge with the DPDK ports

ovs-vsctl add-br br0 -- set bridge br0 datapath_type=netdev protocols=OpenFlow13
ovs-vsctl add-port br0 dpdk0 -- set interface enp1s0f0 type=dpdk options:dpdk-
    --devargs=0000:01:00.0
ovs-vsctl add-port br0 dpdk1 -- set interface enp1s0f1 type=dpdk options:dpdk-
    --devargs=0000:01:00.1
ovs-vsctl set-fail-mode br0 secure
ovs-vsctl set-controller br0 tcp:127.0.0.1:6653
ovs-ofctl show br0
ovs-vsctl get bridge br0 datapath_id
Create faucet.yaml

**Note:** Change dp_id, to the value reported above, prefaced with “0x”.

```
vlans:
  100:
    name: "test"

dps:
  ovsdpdk-1:
    dp_id: 0x000090e2ba7e7564
    hardware: "Open vSwitch"
    interfaces:
      1:
        native_vlan: 100
      2:
        native_vlan: 100
```

Run FAUCET

```
faucet --verbose --ryu-ofp-listen-host=127.0.0.1
```

Test connectivity

Host(s) on enp1s0f0 and enp1s0f1 in the same IP subnet, should now be able to communicate, and FAUCET’s log file should indicate learning is occurring:

```
May 11 14:53:32 faucet.valve INFO DPID 159303465858404 (0x90e2ba7e7564) → Configuring DP
May 11 14:53:32 faucet.valve INFO DPID 159303465858404 (0x90e2ba7e7564) VLAN vid:100 ports:1,2
May 11 14:53:32 faucet.valve INFO DPID 159303465858404 (0x90e2ba7e7564) VLANs changed/added: [100]
May 11 14:53:32 faucet.valve INFO DPID 159303465858404 (0x90e2ba7e7564) → Configuring VLAN vid:100 ports:1,2
May 11 14:53:32 faucet.valve INFO DPID 159303465858404 (0x90e2ba7e7564) Port 1 added
May 11 14:53:32 faucet.valve INFO DPID 159303465858404 (0x90e2ba7e7564) Sending config for port 1
May 11 14:53:32 faucet.valve INFO DPID 159303465858404 (0x90e2ba7e7564) Port 2 added
May 11 14:53:32 faucet.valve INFO DPID 159303465858404 (0x90e2ba7e7564) Sending config for port 2
May 11 14:53:33 faucet.valve INFO DPID 159303465858404 (0x90e2ba7e7564) Packet in src:00:16:41:6d:87:28 in_port:1 vid:100
May 11 14:53:33 faucet.valve INFO learned 1 hosts on vlan 100
```
1.7.9 Faucet Testing with OVS on Hardware

Setup

Faucet configuration file

Listing 54: /etc/faucet/hw_switch_config.yaml

```
# Faucet Configuration file: /etc/faucet/hw_switch_config.yaml
#
# If hw_switch value set to True, map a hardware OpenFlow switch to ports on this
# machine.
# Otherwise, run tests against OVS locally.
hw_switch: True
hardware: 'Open vSwitch'
dp_ports:
  1: eth0
  2: eth1
  3: eth2
  4: eth3

# Hardware switch's DPID
dpid: 0xacd28f18b
cpn_intf: eno1
of_port: 6636
gauge_of_port: 6637
```
Hardware

1. For Network Interface Cards (NICs), prefer Intel branded models.
2. I have also used Hi-Speed USB to dual Ethernet which works great

Software

1. Ubuntu 16.04 Xenial
2. Open vSwitch 2.7.2+

Commands

Commands to be executed on each side - Faucet Test host and Open vSwitch.

Commands on Faucet Test Host

Run these commands as root on the Ubuntu system (v16.04 used)

```bash
echo $'

$ sudo mkdir -p /usr/local/src/
$ sudo mkdir -p /etc/faucet/
$ sudo cd /usr/local/src/
$ sudo git clone https://github.com/faucetsdn/faucet.git
$ cd faucet
$ sudo ip address show
1: lo: <LOOPBACK,UP,LOWER_UP> mtu 65536 qdisc noqueue state UNKNOWN group default qlen 1000
   link/loopback 00:00:00:00:00:00 brd 00:00:00:00:00:00
   inet 127.0.0.1/8 scope host lo
       valid_lft forever preferred_lft forever
   inet6 ::1/128 scope host
       valid_lft forever preferred_lft forever
2: eth0: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc mq state UP group default qlen 1000
   link/ether b4:96:91:00:88:a4 brd ff:ff:ff:ff:ff:ff
   inet 192.168.1.100/24 scope global eth0
       valid_lft forever preferred_lft forever
   inet6 fe80::b696:91ff:fe00:88a4/64 scope link valid_lft forever preferred_lft forever
3: eth1: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc mq state UP group default qlen 1000
   link/ether b4:96:91:00:88:a5 brd ff:ff:ff:ff:ff:ff
   inet 192.168.1.101/24 scope global eth1
       valid_lft forever preferred_lft forever
   inet6 fe80::b696:91ff:fe00:88a5/64 scope link valid_lft forever preferred_lft forever
4: eth2: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc mq state UP group default qlen 1000
   link/ether b4:96:91:00:88:a6 brd ff:ff:ff:ff:ff:ff
   inet 192.168.1.102/24 scope global eth2
       valid_lft forever preferred_lft forever
   inet6 fe80::b696:91ff:fe00:88a6/64 scope link valid_lft forever preferred_lft forever
5: eth3: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc mq state UP group default qlen 1000
   link/ether b4:96:91:00:88:a7 brd ff:ff:ff:ff:ff:ff
   inet 192.168.1.103/24 scope global eth3
       valid_lft forever preferred_lft forever
   inet6 fe80::b696:91ff:fe00:88a7/64 scope link valid_lft forever preferred_lft forever
6: eno1: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc mq state UP group default qlen 1000

(continues on next page)
link/ether 00:1e:67:ff:f6:80 brd ff:ff:ff:ff:ff
inet 10.10.10.7/16 brd 10.20.255.255 scope global enol
valid_lft forever preferred_lft forever
inet6 cafe:babe::21e:67ff:feff:f680/64 scope global mngtmpaddr dynamic
valid_lft 86398sec preferred_lft 14398sec
inet6 fe80::21e:67ff:feff:f680/64 scope link
valid_lft forever preferred_lft forever

**Tip:** To locate the corresponding physical port, you can make the port LED blink with *Ethtool*.

### Commands on Open vSwitch

Login as *root* on the Ubuntu system and install OpenvSwitch and start *openvswitch-switch service*

```bash
$ sudo apt-get install openvswitch-switch
$ sudo systemctl status openvswitch-switch.service
$ sudo ovs-vsctl add-br ovs-br0
$ sudo ovs-vsctl add-port ovs-br0 enp2s0 -- set Interface enp2s0 ofport_request=1
$ sudo ovs-vsctl add-port ovs-br0 enp3s0 -- set Interface enp3s0 ofport_request=2
$ sudo ovs-vsctl add-port ovs-br0 enp5s0 -- set Interface enp5s0 ofport_request=3
$ sudo ovs-vsctl add-port ovs-br0 enp6s0 -- set Interface enp6s0 ofport_request=4
$ sudo ovs-vsctl set-fail-mode ovs-br0 secure
$ sudo ovs-vsctl set bridge ovs-br0 protocols=OpenFlow13
$ sudo ovs-vsctl set-controller ovs-br0 tcp:10.10.10.7:6636 tcp:10.10.10.7:6637
$ sudo ovs-vsctl get bridge ovs-br0 datapath_id
$ sudo ovs-vsctl show
308038ec-495d-412d-9b13-fe95bda4e176
    Bridge "ovs-br0"
        Controller "tcp:10.10.10.7:6636"
        Controller "tcp:10.10.10.7:6637"
        Port "enp3s0"
            Interface "enp3s0"
        Port "enp2s0"
            Interface "enp2s0"
        Port "enp6s0"
            Interface "enp6s0"
        Port "ovs-br0"
            Interface "ovs-br0"
                type: internal
        Port "enp5s0"
            Interface "enp5s0"
                type: system
    ovs_version: "2.7.0"
```

```bash
$ sudo ovs-vsctl -- --columns=name,ofport list Interface
name : "ovs-br0"
ofport : 65534
name : "enp5s0"
ofport : 3
name : "enp2s0"
ofport : 1
```

(continues on next page)
name : "enp6s0"
ofport : 4

name : "enp3s0"
ofport : 2

Tip: To locate the corresponding physical port, you can make the port LED blink with Ethtool.

Check port speed information to make sure that they are at least 1Gbps

```bash
$ sudo ovs-ofctl -O OpenFlow13 dump-ports-desc ovs-br0
OFPST_PORT_DESC reply (OF1.3) (xid=0x2):
  1(enp2s0): addr:00:0e:c4:ce:77:25
    config: 0
    state: 0
    current: 1GB-FD COPPER AUTO_NEG
    advertised: 10MB-HD 10MB-FD 100MB-HD 100MB-FD 1GB-FD COPPER AUTO_NEG AUTO_PAUSE
    supported: 10MB-HD 10MB-FD 100MB-HD 100MB-FD 1GB-FD COPPER AUTO_NEG AUTO_PAUSE
    speed: 1000 Mbps now, 1000 Mbps max

  2(enp3s0): addr:00:0e:c4:ce:77:26
    config: 0
    state: 0
    current: 1GB-FD COPPER AUTO_NEG
    advertised: 10MB-HD 10MB-FD 100MB-HD 100MB-FD 1GB-FD COPPER AUTO_NEG AUTO_PAUSE
    supported: 10MB-HD 10MB-FD 100MB-HD 100MB-FD 1GB-FD COPPER AUTO_NEG AUTO_PAUSE
    speed: 1000 Mbps now, 1000 Mbps max

  3(enp5s0): addr:00:0e:c4:ce:77:27
    config: 0
    state: 0
    current: 1GB-FD COPPER AUTO_NEG
    advertised: 10MB-HD 10MB-FD 100MB-HD 100MB-FD 1GB-FD COPPER AUTO_NEG AUTO_PAUSE
    supported: 10MB-HD 10MB-FD 100MB-HD 100MB-FD 1GB-FD COPPER AUTO_NEG AUTO_PAUSE
    speed: 1000 Mbps now, 1000 Mbps max

  4(enp6s0): addr:00:0a:cd:28:f1:8b
    config: 0
    state: 0
    current: 1GB-FD COPPER AUTO_NEG
    advertised: 10MB-HD COPPER AUTO_NEG AUTO_PAUSE AUTO_PAUSE_ASYM
    supported: 10MB-HD 10MB-FD 100MB-HD 100MB-FD 1GB-HD 1GB-FD COPPER AUTO_NEG
    speed: 1000 Mbps now, 1000 Mbps max
LOCAL(ovs-br0): addr:00:0a:cd:28:f1:8b
    config: PORT_DOWN
    state: LINK_DOWN
    speed: 0 Mbps now, 0 Mbps max
```
Running the tests

Edit the `/etc/faucet/hw_switch_config.yaml` file as shown earlier in this document setting `hw_switch=False` initially for testing.

```
$ sudo cp /usr/local/src/faucet/hw_switch_config.yaml /etc/faucet/hw_switch_config.yaml
$ sudo $EDITOR /etc/faucet/hw_switch_config.yaml
$ cd /usr/local/src/faucet/
```

Install docker by following the Installing docker section and then run the hardware based tests by following the Running the tests section.

Once the above minitest version is successful with `hw_switch=False`, then edit the `/etc/faucet/hw_switch_config.yaml` file and set `hw_switch=True`.

Run tests again, verify they all pass.

Debugging

TCPDump

Many times, we want to know what is coming in on a port. To check on interface `enp2s0`, for example, use

```
$ sudo tcpdump -A -w enp2s0_all.pcap -i enp2s0
```

Or

```
$ sudo tcpdump -A -w enp2s0_all.pcap -i enp2s0 'dst host <controller-ip-address> and port 6653'
```

To read the pcap file, use

```
$ sudo tcpdump -r enp2s0_all.pcap
```

More detailed examples are available @ https://www.wains.be/pub/networking/tcpdump_advanced_filters.txt

Note: On which machine should one run tcpdump?

Depends, if you want to examine the `packet_ins` that are sent from switch to controller, run on the switch listening on the interface that is talking to the controller. If you are interested on what is coming in on a particular test port, then run it on the Test Host on that interface.

Ethtool

To locate a physical port say `enp2s0`, make the LED blink for 5 seconds:

```
$ sudo ethtool -p enp2s0 5
```

To figure out speed on the interface. Note that if Speed on the interface is at least not 1G, then tests may not run correctly.

```
$ sudo ethtool enp2s0
$ sudo ethtool enp2s0 | grep Speed
```
References


1.8 External Resources

1.8.1 Online Tutorials

• http://docs.openvswitch.org/en/latest/tutorials/faucet/
• https://blog.cyberreboot.org/building-a-software-defined-network-with-raspberry-pis-and-a-zodiac-fx-switch-97184032cdc1

1.8.2 Tutorial Videos

• https://www.youtube.com/watch?v=fuqzzjmcwII
2.1 Developer Guide

This file contains an overview of architecture, coding design/practices, testing and style.

2.1.1 Before submitting a PR

- If you have general questions, feel free to reach out to the faucet-dev mailing list.

- If you are new to FAUCET, or are contemplating a major change, it’s recommended to open a github issue with the proposed change. This will enable broad understanding of your work including being able to catch any potential snags very early (for example, adding new dependencies). Architectural and approach questions are best settled at this stage before any code is written.

- Please send relatively small, tightly scoped PRs (approx 200-300 LOC or less). This makes review and analysis easier and lowers risk, including risk of merge conflicts with other PRs. Larger changes must be refactored into incremental changes.

- You must add a test if FAUCET’s functionality changes (ie. a new feature, or correcting a bug).

- All unit and integration tests must pass (please use the docker based tests; see *Software switch testing with docker*). Where hardware is available, please also run the hardware based integration tests also.

- In order to speed up acceptance of your PR we recommend enabling TravisCI on your own github repo, and linking the test results in the body of the PR. This enables the maintainers to quickly verify that your changes pass all tests in a pristine environment while conserving our TravisCI resources on the main branch (by minimizing resources used on potentially failing test runs which could be caught before opening a PR on the main branch).

- You must use the github feature branches (see https://gist.github.com/vlandham/3b2b79c40bc7353ae95a), for your change and squash commits (https://blog.github.com/2016-04-01-squash-your-commits/) when creating the PR.

- Please use the supplied git pre-commit hook (see ../*git-hook/pre-commit*), to automatically run the unit tests and pylint for you at git commit time, which will save you TravisCI resources also.

- pylint must show no new errors or warnings.

- Code must conform to the style guide (see below).
2.1.2 PR handling guidelines

This section documents general guidelines for the maintainers in handling PRs. The overall intent is to enable quality contributions with as low overhead as possible, maximizing the use of tools such as static analysis and unit/integration testing, and supporting rapid and safe advancement of the overall project.

In addition to the above PR submission guidelines, above:

- PRs require a positive review per github’s built in gating feature. The approving reviewer executes the merge.
- PRs that should not be merged until some other criteria are met (e.g. not until release day) must include DO NOT MERGE in the title, with the details in PR comments.
- A typical PR review/adjust/merge cycle should be 2-3 days (timezones, weekends, etc permitting). If a PR upon review appears too complex or requires further discussion it is recommended it be refactored into smaller PRs or discussed in another higher bandwidth forum (e.g. a VC) as appropriate.
- A PR can be submitted at any time, but to simplify release logistics PR merges might not be done before release, on release days.

2.1.3 Code style

Please use the coding style documented at https://github.com/google/styleguide/blob/gh-pages/pyguide.md. Existing code not using this style will be incrementally migrated to comply with it. New code should comply.

2.1.4 Faucet Development Environment

A common way of developing faucet is inside a virtualenv with an IDE such as PyCharm.

Instructions on setting up PyCharm for developing faucet are below.

If you would rather develop on the command line directly, a short summary of the command line setup for development in a virtualenv with Python 3.6+ is included after the PyCharm instructions.

Create a new project in PyCharm

Set the Location of the project to the directory where a checked out copy of the faucet code from git is, for this tutorial I will assume the path is /Dev/faucet/.

Ignore the Project Interpreter settings for now, we will set those up after the project is created.

Click Create when you have completed these steps.

When asked Would you like to create a project from existing sources instead? click Yes.

Create virtual environment

Now that the project is created and source code imported, click the File -> Settings menu. In the dialog box that opens click the Project: faucet -> Project Interpreter sub menu.

Click the cog and select Add...

Under Virtualenv Environment you want to select New environment and select a Location for the virtualenv (which can be inside the directory where the faucet code lives, e.g /Dev/faucet/venv).

The Base interpreter should be set to /usr/bin/python3.
Click Ok which will create the virtualenv.

Now while that virtualenv builds and we still have the settings dialog open we will tweak a few project settings to make them compatible with our code style. Click on the Tools -> Python Integrated Tools menu and change the Docstring format to Google.

Finally, click Ok again to get back to the main screen of PyCharm.

**Install requirements**

Inside the PyCharm editor window if we open one of the code files for faucet (e.g. faucet/faucet.py) we should now get a bar at the top of the window telling us of missing package requirements, click the Install requirements option to install the dependencies for faucet.

**Create log and configuration directories**

Now we need to create a log and configuration directory so that faucet can start:

```
mkdir -p /Dev/faucet/venv/var/log/faucet/
mkdir -p /Dev/faucet/venv/etc/faucet/
```

Copy the sample faucet configuration file from /Dev/faucet/etc/faucet/faucet.yaml to /Dev/faucet/venv/etc/faucet/ and edit this configuration file as necessary.

Copy the sample gauge configuration file from /Dev/faucet/etc/faucet/gauge.yaml to /Dev/faucet/venv/etc/faucet/ and edit this configuration file as necessary.

If you are using the sample configuration “as is” you will also need to copy /Dev/faucet/etc/faucet/acls.yaml to /Dev/faucet/venv/etc/faucet/ as that included by the sample faucet.yaml file, and without it the sample faucet.yaml file cannot be loaded.

You may also wish to copy /Dev/faucet/etc/faucet/ryu.conf to /Dev/faucet/venv/etc/faucet/ as well so everything can be referenced in one directory inside the Python virtual environment.

**Configure PyCharm to run faucet and gauge**

Now we need to configure PyCharm to run faucet, gauge and the unit tests.

First, click the Run -> Run... menu, then select the Edit Configurations... option to get to the build settings dialog.

We will now add run configuration for starting faucet and gauge. Click the + button in the top left hand corner of the window. First, change the name from Unnamed to faucet. Change the Script path to point to ryu-manager inside the virtualenv, for me this was ../venv/bin/ryu-manager. Then set the Parameters to faucet.faucet. Make sure the working directory is set to /Dev/faucet/faucet/.

We will use the same steps as above to add a run configuration for gauge. Changing the Script path to ../venv/bin/ryu-manager and setting the Parameters this time to faucet.gauge. Make sure the working directory is set to /Dev/faucet/faucet/.
Configure PyCharm to run unit tests

For running tests we need a few additional dependencies installed. I couldn’t work out how to do this through PyCharm so run this command from a terminal window to install the correct dependencies inside the virtualenv:

```
/Dev/faucet/venv/bin/pip3 install -r /Dev/faucet/test-requirements.txt
```

To add the test run configuration we will again click the + button in the top left hand corner, select Python tests -> Unittests. You can provide a Name of Faucet Unit Tests for the run configuration. For Target select Script path and enter the path /Dev/faucet/tests/unit/faucet. For Pattern enter test_*.py.

We will also add test run configuration for gauge using the same steps as above. Use Gauge Unit Tests as the Name and for Target select Script path and enter the path /Dev/faucet/tests/unit/gauge. For Pattern enter test_*.py.

You can click Apply and Close now that we’ve added all our new run configuration.

Now that everything is setup you can run either the faucet controller, gauge controller and test suite from the Run menu.

Developing with a Python 3.6+ venv

If you would prefer not to use PyCharm and are comfortable developing Python directly on the command line, these steps should get you started. They have been tested with Ubuntu 18.04 LTS, which includes Python 3.6, but similar instructions should work on other platforms that include Python 3.6+.

Install C/C++ compilers and Python development environment packages:

```
sudo apt-get install python3-venv libpython3.6-dev gcc g++ make
```

If you have not already, clone the faucet git repository:

```
git clone https://github.com/faucetsdn/faucet.git
```

Then create a Python venv environment within it:

```
cd faucet
python3 -m venv "$PWD/venv"
```

and activate that virtual environment for all following steps:

```
. venv/bin/activate
```

Ensure that the faucet config is present within the virtual environment, copying from the default config files if required:

```
mkdir -p "${VIRTUAL_ENV}/var/log/faucet"
mkdir -p "${VIRTUAL_ENV}/etc/faucet"

for FILE in {acls,faucet,gauge}.yaml ryu.conf; do
  if [ -f "${VIRTUAL_ENV}/etc/faucet/${FILE}" ]; then
    echo "Preserving existing ${FILE}"
  else
    echo "Installing template ${FILE}"
    cp -p "etc/faucet/${FILE}" "${VIRTUAL_ENV}/etc/faucet/${FILE}"
  fi
done
```

Then install the runtime and development requirements
Finally install faucet in an editable form:

```
pip install -e .
```

And then confirm that you can run the unit tests:

```
pytest tests/unit/faucet/
pytest tests/unit/gauge/
```

### 2.1.5 Makefile

Makefile is provided at the top level of the directory. Output of `make` is normally stored in `dist` directory. The following are the targets that can be used:

- **uml**: Uses `pyreverse` to provide code class diagrams.
- **codefmt**: Provides command line usage to “Code Style” the Python file
- **codeerrors**: Uses `pylint` on all Python files to generate a code error report and is placed in `dist` directory.
- **stats**: Provides a list of all commits since the last release tag.
- **release**: Used for releasing FAUCET to the next version, Requires `version` and `next_version` variables.

To **directly install** faucet from the cloned git repo, you could use `sudo python setup.py install` command from the root of the directory.

To **build pip installable package**, you could use `python setup.py sdist` command from the root of the directory.

To **remove** any temporarily created directories and files, you could use `rm -rf dist *egg-info` command.

### Building Documentation

The documentation is built with Sphinx, from within the `docs` directory.

To be able to build the documentation ensure you have the relevant packages installed:

```
cd docs
sudo apt-get install librsvg2-bin make
pip3 install -r requirements.txt
```

and then you can build HTML documentation with:

```
cd docs
make html
```

and the documentation will be found under `_build/html` in the `docs` directory.
2.1.6 Key architectural concepts/assumptions:

FAUCET’s architecture depends on key assumptions, which must be kept in mind at all times.

- FAUCET is the only controller for the switch, that can add or remove flows.
- All supported dataplanes must implement OpenFlow functionally (hardware, software or both) identically. No TTP or switch specific drivers.

In addition:

- FAUCET provisions default deny flows (all traffic not explicitly programmed is dropped).
- Use of packet in is minimized.

FAUCET depends upon these assumptions to guarantee that the switch is always in a known and consistent state, which in turn is required to support high availability (FAUCET provides high availability, through multiple FAUCET controllers using the same version of configuration - any FAUCET can give the switch a consistent response - no state sharing between controllers is required). The FAUCET user can program customized flows to be added to the switch using FAUCET ACLs (see below).

FAUCET also programs the dataplane to do flooding (where configured). This minimizes the use of packet in. This is necessary to reduce competition between essential control plane messages (adding and removing flows), and traffic from the dataplane on the limited bandwidth OpenFlow control channel. Unconstrained packet in messages impact the switch CPU, may overwhelm the OpenFlow control channel, and will expose the FAUCET controller to unvalidated dataplane packets, all of which are security and reliability concerns. In future versions, packet in will be eliminated altogether. The FAUCET user is expected to use policy based forwarding (eg ACLs that redirect traffic of interest to high performance dataplane ports for NFV offload), not packet in.

FAUCET requires all supported dataplanes to implement OpenFlow (specifically, a subset of OpenFlow 1.3) in a functionally identical way. This means that there is no switch-specific driver layer - the exact same messages are sent, whether the switch is OVS or hardware. While this does prevent some earlier generation OpenFlow switches from being supported, commercially available current hardware does not have as many restrictions, and eliminating the need for a switch-specific (or TTP) layer greatly reduces implementation complexity and increases controller programmer productivity.

2.2 Architecture

2.2.1 Faucet Design and Architecture

Faucet enables practical SDN for the masses (see http://queue.acm.org/detail.cfm?id=3015763).

- Drop in/replacement for non-SDN L2/L3 IPv4/IPv6 switch/router (easy migration)
- Packet forwarding/flooding/multicasting done entirely by switch hardware (controller only notified on topology change)
- BGP and static routing (other routing protocols provided by NFV)
- Multi vendor/platform support using OpenFlow 1.3 multi table
- Multi switch, vendor neutral “stacking” (Faucet distributed switching, loop free topology without spanning tree)
- ACLs, as well as allow/drop, allow packets to be copied/rewritten for external NFV applications
- Monitored with Prometheus
- Small code base with high code test coverage and automated testing both hardware and software

See unit and integration tests for working configuration examples.
2.2.2 Faucet Openflow Switch Pipeline

This summarizes the global FAUCET pipeline; however, certain tables may be omitted if the functionality is not required. For example, if routing is not configured, neither FIB table nor the VIP table will be provisioned.

Usually the OpenFlow table IDs will be allocated sequentially for the tables actually used, so tables should be referenced by their name rather than the table ID in this diagram.

See also canonical pipeline definitions in faucet_pipeline.py.

**PORT_ACL Table**

- Apply user supplied ACLs to a port and send to next table

**VLAN Table**

- Match fields: eth_dst, eth_type, in_port, vlan_vid

- **Operations:**
  - Drop unwanted L2 protocol traffic (and spoofing of Faucet’s virtual MAC)
  - **For tagged ports**
    * Match VLAN_VID and send to next table
  - **For untagged ports**

---

**Controller**

**Output**

**Output/Mirror**
• Push VLAN frame onto packet with VLAN_VID representing ports native VLAN and send to next table
  – Interception of L2 control traffic (e.g. LACP, LLDP if configured).
  – Unknown traffic is dropped

**VLAN_ACL Table**

• Apply user supplied ACLs to a VLAN and send to next table

**ETH_SRC Table**

• Match fields: eth_dst, eth_src, eth_type, in_port, vlan_vid
• Operations:
  – For IPv4/IPv6 traffic where Faucet is the next hop, send to IPV4_FIB or IPV6_FIB (route)
  – For known source MAC, send to ETH_DST (switch)
  – For unknown source MACs, copy header to controller via packet in (for learning) and send to FLOOD

**IPV4_FIB Table**

• Match fields: eth_type, ipv4_dst, vlan_vid
• Operations:
  – Route IPv4 traffic to a next-hop for each route we have learned
  – Set eth_src to Faucet’s magic MAC address
  – Set eth_dst to the resolved MAC address for the next-hop
  – Decrement TTL
  – Send to ETH_DST/HAIRPIN/VIP table
  – Unknown traffic is dropped

**IPV6_FIB Table**

• Match fields: eth_type, ipv6_dst, vlan_vid
• Operations:
  – Route IPv4 traffic to a next-hop for each route we have learned
  – Set eth_src to Faucet’s magic MAC address
  – Set eth_dst to the resolved MAC address for the next-hop
  – Decrement TTL
  – Send to ETH_DST/HAIRPIN/VIP table
  – Unknown traffic is dropped
VIP Table

- Match fields: `arp_tpa, eth_dst, eth_type, icmpv6_type, ip_proto`
- Operations:
  - Send traffic destined for FAUCET VIPs including IPv4 ARP and IPv6 ND to the controller, and traffic for unresolved hosts in connected IP subnets (if proactively learning).
  - IPv4 ARP/IPv6 ND traffic may be flooded also (sent to FLOOD)

ETH_DST_HAIRPIN Table

- Exact match (no wildcards)
- Match fields: `eth_dst, in_port, vlan_vid`
- Operations:
  - For destination MAC addresses we have learned output packet towards that host (popping VLAN frame if we are outputting on an untagged port), and where hairpinning is desired (e.g. routing between hosts on the same port, but different VLANS).
  - Unknown traffic is sent to ETH_DST table.

ETH_DST Table

- Exact match (no wildcards)
- Match fields: `eth_dst, vlan_vid`
- Operations:
  - For destination MAC addresses we have learned output packet towards that host (popping VLAN frame if we are outputting on an untagged port)
  - Unknown traffic is sent to FLOOD table

FLOOD Table

- Match fields: `eth_dst, in_port, vlan_vid`
- Operations:
  - Flood broadcast within VLAN
  - Flood multicast within VLAN
  - Unknown traffic is flooded within VLAN
2.2.3 Faucet Architecture

2.3 Testing

2.3.1 Installing docker

First, get yourself setup with docker based on our *Installing docker* documentation.

2.3.2 Software switch testing with docker

You can build and run the mininet tests with the following commands:

```bash
sudo docker build --pull -t faucet/tests -f Dockerfile.tests .
sudo apparmor_parser -R /etc/apparmor.d/usr.sbin.tcpdump
sudo modprobe openvswitch
sudo docker run --name=faucet-tests \
    --sysctl net.ipv6.conf.all.disable_ipv6=0 --privileged --rm \
    -v /var/local/lib/docker:/var/lib/docker \
    -v /tmp/faucet-pip-cache:/var/tmp/pip-cache \
    -ti faucet/tests
```
The apparmor command is currently required on Ubuntu hosts to allow the use of tcpdump inside the container.

If you need to use a proxy, the following to your docker run command.

```
--build-arg http_proxy=http://your.proxy:port
```

### 2.3.3 Hardware switch testing with docker

![Hardware switch testing with docker](image)
Requirements

Your test host, requires at least 5 interfaces. 4 interfaces to connect to the dataplane, and one for the CPN for OpenFlow. You will need to assign an IP address to the CPN interface on the host, and configure the switch with a CPN IP address and establish that they can reach each other (eg via ping).

You will need to configure the switch with two OpenFlow controllers, both with the host’s CPN IP address, but with different ports (defaults are given below for of_port and gauge_of_port).

Note: It is very important to disable any process that could cause any traffic on the dataplane test interfaces, and the test interfaces should have all IPv4/IPv6 dynamic address assignment disabled. To achieve this, on Ubuntu for example, you can set the interfaces to “unmanaged” in Network Manager, and make sure processes like Avahi ignores the test interfaces.

Note: Hardware tests must not be run from virtualized hosts (such as under VMware). The tests need to control physical port status, and need low level L2 packet access (eg. to rewrite Ethernet source and destination addresses) which virtualization may interfere with.

Note: Hardware tests require the test switch to have all non-OpenFlow switching/other features (eg. RSTP, DHCP) disabled on the dataplane test interfaces. These features will conflict with the functions FAUCET itself provides (and in turn the tests).

It is assumed that you execute all following commands from your FAUCET source code directory (eg one you have git cloned).

Test configuration

Create a directory for the test configuration:

```
mkdir -p /etc/faucet
$EDITOR /etc/faucet/hw_switch_config.yaml
```

`hw_switch_config.yaml` should contain the correct configuration for your switch:

```
hw_switch: True
hardware: 'Open vSwitch'
# Map ports on the hardware switch, to physical ports on this machine.
dp_ports:
  1: enp1s0f0
  2: enp1s0f1
  3: enp1s0f2
  4: enp1s0f3
# Hardware switch's DPID
dpid: 0xeccd6d9936ed
# Port on this machine that connects to hardware switch's CPN port.
# Hardware switch must use IP address of this port as controller IP.
cpn_intf: enp5s0
# There must be two controllers configured on the hardware switch,
# with same IP (see cpn_intf), but different ports - one for FAUCET,
# one for Gauge.
of_port: 6636
```

(continues on next page)
Running the tests

Before starting the hardware test suite for the first time, you will need to install ebttables on the host machine:

```bash
sudo apt-get install ebttables
```

After every reboot of your host machine you will also need to manually load the `openvswitch` and `ebtables` kernel modules. If using apparmor you will also need to disable the profile for `tcpdump`:

```bash
sudo modprobe openvswitch
sudo modprobe ebttables
sudo apparmor_parser -R /etc/apparmor.d/usr.sbin.tcpdump
```

Then you can build and run the test suite:

```bash
sudo docker build --pull -t faucet/tests -f Dockerfile.tests .
sudo docker run --name=faucet-tests 
    --privileged --rm --net=host --cap-add=NET_ADMIN 
    -v /var/local/lib/docker:/var/lib/docker 
    -v /tmp/faucet-pip-cache:/var/tmp/pip-cache 
    -v /etc/faucet:/etc/faucet 
    -v /var/tmp:/var/tmp 
    -ti faucet/tests
```

### 2.3.4 Test suite options

In both the software and hardware version of the test suite we can provide flags inside the `FAUCET_TESTS` environment variable to run specific parts of the test suite.

**Note:** Multiple flags can be added to `FAUCET_TESTS`, below are just some examples of how individual flags work.

To find the full list of options you can pass to the test suite, set `FAUCET_TESTS` to `--help`.

```
-e FAUCET_TESTS="--help"
```
Running specific integration tests

If specific test names are listed in the FAUCET_TESTS environment then only these integration tests will be run and all others skipped.

If we add the following to either of the previous docker run commands then only the FaucetUntaggedTest will be run.

```
-e FAUCET_TESTS="FaucetUntaggedTest"
```

Running only the integration tests

Sometimes you will want to skip the pytype, linting and documentation tests in order to complete a faucet test suite run against hardware quicker.

```
-e FAUCET_TESTS="-i"
```

Skip code checks

Sometimes you will want to skip the pytype, linting and documentation tests.

This can be done with with the -n flag:

```
-e FAUCET_TESTS="-n"
```

Skip unit tests

Sometimes you will want to skip the unit tests which are small tests that verify small chunks of the code base return the correct values. If these are skipped the integration tests (which spin up virtual networks and tests faucet controllers under different configurations) will still be run.

This can be done with with the -u flag:

```
-e FAUCET_TESTS="-u"
```

Checking test results

If a test fails, you can look in /var/tmp - there will be subdirectories created for each test, which will contain all the logs and debug information (including tcpdumps).

By default the test suite cleans up these files but if we use the -k flag the test suite will keep these files.

```
-e FAUCET_TESTS="-k"
```
2.3.5 Repeatedly running tests until failure

You can run tests until a failure is detected (e.g., to diagnose an unreliable test). Tests will continue to run forever until at least one fails or the test is interrupted.

\[-e \text{FAUCET\_TESTS}=-r\]

2.3.6 Test debugging

Often while debugging a failed integration test it can be useful to pause the test suite at the point of the failure. The test can then be inspected live to narrow down the exact issue. To do this, run your test with the \(--\text{debug}\) flag (replace \textit{TEST\_NAME} with actual name of test).

\[-e \text{FAUCET\_TESTS}=-\text{debug TEST\_NAME}\]

The test suite will now run in a mode where it ignores successful tests and drops into a pdb shell when a failure occurs inside a test. There are a number of different pdb commands that can be run to check the actual test code.

It is also possible to login to the virtual container environment to run interactive debug commands to inspect the state of the system.

\[\text{sudo docker exec -it faucet-tests /bin/bash}\]

One useful thing can be to find the running mininet containers and execute commands inside of them, e.g., ping:

```
ps w | grep mininet:
995 pts/1  Ss+  0:00 bash --norc --noediting -is mininet:faucet-637
997 pts/2  Ss+  0:00 bash --norc --noediting -is mininet:u021
1001 pts/3 Ss+  0:00 bash --norc --noediting -is mininet:u022
1005 pts/4 Ss+  0:00 bash --norc --noediting -is mininet:u023
1009 pts/5 Ss+  0:00 bash --norc --noediting -is mininet:u024
1013 pts/6 Ss+  0:00 bash --norc --noediting -is mininet:s02
1077 pts/7 Ss+  0:00 bash --norc --noediting -is mininet:gauge-637
```

```
m u021 ping 127.0.0.1
```

2.4 Fuzzing

2.4.1 Fuzzing faucet config with docker

First, get yourself setup with docker based on our \textit{Installing docker} documentation.

Then you can build and run the afl-fuzz tests:

```
docker build -t faucet/config-fuzzer -f Dockerfile.fuzz-config .
docker run -d \
-u $(id -u $USER) \
--name config-fuzzer \
-v /var/log/afl:/var/log/afl/ \
faucet/config-fuzzer
```
AFL then will run indefinitely. You can find the output in /var/log/afl/. You will then need to run the output configs with faucet to see the error produced.

### 2.4.2 Fuzzing faucet packet handling with docker

Build and run the afl-fuzz tests:

```bash
docker build -t faucet/packet-fuzzer -f Dockerfile.fuzz-packet .
docker run -d \
  -u $(id -u $USER) \
  --name packet-fuzzer \
  -v /var/log/afl/:/var/log/afl/ \
  -v /var/log/faucet/:/var/log/faucet/ \
  -p 6653:6653 \
  -p 9302:9302 \
  faucet/packet-fuzzer
```

AFL will then fuzz the packet handling indefinitely. The afl output can be found in /var/log/afl/. To check the error produced by an afl crash file use display_packet_crash:

```bash
python3 tests/fuzzer/display_packet_crash.py /var/log/afl/crashes/X
```

Where X is the name of the crash file. The output can then be found in the faucet logs (/var/log/faucet/).

### 2.5 Source Code

#### 2.5.1 faucet

**faucet package**

**Submodules**

**faucet.acl module**

Configuration for ACLs.

```python
class faucet.acl.ACL(_id, dp_id, conf)

Bases: faucet.conf.Conf

Contains the state for an ACL, including the configuration.

ACL Config

ACLs are configured under the ‘acls’ configuration block. The acls block contains a dictionary of individual acls each keyed by its name.

Each acl contains a list of rules, a packet will have the first matching rule applied to it.

Each rule is a dictionary containing the single key ‘rule’ with the value the matches and actions for the rule.

The matches are key/values based on the ryu RESTful API. The key ‘actions’ contains a dictionary with keys/values as follows:

- allow (int): if 1 allow the packet to continue through the Faucet pipeline, if 0 drop the packet.
```
• force_port_vlan (int): if 1, do not verify the VLAN/port association for this packet and override any VLAN
ACL on the forced VLAN.
• meter (str): meter to apply to the packet
• output (dict): used to output a packet directly. details below.
• cookie (int): set flow cookie to this value on this flow

The output action contains a dictionary with the following elements:
• tunnel (dict): the tunnel formation, creates a tunnel from the applied port(s) to the specified destination
• port (int or string): the port to output the packet to
• ports (list): a list of the ports (int or string) to output the packet to
• set_fields (list): a list of fields to set with values
• pop_vlans: (int): pop the packet vlan before outputting
• vlan_vid: (int): push the vlan vid on the packet when outputting
• vlan_vids: (list): push the list of vlans on the packet when outputting, with option eth_type
• swap_vid (int): rewrite the vlan vid of the packet when outputting
• failover (dict): Output with a failover port (experimental)

actions_types = {'allow': <class 'int'>, 'force_port_vlan': <class 'int'>, 'meter': <class 'str'>, 'mirror': (<class 'str'>, <class 'int'>), 'output': <class 'dict'>}

build(meters, vid, port_num)
Check that ACL can be built from config.

cHECK_CONFIG()  
Check config at instantiation time for errors, typically via assert.

defaults = {'dot1x_assigned': False, 'exact_match': False, 'rules': None}
defaults_types = {'dot1x_assigned': <class 'bool'>, 'exact_match': <class 'bool'>, 'rules': <class 'list'>}

finalze()  
Configuration parsing marked complete.

get_in_port_match(tunnel_id)
Returns a port number of the src_port of the tunnel that the ingress tunnel ACL will need to match to.
:params tunnel_id: tunnel identifier to obtain the src_port :type tunnel_id: int

    Returns src_port number if it exists, None otherwise

    Return type int OR None

get_meters()  
get_mirror_destinations()  
get_tunnel_id(rule_index)
gets the tunnel ID for the rule
:params rule_index: Index of the tunnel rule in the self.rules list :type rule_index: int

    Returns Identifier for the tunnel

    Return type tunnel_id (int)

get_tunnel_rule_indices()
Get the rules from the rule conf that contain tunnel outputs :returns: list of integer indices into the self.rules
rule list that contain tunnel information :rtype: rules (list)
output_actions_types = {'failover': <class 'dict'>, 'pop_vlans': <class 'int'>, 'port': (<class 'str'>, <class 'int'>), ...

remove_non_tunnel_rules()

Removes all non-tunnel rules from the ACL and removes all match fields and non-tunnel required actions from the tunnel rules

resolve_ports (resolve_port_cb, resolve_tunnel_objects)

tunele_types = {'dp': <class 'str'>, 'port': (<class 'str'>, <class 'int'>), 'tunnel_id': ('str', <class 'int'>)}

unpack_tunnel (tunnel_id)

Retrieves the information from the tunnel dict for the tunnel with id :param tunnel_id: Identifier for the tunnel :type tunnel_id: int

       Returns Tunnel information
       Return type (src_dp, src_port, dst_dp, dst_port)

update_tunnel_acl_conf (dp)

Update the ACL rule conf if the DP is in the path :param dp: The dp that this tunnel acl object belongs to :type dp: DP

       Returns True if any value was updated
       Return type bool

verify_tunnel_rules (dp)

Verify the actions in the tunnel ACL to by making sure the user hasn’t specified an action/match that will create a clash. :param dp: The dp that this tunnel acl object belongs to :type dp: DP

TODO: Choose what combinations of matches & actions to disallow with a tunnel

faucet.check_faucet_config module

Standalone script to check FAUCET configuration, return 0 if provided config OK.

faucet.check_faucet_config.check_config (conf_files, debug_level, check_output_file)

Return True and successful config dict, if all config can be parsed.

faucet.check_faucet_config.main()

Mainline.

faucet.conf module

Base configuration implementation.

class faucet.conf.Conf(_id, dp_id, conf=None)

   Bases: object

   Base class for FAUCET configuration.

   check_config()

      Check config at instantiation time for errors, typically via assert.

   conf_diff (other)

      Return text diff between two Conf.s.

   conf_hash (dyn=False, subconf=True, ignore_keys=None)

      Return hash of keys configurably filtering attributes.
defaults = None
defaults_types = None
dyn_finalized = False
dyn_hash = None

finalize()
    Configuration parsing marked complete.

ignore_subconf(other, ignore_keys=None)
    Return True if this config same as other, ignoring sub config.

merge_dyn(other_conf)
    Merge dynamic state from other conf object.

mutable_attrs = frozenset({})

set_defaults(defaults=None, conf=None)
    Set default values and run any basic sanity checks.

to_conf()
    Return configuration as a dict.

update(conf)
    Parse supplied YAML config and sanity check.

exception faucet.conf.InvalidConfigError
    Bases: Exception
    This error is thrown when the config file is not valid.

faucet.conf.test_config_condition(cond, msg)
    Evaluate condition and raise InvalidConfigError if condition not True.

faucet.config_parser module

Implement configuration file parsing.

faucet.config_parser.dp_parser(config_file, logname, meta_dp_state=None)
    Parse a config file into DP configuration objects with hashes of config include/files.

faucet.config_parser.dp_preparsed_parser(top_confs, meta_dp_state)
    Parse a preparsed (after include files have been applied) FAUCET config.

faucet.config_parser.get_config_for_api(valves)
    Return config as dict for all DPs.

faucet.config_parser.watcher_parser(config_file, logname, prom_client)
    Return Watcher instances from config.
faucet.config_parser_util module

Utility functions supporting FAUCET/Gauge config parsing.

```python
class faucet.config_parser_util.UniqueKeyLoader(stream)
    Bases: yaml.loader.Loader
        construct_mapping(node, deep=False)
            Check for duplicate YAML keys.
```

```python
faucet.config_parser_util.config_changed(top_config_file, new_top_config_file, config_hashes)
    Return True if configuration has changed.

Parameters
- **top_config_file** (**str**) – name of FAUCET config file
- **new_top_config_file** (**str**) – name, possibly new, of FAUCET config file.
- **config_hashes** (**dict**) – map of config file/includes and hashes of contents.

Returns  True if the file, or any file it includes, has changed.
```

```python
faucet.config_parser_util.config_file_hash(config_file_name)
    Return hash of YAML config file contents.
```

```python
faucet.config_parser_util.dp_config_path(config_file, parent_file=None)
    Return full path to config file.
```

```python
faucet.config_parser_util.dp_include(config_hashes, config_contents, config_file, logname, top_confs)
    Handles including additional config files
```

```python
faucet.config_parser_util.get_logger(logname)
    Return logger instance for config parsing.
```

```python
faucet.config_parser_util.read_config(config_file, logname)
    Return a parsed YAML config file or None.
```

faucet.dp module

Configuration for a datapath.

```python
class faucet.dp.DP (_id, dp_id, conf)
    Bases: faucet.conf.Conf
    Stores state related to a datapath controlled by Faucet, including configuration.
```

```python
DEFAULT_LLDP_MAX_PER_INTERVAL = 5
DEFAULT_LLDP_SEND_INTERVAL = 5
```

```python
add_acl(acl_ident, acl)
    Add an ACL to this DP.
```

```python
add_port(port)
    Add a port to this DP.
```

```python
add_router(router_ident, router)
    Add a router to this DP.
```
classmethod add_stack_link(graph, dp, port)  
    Add a stack link to the stack graph.

all_lags_up()  
    Return True if all LAGs have at least one port up.

any_stack_port_up()  
    Return True if any stack port is up.

base_prom_labels()  
    Return base Prometheus labels for this DP.

bgp_routers()  
    Return list of routers with BGP enabled.

static canonical_port_order(ports)

classification_table()  
    Returns classification table

copy_dyn_state(prev_dp)  
    Clone dynamic state for this dp

cold_start(now)  
    Update to reflect a cold start

coprocessor_ports()  
    Return list of coprocessor ports.

default_table_sizes_types = {'classification': <class 'int'>, 'eth_dst': <class 'int'>, 'eth_dst_hairpin': <class 'int'>, ...<class 'int'>, 'port_acl': <class 'int'>, 'vip': <class 'int'>, 'vlan': <class 'int'>, 'vlan_acl': <class 'int'>}
defaults = {'advertise_interval': 30, 'arp_neighbor_timeout': 30, 'cache_update_guard_time': 0, ... True, 'table_sizes': {}, 'timeout': 300, 'use_classification': False, 'use_idle_timeout': False}
defaults_types = {'advertise_interval': <class 'int'>, 'arp_neighbor_timeout': <class 'int'>, 'cache_update_guard_time': <class 'int'>}
dot1x_defaults_types = {'auth_acl': <class 'str'>, 'nfv_intf': <class 'str'>, 'nfv_sw_port': <class 'int'>, 'noauth_acl': <class 'str'>, 'radius_ip': <class 'str'>, 'radius_port': <class 'int'>, 'radius_secret': <class 'str'>}
dot1x_ports()  
    Return list of ports with 802.1x enabled.

finalize()  
    Need to configure OF tables as very last step.

finalize_config(dps)  
    Perform consistency checks after initial config parsing.

finalize_tunnel_acls(dps)  
    Turn off ACLs not in use and resolve the ACL src dp and port.

    Parameters  
    **dps** (list) – DPs.

get_config_changes(logger, new_dp)  
    Detect any config changes.

    Parameters  
    • **logger** (ValveLogger) – logger instance  
    • **new_dp** (DP) – new dataplane configuration.

    Returns  
    changes tuple containing:

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deleted_ports (set): deleted port numbers. changed_ports (set): changed/added port numbers. changed_acl_ports (set): changed ACL only port numbers. deleted_vlans (set): deleted VLAN IDs. changed_vlans (set): changed/added VLAN IDs. all_ports_changed (bool): True if all ports changed. deleted_meters (set): deleted meter numbers changed_meters (set): changed/added meter numbers

Return type (tuple)

get_config_dict ()
    Return DP config as a dict for API call.

get_native_vlan (port_num)
    Return native VLAN for a port by number, or None.

get_node_link_data ()
    Return network stacking graph as a node link representation

get_tables ()
    Return tables as dict for API call.

in_port_tables ()
    Return list of tables that specify in_port as a match.

is_in_path (src_dp, dst_dp)
    Return True if the current DP is in the path from src_dp to dst_dp

    Parameters
    • src_dp (DP) – DP
    • dst_dp (DP) – DP

    Returns True if self is in the path from the src_dp to the dst_dp.

    Return type bool

is_stack_edge ()
    Return True if this DP is a stack edge.

is_stack_root ()
    Return True if this DP is the root of the stack.

is_stack_root_candidate ()
    Return True if this DP could be a root of the stack.

is_transit_stack_switch ()
    Return true if this is a stack switch in reset_refs self.stack might not be configured yet

lacp_ports ()
    Return ports that have LACP.

lacp_up_ports ()
    Return ports that have LACP up.

lags ()
    Return dict of LAGs mapped to member ports.

lags_up ()
    Return dict of LAGs mapped to member ports that have LACP up.

lldp_beacon_defaults_types = {'max_per_interval': <class 'int'>, 'send_interval': <class 'int'>, 'system_name': <class 'str'>}

lldp_beacon_send_ports (now)
    Return list of ports to send LLDP packets; stacked ports always send LLDP.
**match_tables** (*match_type*)
Return list of tables with matches of a specific match type.

**static modify_stack_topology** (*graph, dp, port, add=True*)
Add/remove an edge to the stack graph which originates from this dp and port.

**mutable_attrs = frozenset({'stack', 'vlans'})**

**non_vlan_ports** ()
Ports that don’t have VLANs on them.

**output_table** ()
Returns first output table

**output_tables** ()
Return tables that cause a packet to be forwarded.

**peer_stack_up_ports** (*peer_dp*)
Return list of stack ports that are up towards a peer.

**port_labels** (*port_no*)
Return port name and description labels for a port number.

**port_no_valid** (*port_no*)
Return True if supplied port number valid on this datapath.

**classmethod remove_stack_link** (*graph, dp, port*)
Remove a stack link to the stack graph.

**reset.refs** (*vlans=None*)
Resets VLAN references.

**resolve_port** (*port_name*)
Resolve a port by number or name.

**resolve_stack_topology** (*dps, meta_dp_state*)
Resolve inter-DP config for stacking.

**restricted_bcast_arpnd_ports** ()
Return ports that have restricted broadcast set.

**set_defaults** ()
Set default values and run any basic sanity checks.

**shortest_path** (*dest_dp, src_dp=None*)
Return shortest path to a DP, as a list of DPs.

**shortest_path_port** (*dest_dp*)
Return first port on our DP, that is the shortest path towards dest DP.

**shortest_path_to_root** (*src_dp=None*)
Return shortest path to root DP, as list of DPs.

**stack_defaults_types = {'priority': <class 'int'>}**

**stack_longest_path_to_root_len** ()
Return length of the longest path to root in the stack.

**table_by_id** (*table_id*)
Gets first table with table id
faucet.faucet module

RyuApp shim between Ryu and Valve.

```python
class faucet.faucet.EventFaucetAdvertise
    Bases: ryu.controller.event.EventBase
    Event used to trigger periodic network advertisements (eg IPv6 RAs).

class faucet.faucet.EventFaucetEventSockHeartbeat
    Bases: ryu.controller.event.EventBase
    Event used to trigger periodic events on event sock, causing it to raise an exception if conn is broken.

class faucet.faucet.EventFaucetExperimentalAPIRegistered
    Bases: ryu.controller.event.EventBase
    Event used to notify that the API is registered with Faucet.

class faucet.faucet.EventFaucetFastAdvertise
    Bases: ryu.controller.event.EventBase
    Event used to trigger periodic fast network advertisements (eg LACP).

class faucet.faucet.EventFaucetFastStateExpire
    Bases: ryu.controller.event.EventBase
    Event used to trigger fast expiration of state in controller.

class faucet.faucet.EventFaucetMaintainStackRoot
    Bases: ryu.controller.event.EventBase
    Event used to maintain stack root.

class faucet.faucet.EventFaucetMetricUpdate
    Bases: ryu.controller.event.EventBase
    Event used to trigger update of metrics.

class faucet.faucet.EventFaucetResolveGateways
    Bases: ryu.controller.event.EventBase
    Event used to trigger gateway re/resolution.

class faucet.faucet.EventFaucetStateExpire
    Bases: ryu.controller.event.EventBase
    Event used to trigger expiration of state in controller.

class faucet.faucet.Faucet(*args, **kwargs)
    Bases: faucet.valve_ryuapp.RyuAppBase
    A RyuApp that implements an L2/L3 learning VLAN switch.
    Valve provides the switch implementation; this is a shim for the Ryu event handling framework to interface with Valve.
```

bgp = None

desc_stats_reply_handler (ryu_event)
    Handle OFPDescStatsReply from datapath.

    Parameters
    1. ryu_event (ryu.controller.ofp_event.EventOFPDescStatsReply) – trigger.
error_handler (ryu_event)
Handle an OFPError from a datapath.

Parameters ryu_event (ryu.controller.ofp_event.EventOFPErrorMsg) – trigger

event_socket_heartbeat_time = 0
exc_logname = 'faucet.exception'

features_handler (ryu_event)
Handle receiving a switch features message from a datapath.

Parameters ryu_event (ryu.controller.ofp_event.EventOFFPStateChange) – trigger.

flowremoved_handler (ryu_event)
Handle a flow removed event.

Parameters ryu_event (ryu.controller.ofp_event.EventOFFPFlowRemoved) – trigger.

get_config()
FAUCET experimental API: return config for all Valves.

get_tables (dp_id)
FAUCET experimental API: return config tables for one Valve.

logname = 'faucet'

metric_update (_)
Handle a request to update metrics in the controller.

notifier = None

packet_in_handler (ryu_event)
Handle a packet in event from the dataplane.


port_status_handler (ryu_event)
Handle a port status change event.

Parameters ryu_event (ryu.controller.ofp_event.EventOFFPPortStatus) – trigger.

reload_config (ryu_event)
Handle a request to reload configuration.

start ()
Start controller.

valves_manager = None
faucet.faucet_bgp module

BGP implementation for FAUCET.

class faucet.faucet_bgp.BgpSpeakerKey (dp_id, vlan_vid, ipv)
    Bases: object
    Uniquely describe a BGP speaker.

class faucet.faucet_bgp.FaucetBgp (logger, exc_logname, metrics, send_flow_msgs)
    Bases: object
    Wrapper for Ryu BGP speaker.
    exc_logname = None
      reset (valves)
        Set up a BGP speaker for every VLAN that requires it.
    shutdown_bgp_speakers ()
        Shutdown any active BGP speakers.
    update_metrics (_now)
        Update BGP metrics.

faucet.faucet_dot1x module

802.1x implementation for FAUCET.

class faucet.faucet_dot1x.FaucetDot1x (logger, exc_logname, metrics, send_flow_msgs)
    Bases: object
    Wrapper for experimental Chewie 802.1x authenticator.
    auth_handler (address, port_id, *args, **kwargs)
      Callback for when a successful auth happens.
    create_flow_pair (dp_id, dot1x_port, nfv_sw_port, valve)
      Creates the pair of flows that redirects the eapol packets to/from the supplicant and nfv port
      Parameters
        • dp_id (int) –
        • dot1x_port (Port) –
        • nfv_sw_port (Port) –
        • valve (Valve) –
      Returns list
    create_mab_flow (dp_id, dot1x_port, nfv_sw_port, valve)
      Creates a flow that mirrors UDP packets from port 68 (DHCP) from the supplicant to the nfv port
      Parameters
        • dp_id (int) –
        • dot1x_port (Port) –
        • nfv_sw_port (Port) –
        • valve (Valve) –


Returns list

ex_logname = None

failure_handler (address, port_id)
Callback for when a EAP failure happens.

log_auth_event (valve, port_num, mac_str, status)
Log an authentication attempt event

log_port_event (event_type, port_type, valve, port_num)
Log a dot1x port event

logoff_handler (address, port_id)
Callback for when an EAP logoff happens.

nfv_sw_port_up (dp_id, dot1x_ports, nfv_sw_port)
Setup the dot1x forward port acls when the nfv_sw_port comes up.
.:param dp_id: :type dp_id: int
.:param dot1x_ports: :type dot1x_ports: Iterable of Port objects
.:param nfv_sw_port: :type nfv_sw_port: Port

Returns list of flowmods

port_down (dp_id, dot1x_port, nfv_sw_port)
Remove the acls added by FaucetDot1x.get_port_acls
.:param dp_id: :type dp_id: int
.:param dot1x_port: :type dot1x_port: Port
.:param nfv_sw_port: :type nfv_sw_port: Port

Returns list of flowmods

port_up (dp_id, dot1x_port, nfv_sw_port)
Setup the dot1x forward port acls.
.:param dp_id: :type dp_id: int
.:param dot1x_port: :type dot1x_port: Port
.:param nfv_sw_port: :type nfv_sw_port: Port

Returns list of flowmods

reset (valves)
Set up a dot1x speaker.

set_mac_str (valve, valve_index, port_num)

Parameters

- **valve** (Valve)
- **valve_index** (int)
- **port_num** (int)

Returns str

faucet.faucet_dot1x.get_mac_str (valve_index, port_num)
Gets the mac address string for the valve/port combo
.:param valve_index: The internally used id of the valve.
.:type valve_index: int
.:param port_num: port number
.:type port_num: int

Returns str
faucet.faucet_event module

FAUCET event notification.

class faucet.faucet_event.FaucetEventNotifier(socket_path, metrics, logger)
    Bases: object
    Event notification, via Unix domain socket.
    check_path(socket_path)
        Check that socket_path is valid.
    notify(dp_id, dp_name, event_dict)
        Notify of an event.
    start()
        Start socket server.

class faucet.faucet_event.NonBlockLock
    Bases: object
    Non blocking lock that can be used as a context manager.
    acquire_nonblock()
        Attempt to acquire a lock.
    release()
        Release lock when done.

faucet.faucet_experimental_api module

Implement experimental API.

class faucet.faucet_experimental_api.FaucetExperimentalAPI(*_args, **_kwargs)
    Bases: object
    An experimental API for communicating with Faucet.
    Contains methods for interacting with a running Faucet controller from within a RyuApp. This app should be run together with Faucet in the same ryu-manager process.
    add_port_acl(port, acl)
        Add an ACL to a port.
    add_vlan_acl(vlan, acl)
        Add an ACL to a VLAN.
    delete_port_acl(port, acl)
        Delete an ACL from a port.
    delete_vlan_acl(vlan, acl)
        Delete an ACL from a VLAN.
    get_config()
        Get the current running config of Faucet as a python dictionary.
    get_tables(dp_id)
        Get current FAUCET tables as a dict of table name: table no.
    is_registered()
        Return True if registered and ready to serve API requests.
**Faucet Documentation**

**push_config(config)**
Push supplied config to FAUCET.

**reload_config()**
Reload config from config file in FAUCET_CONFIG env variable.

**faucet.faucet_metadata module**

This module contains code relating to the use of OpenFlow Metadata within Faucet.

**faucet.faucet_metadata.get_egress_metadata(port_num, vid)**
Return the metadata value to output a packet to port port_num on vlan vid.

**faucet.faucet_metrics module**

Implement Prometheus statistics.

**class faucet.faucet_metrics.FaucetMetrics(reg=None)**
Bases: faucet.prom_client.PromClient
Container class for objects that can be exported to Prometheus.

**inc_var(var, labels, val=1)**

**reset_dpid(dp_labels)**
Set all DPID-only counter/gauges to 0.

**faucet.faucet_pipeline module**

Standard FAUCET pipeline.

**class faucet.faucet_pipeline.ValveTableConfig(name, table_id, exact_match=None, meter=None, output=True, miss_goto=None, size=None, match_types=None, set_fields=None, dec_ttl=None, vlan_scale=None, vlan_port_scale=None, next_tables=None, metadata_match=0, metadata_write=0)**
Bases: object
Configuration for a single table.

**faucet.factl module**

Report state based on FAUCET/Gauge/Prometheus variables.

**faucet.factl.decode_value(metric_name, value)**
Convert values to human readable format based on metric name

**faucet.factl.get_samples(endpoints, metric_name, label_matches, nonzero_only=False, retries=3)**
return a list of Prometheus samples for a given metric
Prometheus Sample objects are named tuples with the fields: name, labels, value, timestamp, exemplar.
Faucet Documentation

- **endpoints** (*list of strings*) – the prometheus endpoints to query
- **metric_name** (*string*) – the metric to retrieve
- **label_matches** (*dict*) – filters results by label
- **nonzero_only** (*bool*) – only return samples with non-zero values
- **retries** (*int*) – number of retries when querying

**Returns** list of Prometheus Sample objects

```python
faucet.fctl.main()
faucet.fctl.parse_args(sys_args)
Parse and return CLI args.
faucet.fctl.report_label_match_metrics(report_metrics, metrics, display_labels=None, nonzero_only=False, delim='\n', label_matches=None)
Text report on a list of Prometheus metrics.
faucet.fctl.scrape_prometheus(endpoints, retries=3, err_output_file=<_io.TextIOWrapper name='<stdout>' mode='w' encoding='UTF-8'>)
Scrape a list of Prometheus/FAUCET/Gauge endpoints and aggregate results.
```

**faucet.gauge module**

RyuApp shim between Ryu and Gauge.

```python
class faucet.gauge.Gauge(*args, **kwargs)
Bases: faucet.valve_ryuapp.RyuAppBase
Ryu app for polling Faucet controlled datapaths for stats/state.
It can poll multiple datapaths. The configuration files for each datapath should be listed, one per line, in the file set as the environment variable GAUGE_CONFIG. It logs to the file set as the environment variable GAUGE_LOG,
exc_logname = 'gauge.exception'
logname = 'gauge'
reload_config(ryu_event)
Handle request for Gauge config reload.
updateWatcherHandler(ryu_event)
Handle any kind of stats/change event.
```

faucet.gauge_influx module

Library for interacting with InfluxDB.

class faucet.gauge_influx.GaugeFlowTableInfluxDBLogger (conf, logname, prom_client)
    Bases: faucet.gauge_pollers.GaugeFlowTablePoller, faucet.gauge_influx.InfluxShipper

Example

```bash
> use faucet
Using database faucet
> show series where table_id = '0' and in_port = '2'
key
---
flow_byte_count,dp_name=windscale-faucet-1,eth_type=2048,in_port=2,ip_proto=17,
→priority=9099,table_id=0,udp_dst=53
flow_byte_count,dp_name=windscale-faucet-1,eth_type=2048,in_port=2,ip_proto=6,
→priority=9098,table_id=0,tcp_dst=53
flow_byte_count,dp_name=windscale-faucet-1,in_port=2,priority=9097,table_id=0
flow_packet_count,dp_name=windscale-faucet-1,eth_type=2048,in_port=2,ip_proto=17,
→priority=9099,table_id=0,udp_dst=53
flow_packet_count,dp_name=windscale-faucet-1,eth_type=2048,in_port=2,ip_proto=6,
→priority=9098,table_id=0,tcp_dst=53
flow_packet_count,dp_name=windscale-faucet-1,in_port=2,priority=9097,table_id=0
> select * from flow_byte_count where table_id = '0' and in_port = '2' and ip_
→proto = '17' and time > now() - 5m
name: flow_byte_count
time              arp_tpa  dp_name     eth_dst  eth_src  eth_type  icmpv6_
→type  in_port  ip_proto  ipv4_dst  ipv6_dst  priority  table_id  tcp_dst  udp_dst  value
----  --------  -------  -------  -------  --------  ---------  --------  --------  ------
1501154797000000000 windscale-faucet-1  2048
→  2  17  9099  0  53  9414
1501154857000000000 windscale-faucet-1  2048
→  2  17  9099  0  53  10554
1501154917000000000 windscale-faucet-1  2048
→  2  17  9099  0  53  10554
1501154977000000000 windscale-faucet-1  2048
→  2  17  9099  0  53  12164
1501155037000000000 windscale-faucet-1  2048
→  2  17  9099  0  53  12239
```

class faucet.gauge_influx.GaugePortStateInfluxDBLogger (conf, logname, prom_client)
    Bases: faucet.gauge_pollers.GaugePortStatePoller, faucet.gauge_influx.InfluxShipper
Example

```sql
> use faucet
Using database faucet
> precision rfc3339
> select * from port_state_reason where port_name = 'port1.0.1' order by time desc limit 10;
```

<table>
<thead>
<tr>
<th>time</th>
<th>dp_name</th>
<th>port_name</th>
<th>value</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017-02-21T02:12:29Z</td>
<td>windscale-faucet-1</td>
<td>port1.0.1</td>
<td>2</td>
</tr>
<tr>
<td>2017-02-21T02:12:25Z</td>
<td>windscale-faucet-1</td>
<td>port1.0.1</td>
<td>2</td>
</tr>
<tr>
<td>2016-07-27T22:05:08Z</td>
<td>windscale-faucet-1</td>
<td>port1.0.1</td>
<td>2</td>
</tr>
<tr>
<td>2016-05-25T04:33:00Z</td>
<td>windscale-faucet-1</td>
<td>port1.0.1</td>
<td>2</td>
</tr>
<tr>
<td>2016-05-25T04:32:57Z</td>
<td>windscale-faucet-1</td>
<td>port1.0.1</td>
<td>2</td>
</tr>
<tr>
<td>2016-05-25T04:31:21Z</td>
<td>windscale-faucet-1</td>
<td>port1.0.1</td>
<td>2</td>
</tr>
<tr>
<td>2016-05-25T04:31:18Z</td>
<td>windscale-faucet-1</td>
<td>port1.0.1</td>
<td>2</td>
</tr>
<tr>
<td>2016-05-25T04:27:07Z</td>
<td>windscale-faucet-1</td>
<td>port1.0.1</td>
<td>2</td>
</tr>
<tr>
<td>2016-05-25T04:27:04Z</td>
<td>windscale-faucet-1</td>
<td>port1.0.1</td>
<td>2</td>
</tr>
<tr>
<td>2016-05-25T04:24:53Z</td>
<td>windscale-faucet-1</td>
<td>port1.0.1</td>
<td>2</td>
</tr>
</tbody>
</table>
```

```python
class faucet.gauge_influx.GaugePortStatsInfluxDBlogger (conf, logname, prom_client)
Bases: faucet.gauge_pollers.GaugePortStatsPoller, faucet.gauge_influx.InfluxShipper
```

Periodically sends a port stats request to the datapath and parses and outputs the response.

Example

```sql
> use faucet
Using database faucet
> show measurements
name: measurements
------------------
bytes_in
bytes_out
dropped_in
dropped_out
errors_in
packets_in
packets_out
port_state_reason
> precision rfc3339
> select * from packets_out where port_name = 'port1.0.1' order by time desc limit 10;
```

<table>
<thead>
<tr>
<th>time</th>
<th>dp_name</th>
<th>port_name</th>
<th>value</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017-03-06T05:21:42Z</td>
<td>windscale-faucet-1</td>
<td>port1.0.1</td>
<td>76083431</td>
</tr>
<tr>
<td>2017-03-06T05:21:33Z</td>
<td>windscale-faucet-1</td>
<td>port1.0.1</td>
<td>76081172</td>
</tr>
<tr>
<td>2017-03-06T05:21:22Z</td>
<td>windscale-faucet-1</td>
<td>port1.0.1</td>
<td>76078727</td>
</tr>
<tr>
<td>2017-03-06T05:21:12Z</td>
<td>windscale-faucet-1</td>
<td>port1.0.1</td>
<td>76076612</td>
</tr>
<tr>
<td>2017-03-06T05:21:02Z</td>
<td>windscale-faucet-1</td>
<td>port1.0.1</td>
<td>76074546</td>
</tr>
<tr>
<td>2017-03-06T05:20:52Z</td>
<td>windscale-faucet-1</td>
<td>port1.0.1</td>
<td>76072730</td>
</tr>
<tr>
<td>2017-03-06T05:20:42Z</td>
<td>windscale-faucet-1</td>
<td>port1.0.1</td>
<td>76070528</td>
</tr>
<tr>
<td>2017-03-06T05:20:32Z</td>
<td>windscale-faucet-1</td>
<td>port1.0.1</td>
<td>76068211</td>
</tr>
</tbody>
</table>
```

(continues on next page)
class faucet.gauge_influx.InfluxShipper
    Bases: object

    Convenience class for shipping values to InfluxDB.
    Inheritors must have a WatcherConf object as conf.

    conf = None
    logger = None

    static make_point(*tags, rcv_time, stat_name, stat_val)
        Make an InfluxDB point.

    make_port_point(dp_name, port_name, rcv_time, stat_name, stat_val)
        Make an InfluxDB point about a port measurement.

    ship_error_prefix = 'error shipping points: '
    ship_points(*points)
        Make a connection to InfluxDB and ship points.

faucet.gauge_pollers module

Library for polling dataplanes for statistics.

class faucet.gauge_pollers.GaugeFlowTablePoller(*conf, logname, prom_client)
    Bases: faucet.gauge_pollers.GaugeThreadPoller

    Periodically dumps the current datapath flow table as a yaml object.
    Includes a timestamp and a reference ($DATAPATHNAME-flowtables). The flow table is dumped as an OF-
    FlowStatsReply message (in yaml format) that matches all flows.

    send_req()
        Send a stats request to a datapath.

class faucet.gauge_pollers.GaugeMeterStatsPoller(*conf, logname, prom_client)
    Bases: faucet.gauge_pollers.GaugeThreadPoller

    Poll for all meter stats.

    send_req()
        Send a stats request to a datapath.

class faucet.gauge_pollers.GaugePoller(*conf, logname, prom_client)
    Bases: object

    Abstraction for a poller for statistics.

    static is_active()
        Return True if the poller is controlling the request loop for its stat

    no_response()
        Called when a polling cycle passes without receiving a response.

    report_dp_status(dp_status)
        Report DP status.

2.5. Source Code
running()  
Return True if the poller is running.

send_req()  
Send a stats request to a datapath.

start (ryudp, active)  
Start the poller.

stop()  
Stop the poller.

update (rcv_time, msg)  
Handle the responses to requests.

Called when a reply to a stats request sent by this object is received by the controller.

It should acknowledge the receipt by setting self.reply_pending to false.

Parameters

- rcv_time – the time the response was received
- msg – the stats reply message

class faucet.gauge_pollers.GaugePortStatePoller (conf, logname, prom_client)  
Bases: faucet.gauge_pollers.GaugePoller

Abstraction for port state poller.

no_response()  
Called when a polling cycle passes without receiving a response.

send_req()  
Send a stats request to a datapath.

class faucet.gauge_pollers.GaugePortStatsPoller (conf, logname, prom_client)  
Bases: faucet.gauge_pollers.GaugeThreadPoller

Periodically sends a port stats request to the datapath and parses and outputs the response.

send_req()  
Send a stats request to a datapath.

class faucet.gauge_pollers.GaugeThreadPoller (conf, logname, prom_client)  
Bases: faucet.gauge_pollers.GaugePoller

A ryu thread object for sending and receiving OpenFlow stats requests.

The thread runs in a loop sending a request, sleeping then checking a response was received before sending another request.

The methods send_req, update and no_response should be implemented by subclasses.

is_active()  
Return True if the poller is controlling the request loop for its stat

send_req()  
Send a stats request to a datapath.

start (ryudp, active)  
Start the poller.

stop()  
Stop the poller.
faucet.gauge_prom module

Prometheus for Gauge.

```python
class faucet.gauge_prom.GaugeFlowTablePrometheusPoller (conf, logname, prom_client)
    Bases: faucet.gauge_pollers.GaugeFlowTablePoller

    Export flow table entries to Prometheus.

    update (rcv_time, msg)
        Handle the responses to requests.
        Called when a reply to a stats request sent by this object is received by the controller.
        It should acknowledge the receipt by setting self.reply_pending to false.
        Parameters
        • rcv_time – the time the response was received
        • msg – the stats reply message
```

```python
class faucet.gauge_prom.GaugeMeterStatsPrometheusPoller (conf, logger, prom_client)
    Bases: faucet.gauge_pollers.GaugePortStatsPoller

    Exports meter stats to Prometheus.

    update (rcv_time, msg)
        Handle the responses to requests.
        Called when a reply to a stats request sent by this object is received by the controller.
        It should acknowledge the receipt by setting self.reply_pending to false.
        Parameters
        • rcv_time – the time the response was received
        • msg – the stats reply message
```

```python
class faucet.gauge_prom.GaugePortStatePrometheusPoller (conf, logname, prom_client)
    Bases: faucet.gauge_pollers.GaugePortStatePoller

    Export port state changes to Prometheus.

    update (rcv_time, msg)
        Handle the responses to requests.
        Called when a reply to a stats request sent by this object is received by the controller.
        It should acknowledge the receipt by setting self.reply_pending to false.
        Parameters
        • rcv_time – the time the response was received
        • msg – the stats reply message
```

```python
class faucet.gauge_prom.GaugePortStatsPrometheusPoller (conf, logger, prom_client)
    Bases: faucet.gauge_pollers.GaugePortStatsPoller

    Exports port stats to Prometheus.

    update (rcv_time, msg)
        Handle the responses to requests.
        Called when a reply to a stats request sent by this object is received by the controller.
        It should acknowledge the receipt by setting self.reply_pending to false.
        Parameters
        • rcv_time – the time the response was received
        • msg – the stats reply message
```
It should acknowledge the receipt by setting `self.reply_pending` to false.

**Parameters**

- `rcv_time` – the time the response was received
- `msg` – the stats reply message

```python
class faucet.gauge_prom.GaugePrometheusClient(reg=None)
    Bases: faucet.prom_client.PromClient

    Wrapper for Prometheus client that is shared between all pollers.

    reregister_flow_vars(table_name, table_tags)
        Register the flow variables needed for this client
```

**faucet.meter module**

Configure meters.

```python
class faucet.meter.Meter(_id, dp_id, conf)
    Bases: faucet.conf.Conf

    Implement FAUCET configuration for an OpenFlow meter.

    check_config()
        Check conf at instantiation time for errors, typically via assert.

    defaults = {'entry': None, 'meter_id': None}
    defaults_types = {'entry': <class 'dict'>, 'meter_id': <class 'int'>}

    entry = None
    entry_msg = None
    meter_id = None
```

**faucet.port module**

Port configuration.

```python
class faucet.port.Port(_id, dp_id, conf=None)
    Bases: faucet.conf.Conf

    Stores state for ports, including the configuration.

    actor_init()
        Set the LACP actor state to INIT

    actor_noact()
        Set the LACP actor state to NOACT

    actor_state()
        Return the current LACP actor state

    actor_state_name(state)
        Return the string of the actor state

    actor_up()
        Set the LACP actor state to UP
```
check_config()
    Check config at instantiation time for errors, typically via assert.

coprocessor_defaults_types = {'strategy': <class 'str'>, 'vlan_vid_base': <class 'int'>}
defaults = {'acl_in': None, 'acls_in': None, 'coprocessor': {}, 'description': None}
defaults_types = {'acl_in': (<class 'str'>, <class 'int'>), 'acls_in': <class 'list'>}
deselect_port()
    UNSELECT the current LACP port

finalize()
    Configuration parsing marked complete.

go_get_lacp_flags()
    Get the LACP flags for the state the port is in Return sync, collecting, distributing flag values

hosts (vlans=None)
    Return all host cache entries this port has learned (on all or specified VLANs).

hosts_count (vlans=None)
    Return count of all hosts this port has learned (on all or specified VLANs).

is_actor_init()
    Return true if the LACP actor state is INIT

is_actor_noact()
    Return true if the LACP actor state is NOACT

is_actor_up()
    Return true if the LACP actor state is UP

is_port_selected()
    Return true if the lacp is a SELECTED port

is_port_standby()
    Return true if the lacp is a STANDBY port

is_port_unselected()
    Return true if the lacp is an UNSELECTED port

is_stack_admin_down()
    Return True if port is in ADMIN_DOWN state.

is_stack_bad()
    Return True if port is in BAD state.

is_stack_gone()
    Return True if port is in GONE state.

is_stack_init()
    Return True if port is in INIT state.

is_stack_none()
    Return True if port is in NONE state.

is_stack_up()
    Return True if port is in UP state.

lacp_port_state()
    Return the current LACP port state
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```
lacp_update(lacp_up, now=None, lacp_pkt=None)
   Update the LACP state
   :param lacp_up: The intended LACP/port state
   :type lacp_up: bool
   :param now: Current time
   :param lacp_pkt: Received LACP packet
   Returns dyn_lacp_actor_state, dyn_lacp_current_state

llaep_beacon_defaults_types = {'enable': <class 'bool'>, 'org_tlvs': <class 'list'>,
llaep_beacon_enabled()
   Return True if LLDP beacon enabled on this port.
llaep_org_tlv_defaults_types = {'info': (<class 'str'>, <class 'bytearray'>), 'oui':
mirror_actions()
   Return OF actions to mirror this port.
non_stack_forwading()
   Returns True if port is not-Stacking and, and able to forward packets.
port_role_name(state)
   Return the LACP port role state name
running()
   Return True if port enabled and up.
select_port()
   SELECT the current LACP port
set_defaults()
   Set default values and run any basic sanity checks.
stack_admin_down()
   Change the current stack state to ADMIN_DOWN.
stack_bad()
   Change the current stack state to BAD.
stack_defaults_types = {'dp': <class 'str'>, 'port': (<class 'str'>, <class 'int'>)}
stack_descr()
   "Return stacking annotation if this is a stacking port.
stack_gone()
   Change the current stack state to GONE.
stack_init()
   Change the current stack state to INIT_DOWN.
stack_up()
   Change the current stack state to UP.
standby_port()
   Set the LACP port to STANDBY
vlans()
   Return all VLANs this port is in.
```
**faucet.prom_client module**

Implement Prometheus client.

```python
class faucet.prom_client.PromClient(reg=None):
    Bases: object
    Prometheus client.
    REQUIRED_LABELS = ['dp_id', 'dp_name']
    start(prom_port, prom_addr, use_test_thread=False)
    Start webserver.
faucet.prom_client.make_wsgi_app(registry)
    Create a WSGI app which serves the metrics from a registry.
```

**faucet.router module**

Configure routing between VLANs.

```python
class faucet.router.Router(_id, dp_id, conf):
    Bases: faucet.conf.Conf
    Implement FAUCET configuration for a router.

    bgp_as()
    Return BGP AS.

    bgp_connect_mode()
    Return BGP connect mode.

    bgp_defaults_types = {'as': <class 'int'>, 'connect_mode': <class 'str'>, 'neighbor_addresses': <class 'list'>, ...
    bgp_ipvs()
    Return list of IP versions for BGP configured on this VLAN.

    bgp_neighbor_addresses()
    Return BGP neighbor addresses.

    bgp_neighbor_addresses_by_ipv(ipv)
    Return BGP neighbor addresses with specified IP version on this VLAN.

    bgp_neighbor_as()
    Return BGP neighbor AS number.

    bgp_port()
    Return BGP port.

    bgp_routerid()
    Return BGP router ID.

    bgp_server_addresses()
    Return BGP server addresses.

    bgp_server_addresses_by_ipv(ipv)
    Return BGP server addresses with specified IP version on this VLAN.

    bgp_vlan()
    Return BGP VLAN.

    check_config()
    Check config at instantiation time for errors, typically via assert.
```
defaults = {'bgp': {}, 'vlans': None}
defaults_types = {'bgp': <class 'dict'>, 'vlans': <class 'list'>}

finalize()
Configuration parsing marked complete.

ipaddress_fields = ('neighbor_addresses', 'server_addresses')

set_bgp_vlan(vlan)
Set BGP VLAN.

set_defaults(defaults=None, conf=None)
Set default values and run any basic sanity checks.

vip_map(ipa)
Return VIP for IP address, if any.

faucet.tfm_pipeline module

Configure switch tables with TFM messages.

faucet.tfm_pipeline.fill_required_properties(new_table)
Ensure TFM has all required properties.

faucet.tfm_pipeline.init_table(table_id, name, max_entries, metadata_match, metadata_write)
Initialize a TFM.

faucet.tfm_pipeline.load_tables(dp, valve_cl, max_table_id, min_max_flows, use_oxm_ids, fill_req)
Configure switch tables with TFM messages.

faucet.valve module

Implementation of Valve learning layer 2/3 switch.

class faucet.valve.AlliedTelesis(dp, logname, metrics, notifier, dot1x)
Bases: faucet.valve.OVSValve
Valve implementation for AT.

DEC_TTL = False

acl_manager
dot1x
dp
flood_manager
host_manager
logger
logname
metrics
notifier
ofchannel_logger
pipeline
recent_ofmsgs
class faucet.valve.ArubaValve(dp, logname, metrics, notifier, dot1x):
    Bases: faucet.valve.TfmValve
    Valve implementation for Aruba.
    DEC_TTL = False
    FILL_REQ = False
    acl_manager
    dot1x
    dp
    flood_manager
    host_manager
    logger
    logname
    metrics
    notifier
    ofchannel_logger
    pipeline
    recent_ofmsgs
class faucet.valve.CiscoC9KValve(dp, logname, metrics, notifier, dot1x):
    Bases: faucet.valve.TfmValve
    Valve implementation for C9K.
    acl_manager
    dot1x
    dp
    flood_manager
    host_manager
    logger
    logname
    metrics
    notifier
    ofchannel_logger
    pipeline
    recent_ofmsgs
class faucet.valve.NoviFlowValve(dp, logname, metrics, notifier, dot1x):
    Bases: faucet.valve.Valve
    Valve implementation for NoviFlow with static pipeline.
    STATIC_TABLE_IDS = True
USE_BARRIERS = True

class faucet.valve.OVSTfmValve(dp, logname, metrics, notifier, dot1x)
Bases: faucet.valve.TfmValve
Valve implementation for OVS.
MAX_TABLE_ID = 253
MIN_MAX_FLOWS = 1000000
USE_BARRIERS = False
USE_OXM_IDS = False

class faucet.valve.OVSValve(dp, logname, metrics, notifier, dot1x)
Bases: faucet.valve.Valve
Valve implementation for OVS.
USE_BARRIERS = False

dot1x
dp
flood_manager
host_manager
logger
logname
metrics
notifier
ofchannel_logger
pipeline
recent_ofmsgs
class faucet.valve.TfmValve(dp, logname, metrics, notifier, dot1x)
    Bases: faucet.valve.Valve
    Valve implementation that uses OpenFlow send table features messages.
    FILL_REQ = True
    MAX_TABLE_ID = 0
    MIN_MAX_FLOWS = 0
    USE_OXM_IDS = True
    acl_manager
dot1x
dp
flood_manager
host_manager
logger
logname
metrics
notifier
ofchannel_logger
pipeline
recent_ofmsgs
class faucet.valve.Valve(dp, logname, metrics, notifier, dot1x)
    Bases: object
    Generates the messages to configure a datapath as a l2 learning switch.
    Vendor specific implementations may require sending configuration flows. This can be achieved by inheriting
    from this class and overwriting the function switch_features.
    DEC_TTL = True
    GROUPS = True
STATIC_TABLE_IDS = False
USE_BARRIERS = True

click_manager

add_dot1x_native_vlan(port_num, vlan_name)

add_route(vlan, ip_gw, ip_dst)
    Add route to VLAN routing table.

add_vlan(vlan)
    Configure a VLAN.

add_vlans(vlans)

advertise(now, _other_values)
    Called periodically to advertise services (eg. IPv6 RAs).

close_logs()
    Explicitly close any active loggers.

datapath_connect(now, discovered_up_ports)
    Handle Ryu datapath connection event and provision pipeline.

    Parameters
    • now(float) – current epoch time.
    • discovered_up_ports(set) – datapath port numbers that are up.

    Returns OpenFlow messages to send to datapath.

    Return type list

datapath_disconnect()
    Handle Ryu datapath disconnection event.

del_dot1x_native_vlan(port_num)

del_route(vlan, ip_dst)
    Delete route from VLAN routing table.

del_vlan(vlan)
    Delete a configured VLAN.

del_vlans(vlans)

dot1x

dot1x_event(event_dict)

dp

dp_init(new_dp=None)
    Initialize datapath state at connection/re/config time.

fast_advertise(now, _other_values)
    Called periodically to send LLDP/LACP packets.

fast_state_expire(now, other_valves)
    Called periodically to verify the state of stack ports.

flood_manager

defloods_to_root()
    Return True if our dp floods (only) to root switch
flow_timeout (now, table_id, match)
Call flow timeout message handler:

Parameters

• now (float) – current epoch time.
• table_id (int) – ID of table where flow was installed.
• match (dict) – match conditions for expired flow.

Returns  OpenFlow messages, if any.

Return type  list

get_config_dict ()
Return datapath config as a dict for experimental API.

get_lacp_dpid_nomination (lacp_id, other_valves)
Chooses the DP for a given LAG The DP will be nominated by the following conditions in order:

1) Number of LAG ports
2) Root DP
3) Lowest DPID

Parameters

• lacp_id – The LACP LAG ID
• other_valves (list) – list of other valves

Returns nominated_dpid, reason

get_tunnel_flowmods ()
Returns flowmods for the tunnels

host_manager

lacp_disable_forwarding (port, cold_start=False)
Return OpenFlow messages for initial LACP states and when packets from the link should not be sent through the pipeline

lacp_enable_forwarding (port)
Enables packets from the LAG link to progress through the pipeline also recomputes the flooding & host rules
Should only be called when a LACP port is both ACTOR_UP & SELECTED Return OpenFlow messages when LACP is UP and SELECTED on a port

lacp_handler (now, pkt_meta, other_valves)

Returns  dict: OpenFlow messages, if any by Valve

lacp_update (port, lacp_up, now=None, lacp_pkt=None, other_valves=None, cold_start=False)
Update the port’s LACP states and enables/disables packets from the link to be processed further through the pipeline based on the state changes

Parameters
• **port** – The port the packet is being received on
• **lACP\_up (bool)** – Whether the lACP actor is up
• **now (float)** – The current time
• **lACP\_pkt (PacketMeta)** – The received LACP packet
• **other\_valves (list)** – List of other valves (in the stack)
• **cold\_state (bool)** – Whether Faucet is being cold started or not

**Returns** ofmsgs

**lACP\_update\_actor\_state (port, lACP\_up, now=None, lACP\_pkt=None)**
Updates a LAG actor state

:param port: LACP port
:type port: Port
:param lacp\_up: Whether LACP is going UP or DOWN
:type lacp\_up: bool
:param now: Current epoch time
:type now: float
:param lacp\_pkt: LACP packet
:type lacp\_pkt: PacketMeta

**Returns** True if LACP state changed

**Return type** bool

**lACP\_update\_port\_selection\_state (port, other\_valves=None)**
Update the LACP port selection state

:param port: LACP port
:type port: Port
:param port: Port
:type port: Port
:param other\_valves: List of other valves
:type other\_valves: list

**Returns** True if port state changed

**Return type** bool

**learn\_host (now, pkt\_meta, other\_valves)**
Possibly learn a host on a port.

**Parameters**

- **now (float)** – current epoch time.
- **pkt\_meta (PacketMeta)** – PacketMeta instance for packet received.
- **other\_valves (list)** – all Valves other than this one.

**Returns** OpenFlow messages, if any.

**Return type** list

**lldp\_handler (now, pkt\_meta, other\_valves)**
Handle an LLDP packet.

**Parameters**

- **pkt\_meta (PacketMeta)** – packet for control plane.

**logger**

**logname**

**metrics**

**notifier**

**notify (event\_dict)**
Send an event notification.

**ofchannel\_log (ofmsgs)**
Log OpenFlow messages in text format to debugging log.

**ofchannel\_logger**
ofdescstats_handler(body)
Handle OF DP description.

oferror(msg)
Correlate OFError message with flow we sent, if any.

Parameters msg(ryu.controller.ofp_event.EventOFPMsgBase) – message from datapath.

parse_pkt_meta(msg)
Parse OF packet-in message to PacketMeta.

parse_rcv_packet(in_port, vlan_vid, eth_type, data, orig_len, pkt, eth_pkt, vlan_pkt)
Parse a received packet into a PacketMeta instance.

Parameters

• in_port(int) – port packet was received on.
• vlan_vid(int) – VLAN VID of port packet was received on.
• eth_type(int) – Ethernet type of packet.
• data(bytes) – Raw packet data.
• orig_len(int) – Original length of packet.
• pkt(ryu.lib.packet.packet) – parsed packet received.
• eth_pkt(ryu.lib.packet.ethernet) – parsed Ethernet header.
• vlan_pkt(ryu.lib.packet.vlan) – parsed VLAN Ethernet header.

Returns PacketMeta instance.

pipeline

port_add(port_num)
Handle addition of a single port.

Parameters port_num(list) – list of port numbers.

Returns OpenFlow messages, if any.

Return type list

port_delete(port_num, keep_cache=False, other_valves=None)
Return flow messages that delete port from pipeline.

port_status_handler(port_no, reason, state, _other_valves, now)
Return OpenFlow messages responding to port operational status change.

ports_add(port_nums, cold_start=False, log_msg='up')
Handle the addition of ports.

Parameters

• port_num(list) – list of port numbers.
• cold_start(bool) – True if configuring datapath from scratch.

Returns OpenFlow messages, if any.

Return type list

ports_delete(port_nums, log_msg='down', keep_cache=False, other_valves=None)
Handle the deletion of ports.
Parameters **port_nums** *(list)* – list of port numbers.

Returns OpenFlow messages, if any.

Return type list

**prepare_send_flows** *(flow_msgs)*
Prepare to send flows to datapath.

Parameters **flow_msgs** *(list)* – OpenFlow messages to send.

**rate_limit_packet_ins** *(now)*
Return True if too many packet ins this second.

**rcv_packet** *(now, other_valves, pkt_meta)*
Handle a packet from the dataplane (eg to re/learn a host).

The packet may be sent to us also in response to FAUCET initiating IPv6 neighbor discovery, or ARP, to resolve a nexthop.

Parameters

- **other_valves** *(list)* – all Valves other than this one.
- **pkt_meta** *(PacketMeta)* – packet for control plane.

Returns OpenFlow messages, if any by Valve.

Return type dict

**recent_ofmsgs**

**reload_config** *(now, new_dp)*
Reload configuration new_dp.

Following config changes are currently supported:

- Port config: support all available configs (e.g. native_vlan, acl_in) & change operations (add, delete, modify) a port
- ACL config: support any modification, currently reload all rules belonging to an ACL
- VLAN config: enable, disable routing, etc...

Parameters

- **now** *(float)* – current epoch time.
- **new_dp** *(DP)* – new dataplane configuration.

Returns OpenFlow messages.

Return type ofmsgs (list)

**resolve_gateways** *(now, _other_valves)*
Call route managers to re/resolve gateways.

Returns OpenFlow messages, if any by Valve.

Return type dict

**router_learn_host** *(pkt_meta)*
Add L3 forwarding rule.

Parameters **pkt_meta** *(PacketMeta)* – PacketMeta instance for packet received.

Returns OpenFlow messages, if any.
**Faucet Documentation**

**Return type** list

`router_rcv_packet (now, pkt_meta)`

Process packets destined for router or run resolver.

**Parameters**
- `now (float)` – current epoch time.
- `pkt_meta (PacketMeta)` – packet for control plane.

**Returns** OpenFlow messages.

**Return type** list

`router_vlan_for_ip_gw (vlan, ip_gw)`

`send_flows (ryu_dp, flow_msgs)`

Send flows to datapath (or disconnect an OF session).

**Parameters**
- `flow_msgs (list)` – OpenFlow messages to send.

`state_expire (now, other_valves)`

Expire controller caches/state (e.g. hosts learned).

**Parameters**
- `now (float)` – current epoch time.
- `other_valves (list)` – all Valves other than this one.

**Returns** OpenFlow messages, if any by Valve.

**Return type** dict

`switch_features (_msg)`

Send configuration flows necessary for the switch implementation.

**Parameters**
- `msg (OFPSwitchFeatures)` – msg sent from switch.

Vendor specific configuration should be implemented here.

`update_config_metrics ()`

Update table names for configuration.

`update_metrics (now, updated_port=None, rate_limited=False)`

Update Gauge/metrics.

`update_tunnel_flowrules ()`

Update tunnel ACL rules because the stack topology has changed

**class faucet.valve.ValveLogger (logger, dp_id, dp_name)**

**Bases:** object

Logger for a Valve that adds DP ID.

`debug (log_msg)`

Log debug level message.

`error (log_msg)`

Log error level message.

`info (log_msg)`

Log info level message.
warning (log_msg)
   Log warning level message.

faucet.valve.valve_factory (dp)
   Return a Valve object based dp’s hardware configuration field.

   Parameters dp (DP) – DP instance with the configuration for this Valve.

faucet.valve_acl module

Compose ACLs on ports.

class faucet.valve_acl.ValveAclManager (port_acl_table, vlan_acl_table, egress_acl_table, pipeline, meters, dp_acls=None)

   Bases: faucet.valve_manager_base.ValveManagerBase

   Handle installation of ACLs on a DP

   add_authed_mac (port_num, mac)
      Add authed mac address

   add_port (port)
      Install port acls if configured

   add_port_acl (acl, port_num, mac=None)
      Create ACL openflow rules for Port

   add_vlan (vlan)
      Install vlan acls if configured

   cold_start_port (port)
      Reload acl for a port by deleting existing rules and calling add_port

   create_acl_tunnel (dp)
      Create tunnel acls from ACLs that require applying in DP Returns flowmods for the tunnel
      :param dp: DP that contains the tunnel acls to build
      :type dp: DP

   create_dot1x_flow_pair (port_num, nfv_sw_port_num, mac)
      Create dot1x flow pair

   create_mab_flow (port_num, nfv_sw_port_num, mac)
      Create MAB ACL for sending IP Activity to Chewie NFV
      Returns flowmods to send all IP traffic to Chewie

      Parameters
      • port_num (int) – Number of port in
      • nfv_sw_port_num (int) – Number of port out
      • mac (str) – MAC address of the valve/port combo

   del_authed_mac (port_num, mac=None, strict=True)
      remove authed mac address

   del_dot1x_flow_pair (port_num, nfv_sw_port_num, mac)
      Deletes dot1x flow pair

   del_mab_flow (port_num, nfv_sw_port_num, mac)
      Remove MAB ACL for sending IP Activity to Chewie NFV
      Returns flowmods to send all IP traffic to Chewie
Parameters

- **port_num** *(int)* – Number of port in
- **nfv_sw_port_num** *(int)* – Number of port out
- **mac** *(str)* – MAC address of the valve/port combo

```python
def del_port_acl(acl, port_num, mac=None)
    # Delete ACL rules for Port
```

```python
def initialise_tables()
    # Install dp acls if configured
```

```python
faucet.valve_acl.add_mac_address_to_match(match, eth_src)
    # Add or change the value of a match type
```

```python
faucet.valve_acl.build_acl_entry(acl_table, rule_conf, meters, acl_allow_inst, acl_force_port_vlan_inst, port_num=None, vlan_vid=None)
    # Build flow/groupmods for one ACL rule entry.
```

```python
faucet.valve_acl.build_acl_ofmsgs(acls, acl_table, acl_allow_inst, acl_force_port_vlan_inst, highest_priority, meters, exact_match, port_num=None, vlan_vid=None)
    # Build flow/groupmods for all entries in an ACL.
```

```python
faucet.valve_acl.build_acl_port_of_msgs(acl, vid, port_num, acl_table, goto_table, priority)
    # A Helper function for building Openflow Mod Messages for Port ACLs
```

```python
faucet.valve_acl.build_output_actions(acl_table, output_dict)
    # Implement actions to alter packet/output.
```

```python
faucet.valve_acl.push_vlan(acl_table, vlan_vid)
    # Push a VLAN tag with optional selection of eth type.
```

```python
faucet.valve_acl.rewrite_vlan(acl_table, output_dict)
    # Implement actions to rewrite VLAN headers.
```

### faucet.valve_flood module

Manage flooding to ports on VLANs.

```python
class faucet.valve_flood.ValveFloodManager(logger, flood_table, pipeline, use_group_table, groups, combinatorial_port_flood, canonical_port_order, restricted_bcast_arps)

    Bases: faucet.valve_manager_base.ValveManagerBase
```

Implement dataplane based flooding for standalone dataplanes.

```python
FLOOD_DSTS = ((True, None, None, None), (False, None, '01:80:c2:00:00:00', 'ff:ff:ff:ff:ff:ff'))
RESTRICTED_FLOOD_DSTS = ((False, 2054, '33:33:00:00:00:01', 'ff:ff:ff:ff:ff:ff'), (False, 2054, '33:33:00:00:00:02', 'ff:ff:ff:ff:ff:ff'), (False, 2054, 'ff:ff:ff:ff:ff:ff', 'ff:ff:ff:ff:ff:ff'))
```

```python
faucet.valve_flood.add_vlan(vlan)
    # install flows in response to a new VLAN
```

```python
faucet.valve_flood.build_flood_rules(vlan, modify=False)
    # Add flows to flood packets to unknown destinations on a VLAN.
```

```python
faucet.valve_flood.del_vlan(vlan)
    # delete flows in response to a VLAN removal
```
static edge_learn_port (_other_valves, pkt_meta)
    Possibly learn a host on a port.

    Parameters
    • **other_valves** (list) – All Valves other than this one.
    • **pkt_meta** (PacketMeta) – PacketMeta instance for packet received.

    Returns port to learn host on.

floods_to_root (_dp_obj)
    Return True if the given dp floods (only) to root switch

initialise_tables ()
    Initialise the flood table with filtering flows.

static update_stack_topo (event, dp, port)
    Update the stack topology. It has nothing to do for non-stacking DPs.

update_vlan (vlan)
    flows in response to updating an existing VLAN.

class faucet.valve_flood.ValveFloodStackManagerBase (logger, flood_table, pipeline,
    use_group_table, groups,
    combinatorial_port_flood,
    canonical_port_order,
    restricted_bcast_arpnd,
    stack_ports, hasExternals,
    dp_shortest_path_to_root, shortest_path_port,
    is_stack_root,
    is_stack_root_candidate,
    is_stack_edge, graph)

    Bases: faucet.valve_flood.ValveFloodManager

    Base class for dataplane based flooding on stacked dataplanes.

def edge_learn_port (other_valves, pkt_meta)
    Find a port towards the edge DP where the packet originated from

    Parameters
    • **other_valves** (list) – All Valves other than this one.
    • **pkt_meta** (PacketMeta) – PacketMeta instance for packet received.

    Returns port to learn host on, or None.

def shortest_path_root (edge_dp_name)
    Return the port along the shortest path to/from root for edge learning

update_stack_topo (event, dp, port)
    Update the stack topo according to the event.
class faucet.valve_flood.ValveFloodStackManagerNoReflection (logger, flood_table, pipeline, use_group_table, groups, combinatorial_port_flood, canonical_port_order, restricted_bcast_arpnd, stack_ports, hasexternals, dp_shortest_path_to_root, shortest_path_port, is_stack_root, is_stack_root_candidate, is_stack_edge, graph)

Bases: faucet.valve_flood.ValveFloodStackManagerBase

Stacks of size 2 - all switches directly connected to root.

Root switch simply floods to all other switches.

Non-root switches simply flood to the root.

class faucet.valve_flood.ValveFloodStackManagerReflection (logger, flood_table, pipeline, use_group_table, groups, combinatorial_port_flood, canonical_port_order, restricted_bcast_arpnd, stack_ports, hasexternals, dp_shortest_path_to_root, shortest_path_port, is_stack_root, is_stack_root_candidate, is_stack_edge, graph)

Bases: faucet.valve_flood.ValveFloodStackManagerBase

Stacks size > 2 reflect floods off of root (selective flooding).

<table>
<thead>
<tr>
<th>Hosts</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>-----+-----+-----+</td>
</tr>
<tr>
<td>1+---+</td>
</tr>
<tr>
<td>24+++</td>
</tr>
<tr>
<td>34+++</td>
</tr>
<tr>
<td>5++++5</td>
</tr>
<tr>
<td>++---+</td>
</tr>
<tr>
<td>Root DP</td>
</tr>
</tbody>
</table>

Non-root switches flood only to the root. The root switch reflects incoming floods back out. Non-root switches flood packets from the root locally and to switches further away from the root. Flooding is entirely implemented in the dataplane.
A host connected to a non-root switch can receive a copy of its own flooded packet (because the non-root switch
does not know it has seen the packet already).

A host connected to the root switch does not have this problem (because flooding is always away from the root).
Therefore, connections to other non-FAUCET stacking networks should only be made to the root.

On the root switch (left), flood destinations are:
1: 2 3 4 5(s) 2: 1 3 4 5(s) 3: 1 2 4 5(s) 4: 1 2 3 5(s) 5: 1 2 3 4 5(s, note reflection)

On the middle switch:
1: 5(s) 2: 5(s) 3: 5(s) 4: 5(s) 5: 1 2 3 4 6(s) 6: 5(s)

On the rightmost switch:
1: 5(s) 2: 5(s) 3: 5(s) 4: 5(s) 5: 1 2 3 4

**faucet.valve_host module**

Manage host learning on VLANs.

```python
class faucet.valve_host.ValveHostFlowRemovedManager(logger, ports, vlans, 
eth_src_table, eth_dst_table, 
ethDstHairpinTable, 
pipeline, learn_timeout, learn_jitter, learn_ban_timeout, 
cache_update_guard_time, idle_dst, stack, has_externals, 
stack_root_flood_reflection)
```

**Note:** not currently reliable.

```python
expire_hosts_from_vlan(_vlan, _now)
   Expire hosts from VLAN cache.

flow_timeout(now, table_id, match)
   Handle a flow timed out message from dataplane.

learn_host_timeouts(port, eth_src)
   Calculate flow timeouts for learning on a port.
```

```python
class faucet.valve_host.ValveHostManager(logger, ports, vlans, 
eth_src_table, eth_dst_table, 
ethDstHairpinTable, 
pipeline, learn_timeout, learn_jitter, learn_ban_timeout, 
cache_update_guard_time, idle_dst, stack, has_externals, 
stack_root_flood_reflection)
```

**Bases:** faucet.valve_host.ValveHostManager

Trigger relearning on flow removed notifications.

```python
add_port(port)
   install flows in response to a new port

add_vlan(vlan)
   install flows in response to a new VLAN
```
**ban_rules** (*pkt_meta*)

Limit learning to a maximum configured on this port/VLAN.

**Parameters**

- **pkt_meta** – PacketMeta instance.

**Returns**

OpenFlow messages, if any.

**Return type**

list

**del_port** (*port*)

delete flows in response to a port removal

**delete_host_from_vlan** (*eth_src, vlan*)

Delete a host from a VLAN.

**expire_hosts_from_vlan** (*vlan, now*)

Expire hosts from VLAN cache.

**flow_timeout** (*_now, _table_id, _match*)

Handle a flow timed out message from dataplane.

**learn_host_intervlan_routing_flows** (*port, vlan, eth_src, eth_dst*)

Returns flows for the eth_src_table that enable packets that have been routed to be accepted from an adjacent DP and then switched to the destination. Eth_src_table flow rule to match on port, eth_src, eth_dst and vlan

**Parameters**

- **port** (*Port*) – Port to match on.
- **vlan** (*VLAN*) – VLAN to match on
- **eth_src** – source MAC address (should be the router MAC)
- **eth_dst** – destination MAC address

**learn_host_on_vlan_port_flows** (*port, vlan, eth_src, delete_existing, refresh_rules, src_rule_idle_timeout, src_rule_hard_timeout, dst_rule_idle_timeout*)

Return flows that implement learning a host on a port.

**learn_host_on_vlan_ports** (*now, port, vlan, eth_src, delete_existing=True, last_dp_coldstart_time=None*)

Learn a host on a port.

**learn_host_timeouts** (*port, eth_src*)

Calculate flow timeouts for learning on a port.

---

**faucet.valve_manager_base module**

Valve Manager base class

**class faucet.valve_manager_base.ValveManagerBase**

**Bases:** object

Base class for ValveManager objects.

Expected to control the installation of flows into datapath tables.

Ideally each datapath table should be controlled by 1 manager only.
**Faucet Documentation**

- **add_port**(port)
  - install flows in response to a new port

- **add_vlan**(vlan)
  - install flows in response to a new VLAN

- **del_port**(port)
  - delete flows in response to a port removal

- **del_vlan**(vlan)
  - delete flows in response to a VLAN removal

- **initialise_tables**()
  - initialise tables controlled by this manager.

- **update_vlan**(vlan)
  - flows in response to updating an existing VLAN.

---

**faucet.valve_of module**

Utility functions to parse/create OpenFlow messages.

- **faucet.valve_of.apply_actions**(actions)
  - Return instruction that applies action list.
  
  **Parameters**
  
  - **actions**(list) – list of OpenFlow actions.
  
  **Returns**
  
  - instruction of actions.
  
  **Return type**
  
  - ryu.ofproto.ofproto_v1_3_parser.OFPInstruction

- **faucet.valve_of.apply_meter**(meter_id)
  - Return instruction to apply a meter.

- **faucet.valve_of.barrier**
  - Return OpenFlow barrier request.

  **Returns**
  
  - barrier request.

  **Return type**
  
  - ryu.ofproto.ofproto_v1_3_parser.OFPBarrierRequest

- **faucet.valve_of.bucket**(weight=0, watch_port=4294967295, watch_group=4294967295, actions=None)
  - Return a group action bucket with provided actions.

- **faucet.valve_of.build_group_flood_buckets**(vlan_floodActs)
  - Return a list of group buckets to implement flooding on a VLAN.

- **faucet.valve_of.build_match_dict**

- **faucet.valve_of.controller_pps_meteradd**(datapath=None, pps=0)
  - Add a PPS meter towards controller.

- **faucet.valve_of.controller_pps_meterdel**(datapath=None)
  - Delete a PPS meter towards controller.

- **faucet.valve_of.dec_ip_ttl**()
  - Return OpenFlow action to decrement IP TTL.

  **Returns**
  
  - decrement IP TTL.

  **Return type**
  
  - ryu.ofproto.ofproto_v1_3_parser.OFPActionDecNwTtl
faucet.valve_of.dedupe_ofmsgs (input_ofmsgs, random_order)
    Return deduplicated ofmsg list.

faucet.valve_of.dedupe_output_portActs (output_portActs)
    Deduplicate parser.OFPActionOutputs (because Ryu doesn’t define __eq__).

    **Parameters**
    parser.OFPActionOutput (list) – output to port actions.

    **Returns**
    output to port actions.

faucet.valve_of.desc_stats_request (datapath=None)
    Query switch description.

faucet.valve_of.devid_present (vid)
    Return VLAN VID without VID_PRESENT flag set.

    **Parameters**
    vid (int) – VLAN VID with VID_PRESENT.

    **Returns**
    VLAN VID.

    **Return type**
    int

faucet.valve_of.faucet_async (datapath=None, notify_flow_removed=False, packet_in=True, port_status=True)
    Return async message config for FAUCET/Gauge

faucet.valve_of.faucet_config (datapath=None)
    Return switch config for FAUCET.

faucet.valve_of.flood_port_outputs (tagged_ports, untagged_ports, in_port=None, exclude_ports=None)
    Return actions for both tagged and untagged ports.

faucet.valve_of.flood_tagged_port_outputs (ports, in_port=None, exclude_ports=None)
    Return list of actions necessary to flood to list of tagged ports.

faucet.valve_of.flood_untagged_port_outputs (ports, in_port=None, exclude_ports=None)
    Return list of actions necessary to flood to list of untagged ports.

faucet.valve_of.flowmod (cookie, command, table_id, priority, out_port, out_group, match_fields, inst, hard_timeout, idle_timeout, flags=0)

faucet.valve_of.goto_table (table)
    Return instruction to goto table.

    **Parameters**
    table (ValveTable) – table to goto.

    **Returns**
    goto instruction.

    **Return type**
    ryu.ofproto.ofproto_v1_3_parser.OFPInstruction

faucet.valve_of.group_act (group_id)
    Return an action to run a group.

faucet.valve_of.groupadd (datapath=None, type_=0, group_id=0, buckets=None)
    Add a group.

faucet.valve_of.groupadd_ff (datapath=None, group_id=0, buckets=None)
    Add a fast failover group.

faucet.valve_of.groupdel (datapath=None, group_id=4294967292)
    Delete a group (default all groups).
faucet.valve_of.groupmod(datapath=None, type_=0, group_id=0, buckets=None)
    Modify a group.

faucet.valve_of.groupmod_ff(datapath=None, group_id=0, buckets=None)
    Modify a fast failover group.

faucet.valve_of.ignore_port(port_num)
    Return True if FAUCET should ignore this port.

    Parameters
    port_num (int) -- switch port.

    Returns
    True if FAUCET should ignore this port.

    Return type
    bool

faucet.valve_of.is_apply_actions(instruction)
    Return True if an apply action.

    Parameters
    instruction -- OpenFlow instruction.

    Returns
    True if an apply action.

    Return type
    bool

faucet.valve_of.is_flowdel(ofmsg)
    Return True if flow message is a FlowMod and a delete.

    Parameters
    ofmsg -- ryu.ofproto.ofproto_v1_3_parser message.

    Returns
    True if is a FlowMod delete/strict.

    Return type
    bool

faucet.valve_of.is_flowmod(ofmsg)
    Return True if flow message is a FlowMod.

    Parameters
    ofmsg -- ryu.ofproto.ofproto_v1_3_parser message.

    Returns
    True if is a FlowMod

    Return type
    bool

faucet.valve_of.is_global_flowdel(ofmsg)
    Is a delete of all flows in all tables.

faucet.valve_of.is_global_groupdel(ofmsg)
    Is a delete of all groups.

faucet.valve_of.is_global_meterdel(ofmsg)
    Is a delete of all meters.

faucet.valve_of.is_groupadd(ofmsg)
    Return True if OF message is a GroupMod and command is add.

    Parameters
    ofmsg -- ryu.ofproto.ofproto_v1_3_parser message.

    Returns
    True if is a GroupMod add

    Return type
    bool

faucet.valve_of.is_groupdel(ofmsg)
    Return True if OF message is a GroupMod and command is delete.

    Parameters
    ofmsg -- ryu.ofproto.ofproto_v1_3_parser message.

    Returns
    True if is a GroupMod delete

    Return type
    bool
faucet.valve_of.is_groupmod(ofmsg)
    Return True if OF message is a GroupMod.
    Parameters ofmsg – ryu.ofproto.ofproto_v1_3_parser message.
    Returns True if is a GroupMod
    Return type bool

faucet.valve_of.is_meter(instruction)
    Return True if a meter.
    Parameters instruction – OpenFlow instruction.
    Returns True if a meter.
    Return type bool

faucet.valve_of.is_meteradd(ofmsg)
    Return True if OF message is a MeterMod and command is add.
    Parameters ofmsg – ryu.ofproto.ofproto_v1_3_parser message.
    Returns True if is a MeterMod add
    Return type bool

faucet.valve_of.is_meterdel(ofmsg)
    Return True if OF message is a MeterMod and command is delete.
    Parameters ofmsg – ryu.ofproto.ofproto_v1_3_parser message.
    Returns True if is a MeterMod delete
    Return type bool

faucet.valve_of.is_metermod(ofmsg)
    Return True if OF message is a MeterMod.
    Parameters ofmsg – ryu.ofproto.ofproto_v1_3_parser message.
    Returns True if is a MeterMod
    Return type bool

faucet.valve_of.is_output(ofmsg)
    Return True if flow message is an action output message.
    Parameters ofmsg – ryu.ofproto.ofproto_v1_3_parser message.
    Returns True if is a OFPActionOutput.
    Return type bool

faucet.valve_of.is_packetout(ofmsg)
    Return True if OF message is a PacketOut
    Parameters ofmsg – ryu.ofproto.ofproto_v1_3_parser message.
    Returns True if is a PacketOut
    Return type bool

faucet.valve_of.is_set_field(action)

faucet.valve_of.is_table_features_req(ofmsg)
    Return True if flow message is a TFM req.
    Parameters ofmsg – ryu.ofproto.ofproto_v1_3_parser message.
Faucet Documentation

Returns True if is a TFM req.

Return type bool

faucet.valve_of.match(match_fields)
Return OpenFlow matches from dict.

Parameters match_fields(dict) – match fields and values.

Returns matches.

Return type ryu.ofproto.ofproto_v1_3_parser.OFPMatch

faucet.valve_of.match_from_dict(match_dict)

faucet.valve_of.metadata_goto_table(metadata, mask, table)
Return instructions to write metadata and goto table.

Parameters
• metadata(int) – metadata to write to packet
• mask(int) – mask to apply to metadata
• table(ValveTable) – table to goto.

Returns list of OFPInstructions

faucet.valve_of.meteradd(meter_conf, command=0)
Add a meter based on YAML configuration.

faucet.valve_of.meterdel(datapath=None, meter_id=4294967295)
Delete a meter (default all meters).

faucet.valve_of.output_controller
Return OpenFlow action to packet in to the controller.

Parameters max_len(int) – max number of bytes from packet to output.

Returns packet in action.

Return type ryu.ofproto.ofproto_v1_3_parser.OFPActionOutput

faucet.valve_of.output_in_port
Return OpenFlow action to output out input port.

Returns ryu.ofproto.ofproto_v1_3_parser.OFPActionOutput.

faucet.valve_of.output_non_output_actions
Split output actions into deduped actions, output ports, and non-output port actions.

Parameters of ryu.ofproto.ofproto_v1_3_parser.OFPActions(list) – flood actions.

Returns set of deduped actions, output ports, and non-output actions.

faucet.valve_of.output_port
Return OpenFlow action to output to a port.

Parameters
• port_num(int) – port to output to.
• max_len(int) – maximum length of packet to output (default no maximum).

Returns output to port action.

Return type ryu.ofproto.ofproto_v1_3_parser.OFPActionOutput
faucet.valve_of.packetout \((\text{port\_num}, \text{data})\)
Return OpenFlow action to packet out to dataplane from controller.

Parameters

- **port\_num** \((\text{int})\) – port to output to.
- **data** \((\text{str})\) – raw packet to output.

Returns packet out action.

Return type ryu.ofproto.ofproto_v1_3_parser.OFPActionOutput

faucet.valve_of.packetouts \((\text{port\_nums}, \text{data})\)
Return OpenFlow action to multiply packet out to dataplane from controller.

Parameters

- **port\_num** \((\text{list})\) – ints, ports to output to.
- **data** \((\text{str})\) – raw packet to output.

Returns packet out action.

Return type ryu.ofproto.ofproto_v1_3_parser.OFPActionOutput

faucet.valve_of.pop_vlan
Return OpenFlow action to pop outermost Ethernet 802.1Q VLAN header.

Returns Pop VLAN.

Return type ryu.ofproto.ofproto_v1_3_parser.OFPActionPopVlan

faucet.valve_of.port_status_from_state \((\text{state})\)
Return True if OFPPS_LINK_DOWN is not set.

faucet.valve_of.ports_from_output_port_acts \((\text{output\_port\_acts})\)
Return unique port numbers from OFPActionOutput actions.

Parameters of ryu.ofproto.ofproto_v1_3_parser.OFPActionOutput \((\text{list})\) – output to port actions.

Returns set of port number ints.

faucet.valve_of.push_vlan_act
Return OpenFlow action list to push Ethernet 802.1Q header with VLAN VID.

Parameters **vid** \((\text{int})\) – VLAN VID.

Returns actions to push 802.1Q header with VLAN VID set.

Return type list

faucet.valve_of.set_field(**kwds)**
Return action to set any field.

Parameters **kwds** \((\text{dict})\) – exactly one field to set

Returns set field action.

Return type ryu.ofproto.ofproto_v1_3_parser.OFPActionSetField

faucet.valve_of.slowpath_pps_meteradd \((\text{datapath=}\text{None}, \text{pps=0})\)
Add a PPS meter towards controller.

faucet.valve_of.slowpath_pps_meterdel \((\text{datapath=}\text{None})\)
Delete a PPS meter towards controller.
faucet.valve_of.table_features(body)

faucet.valve_of.valve_flowreorder(input_ofmsgs, use_barriers=True)
    Reorder flows for better OFA performance.

faucet.valve_of.valve_match_vid

faucet.valve_of.vid_present(vid)
    Return VLAN VID with VID_PRESENT flag set.
    Parameters vid(int) – VLAN VID
    Returns VLAN VID with VID_PRESENT.
    Return type int

faucet.valve_of_old module

Deprecated OF matches.

faucet.valve_packet module

Utility functions for parsing and building Ethernet packet/contents.

class faucet.valve_packet.PacketMeta(data, orig_len, pkt, eth_pkt, vlan_pkt, port, valve_vlan, eth_src, eth_dst, eth_type)

    Bases: object
    Original, and parsed Ethernet packet metadata.

    ETH_TYPES_PARSERS = {2048: (4, <functools._lru_cache_wrapper object>, <class 'ryu.lib.packet.ipv4.ipv4'>), 2054: (None, None, <class 'ryu.lib.packet.arp.arp'>), 34525: (6, None, <class 'ryu.lib.packet.ipv6.ipv6'>)}

    MAX_ETH_TYPE_PKT_SIZE = {2048: 174, 2054: 64}

    MIN_ETH_TYPE_PKT_SIZE = {2048: 38, 2054: 46, 34525: 58}

    data
    eth_dst
    eth_pkt
    eth_src
    eth_type
    ip_ver()
        Return IP version number.

    l3_dst
    l3_PKT
    l3_src
    log()
    orig_len
    packet_complete()
        True if we have the complete packet.

    pkt
    port
**reparse** (*max_len*)
Reparse packet using data up to the specified maximum length.

**reparse_all**()
Reparse packet with all available data.

**reparse_ip** (*payload=0*)
Reparse packet with specified IP header type and optionally payload.

**vlan**

**vlan_pkt**

`faucet.valve_packet.arp_reply`
Return an ARP reply packet.

**Parameters**
- `vid` (*int or None*) – VLAN VID to use (or None).
- `eth_src` (*str*) – Ethernet source address.
- `eth_dst` (*str*) – destination Ethernet MAC address.
- `src_ip` (*ipaddress.IPv4Address*) – source IPv4 address.
- `dst_ip` (*ipaddress.IPv4Address*) – destination IPv4 address.

**Returns** serialized ARP reply packet.

**Return type** `ryu.lib.packet.arp`

`faucet.valve_packet.arp_request`
Return an ARP request packet.

**Parameters**
- `vid` (*int or None*) – VLAN VID to use (or None).
- `eth_src` (*str*) – Ethernet source address.
- `eth_dst` (*str*) – Ethernet destination address.
- `src_ip` (*ipaddress.IPv4Address*) – source IPv4 address.
- `dst_ip` (*ipaddress.IPv4Address*) – requested IPv4 address.

**Returns** serialized ARP request packet.

**Return type** `ryu.lib.packet.arp`

`faucet.valve_packet.build_pkt_header` (*vid, eth_src, eth_dst, dl_type*)
Return an Ethernet packet header.

**Parameters**
- `vid` (*int or None*) – VLAN VID to use (or None).
- `eth_src` (*str*) – source Ethernet MAC address.
- `eth_dst` (*str*) – destination Ethernet MAC address.
- `dl_type` (*int*) – EtherType.

**Returns** Ethernet packet with header.

**Return type** `ryu.lib.packet.ethernet`
faucet.valve_packet.echo_reply(vid, eth_src, eth_dst, src_ip, dst_ip, data)
Return an ICMP echo reply packet.

Parameters
- **vid** *(int or None)* – VLAN VID to use (or None).
- **eth_src** *(str)* – Ethernet source address.
- **eth_dst** *(str)* – destination Ethernet MAC address.
- **src_ip** *(ipaddress.IPv4Address)* – source IPv4 address.
- **dst_ip** *(ipaddress.IPv4Address)* – destination IPv4 address.

Returns serialized ICMP echo reply packet.

Return type *ryu.lib.packet.icmp*

faucet.valve_packet.faucet_lldp_stack_state_tlvs(dp, port)
Return a LLDP TLV for state of a stack port.

faucet.valve_packet.faucet_lldp_tlvs(dp)
Return LLDP TLVs for a datapath.

faucet.valve_packet.faucet_oui(mac)
Return first 3 bytes of MAC address (given as str).

faucet.valve_packet.faucet_tlvs(lldp_pkt, faucet_dp_mac)
Return list of TLVs with FAUCET OUI.

faucet.valve_packet.icmpv6_echo_reply(vid, eth_src, eth_dst, src_ip, dst_ip, hop_limit, id_, seq, data)
Return IPv6 ICMP echo reply packet.

Parameters
- **vid** *(int or None)* – VLAN VID to use (or None).
- **eth_src** *(str)* – source Ethernet MAC address.
- **eth_dst** *(str)* – destination Ethernet MAC address.
- **src_ip** *(ipaddress.IPv6Address)* – source IPv6 address.
- **dst_ip** *(ipaddress.IPv6Address)* – destination IPv6 address.
- **hop_limit** *(int)* – IPv6 hop limit.
- **id_** *(int)* – identifier for echo reply.
- **seq** *(int)* – sequence number for echo reply.
- **data** *(str)* – payload for echo reply.

Returns Serialized IPv6 ICMP echo reply packet.

Return type *ryu.lib.packet.ethernet*

faucet.valve_packet.int_from_mac
faucet.valve_packet.int_in_mac
faucet.valve_packet.ipv4_parseable
Return True if an IPv4 packet we could parse.
faucet.valve_packet.ipv6_link_eth_mcast
Return an Ethernet multicast address from an IPv6 address.

See RFC 2464 section 7.

Parameters dst_ip (ipaddress.IPv6Address) – IPv6 address.

Returns Ethernet multicast address.

Return type str

faucet.valve_packet.ipv6_solicited_node_from_ucast
Return IPv6 solicited node multicast address from IPv6 unicast address.

See RFC 3513 section 2.7.1.

Parameters ucast (ipaddress.IPv6Address) – IPv6 unicast address.

Returns IPv6 solicited node multicast address.

Return type ipaddress.IPv6Address

faucet.valve_packet.lacp_actor_up(lacp_pkt)
Return 1 if remote LACP link is up.

faucet.valve_packet.lacp_reqreply
Return a LACP frame.

Parameters

• eth_src (str) – source Ethernet MAC address.
• actor_system (str) – actor system ID (MAC address)
• actor_key (int) – actor’s LACP key assigned to this port.
• actor_port (int) – actor port number.
• actor_state_synchronization (int) – 1 if we will use this link.
• actor_state_activity (int) – 1 if actively sending LACP.
• actor_state_collecting (int) – 1 if receiving on this link.
• actor_state_distributing (int) – 1 if transmitting on this link.
• partner_system (str) – partner system ID (MAC address)
• partner_key (int) – partner’s LACP key assigned to this port.
• partner_port (int) – partner port number.
• partner_system_priority (int) – partner’s system priority.
• partner_port_priority (int) – partner’s port priority.
• partner_state_defaulted (int) – 1 if partner reverted to defaults.
• partner_state_expired (int) – 1 if partner thinks LACP expired.
• partner_state_timeout (int) – 1 if partner has short timeout.
• partner_state_collecting (int) – 1 if partner receiving on this link.
• partner_state_distributing (int) – 1 if partner transmitting on this link.
• partner_state_aggregation (int) – 1 if partner can aggregate this link.
• partner_state_synchronization (int) – 1 if partner will use this link.
• **partner_state_activity**(int) – 1 if partner actively sends LACP.

  Returns Ethernet packet with header.

  Return type ryu.lib.packet.ethernet

  faucet.valve_packet.lldp_beacon(*eth_src*, *chassis_id*, *port_id*, *ttl*, *org_tlvs=None*, *system_name=None*, *port_descr=None*)

  Return an LLDP frame suitable for a host/access port.

  Parameters

  • *eth_src*(str) – source Ethernet MAC address.

  • *chassis_id*(str) – Chassis ID.

  • *port_id*(int) – port ID,

  • *TTL*(int) – TTL for payload.

  • *org_tlvs*(list) – list of tuples of (OUI, subtype, info).

  Returns Ethernet packet with header.

  Return type ryu.lib.packet.ethernet

  faucet.valve_packet.mac_addr_all_zeros

  Returns True if mac_addr is all zeros.

  Parameters *mac_addr*(str) – MAC address.

  Returns True if all zeros.

  Return type bool

  faucet.valve_packet.mac_addr_is_unicast

  Returns True if mac_addr is a unicast Ethernet address.

  Parameters *mac_addr*(str) – MAC address.

  Returns True if a unicast Ethernet address.

  Return type bool

  faucet.valve_packet.mac_byte_mask(*mask_bytes=0*)

  Return a MAC address mask with n bytes masked out.

  faucet.valve_packet.mac_mask_bits

  Return number of bits in MAC mask or 0.

  faucet.valve_packet.nd_advert

  Return IPv6 neighbor advertisement packet.

  Parameters

  • *vid*(int or None) – VLAN VID to use (or None).

  • *eth_src*(str) – source Ethernet MAC address.

  • *eth_dst*(str) – destination Ethernet MAC address.

  • *src_ip*(ipaddress.IPv6Address) – source IPv6 address.

  • *dst_ip*(ipaddress.IPv6Address) – destination IPv6 address.

  Returns Serialized IPv6 neighbor discovery packet.

  Return type ryu.lib.packet.ethernet
faucet.valve_packet.nd_request
Return IPv6 neighbor discovery request packet.

Parameters

• **vid** *(int or None)* – VLAN VID to use (or None).
• **eth_src** *(str)* – source Ethernet MAC address.
• **eth_dst** *(str)* – Ethernet destination address.
• **src_ip** *(ipaddress.IPv6Address)* – source IPv6 address.
• **dst_ip** *(ipaddress.IPv6Address)* – requested IPv6 address.

Returns Serialized IPv6 neighbor discovery packet.

Return type *ryu.lib.packet.ethernet

faucet.valve_packet.parse_eth_pkt(pkt)
Return parsed Ethernet packet.

Parameters pkt *(ryu.lib.packet.packet)* – packet received from dataplane.

Returns Ethernet packet.

Return type *ryu.lib.packet.ethernet

faucet.valve_packet.parse_faucet_lldp(lldp_pkt, faucet_dp_mac)
Parse and return FAUCET TLVs from LLDP packet.

faucet.valve_packet.parse_lacp_pkt(pkt)
Return parsed LACP packet.

Parameters pkt *(ryu.lib.packet.packet)* – packet received from dataplane.

Returns LACP packet.

Return type *ryu.lib.packet.lacp

faucet.valve_packet.parse_lldp(pkt)
Return parsed LLDP packet.

Parameters pkt *(ryu.lib.packet.packet)* – packet received from dataplane.

Returns LLDP packet.

Return type *ryu.lib.packet.lldp

faucet.valve_packet.parse_packet_in_pkt
Parse a packet received via packet in from the dataplane.

Parameters

• **data** *(bytearray)* – packet data from dataplane.
• **max_len** *(int)* – max number of packet data bytes to parse.

Returns raw packet *ryu.lib.packet.ethernet*: parsed Ethernet packet. int: Ethernet type of packet (inside VLAN) int: VLAN VID (or None if no VLAN)

Return type *ryu.lib.packet.packet

faucet.valve_packet.router_advert(vid, eth_src, eth_dst, src_ip, dst_ip, vips, pi_flags=6)
Return IPv6 ICMP Router Advert.

Parameters

• **vid** *(int or None)* – VLAN VID to use (or None).
• **eth_src** *(str)* – source Ethernet MAC address.

• **eth_dst** *(str)* – dest Ethernet MAC address.

• **src_ip** *(ipaddress.IPv6Address)* – source IPv6 address.

• **vips** *(list)* – prefixes (ipaddress.IPv6Address) to advertise.

• **pi_flags** *(int)* – flags to set in prefix information field (default set A and L)

    **Returns** Serialized IPv6 ICMP RA packet.

    **Return type** ryu.lib.packet.ethernet

`faucet.valve_packet.tlv_cast(tlvs, tlv_attr, cast_func)`

Return cast’d attribute of first TLV or None.

`faucet.valve_packet.tlvs_by_subtype(tlvs, subtype)`

Return list of TLVs with matching type.

`faucet.valve_packet.tlvs_by_type(tlvs, tlv_type)`

Return list of TLVs with matching type.

### faucet.valve_pipeline module

Manages movement of packets through the faucet pipeline.

**class faucet.valve_pipeline.ValvePipeline(dp)**

**Bases:** faucet.valve_manager_base.ValveManagerBase

Responsible for maintaining the integrity of the Faucet pipeline for a single valve.

Controls what packets a module sees in its tables and how it can pass packets through the pipeline.

Responsible for installing flows in the vlan, egress and classification tables

**accept_to_classification**(actions=None)

Get instructions to forward packet through the pipeline to classification table. :param actions: (optional) list of actions to apply to packet.

    **Returns** list of instructions

**accept_to_egress**(actions=None)

Get instructions to forward packet through the pipeline to egress table

Raises an assertion error if egress pipeline is not configured

    **Parameters** actions – (optional) list of actions to apply to the packet

    **Returns**

    **Return type** list of instructions

**accept_to_l2_forwarding**(actions=None)

Get instructions to forward packet through the pipeline to l2 forwarding. :param actions: (optional) list of actions to apply to packet.

    **Returns** list of instructions

**accept_to_vlan**(actions=None)

Get instructions to forward packet through the pipeline to vlan table. :param actions: (optional) list of actions to apply to packet.

    **Returns** list of instructions
**add_port** *(port)*
install flows in response to a new port

**del_port** *(port)*
delete flows in response to a port removal

**filter_packets** *(match_dict, priority_offset=0)*
get a list of flow modification messages to filter packets from the pipeline. :param match_dict: a dictionary specifying the match fields :param priority_offset: used to prevent overlapping entries

**initialise_tables** ()
Install rules to initialise the classification_table

**output** *(port, vlan, hairpin=False, external_forwarding_requested=None)*
Get instructions list to output a packet through the regular pipeline.

Parameters

* port – Port object of port to output packet to
* vlan – Vlan object of vlan to output packet on
* hairpin – if True, hairpinning is required
* apply_egress_acl – if True the packet will be sent to the egress acl table before being output

Returns list of Instructions

**remove_filter** *(match_dict, strict=True, priority_offset=0)*
retrieve flow mods to remove a filter from the classification table

**select_packets** *(target_table, match_dict, actions=None, priority_offset=0)*
retrieve rules to redirect packets matching match_dict to table

**faucet.valve_route module**

Valve IPv4/IPv6 routing implementation.

**class** faucet.valve_route.AnonVLAN *(vid)*
Bases: object

**class** faucet.valve_route.NextHop *(eth_src, port, now)*
Bases: object

Describes a directly connected (at layer 2) nexthop.

**age** *(now)*
Return age of this nexthop.

**cache_time**

**dead** *(max_fib_retries)*
Return True if this nexthop is considered dead.

**eth_src**

**last_retry_time**

**next_retry** *(now, max_resolve_backoff_time)*
Increment state for next retry.

**next_retry_time**
port

resolution_due(now, max_age)
Return True if this nexthop is due to be re resolved/retried.

resolve_retries
class faucet.valve_route.ValveIPv4RouteManager(logger, notify, global_vlan, neighbor_timeout, max_hosts_per_resolve_cycle, max_host_fib_retry_count, max_resolve_backoff_time, proactive_learn, dec_ttl, multi_out, fib_table, vip_table, pipeline, routers, flood_manager)

Bases: faucet.valve_route.ValveRouteManager
Implement IPv4 RIB/FIB.

CONTROL_ETH_TYPES = (2048, 2054)
ETH_TYPE = 2048
ICMP_SIZE = 174
ICMP_TYPE = 1
IPV = 4
IP_PKT
    alias of ryu.lib.packet.ipv4.ipv4
active
advertise(_vlan)
control_plane_handler(now, pkt_meta)
    Handle packets destined for router otherwise proactively learn host information
dec_ttl
fib_table
flood_manager
global_routing
global_vlan
logger
max_host_fib_retry_count
max_hosts_per_resolve_cycle
max_resolve_backoff_time
multi_out
neighbor_timeout
notify
pipeline
proactive_learn
route_priority
routers
vip_table
class faucet.valve_route.ValveIPv6RouteManager (logger, notify, global_vlan, neighbor_timeout, max_hosts_per_resolve_cycle, max_host_fib_retry_count, max_resolve_backoff_time, proactive_learn, dec_ttl, multi_out, fib_table, vip_table, pipeline, routers, flood_manager)

Bases: faucet.valve_route.ValveRouteManager

Implement IPv6 FIB.

CONTROL_ETH_TYPES = (34525,)
ETH_TYPE = 34525
ICMP_SIZE = 194
ICMP_TYPE = 58
IPV = 6
IP_PKT
    alias of ryu.lib.packet.ipv6.ipv6
active
advertise (vlan)
control_plane_handler (now, pkt_meta)
    Resolve packets destined for router or proactively learn host information
dec_ttl
fib_table
flood_manager
global_routing
global_vlan
logger
max_host_fib_retry_count
max_hosts_per_resolve_cycle
max_resolve_backoff_time
multi_out
neighbor_timeout
notify
pipeline
proactive_learn
route_priority
routers
vip_table
**Faucet Documentation**

```python
class faucet.valve_route.ValveRouteManager(
    logger, notify, global_vlan, neighbor_timeout,
    max_hosts_per_resolve_cycle, max_host_fib_retry_count,
    max_resolve_backoff_time, proactive_learn,
    dec_ttl, multi_out, fib_table, vip_table,
    pipeline, routers, flood_manager)
```

Bases: `faucet.valve_manager_base.ValveManagerBase`

Base class to implement RIB/FIB.

```py
CONTROL_ETH_TYPES = ()
ETH_TYPE = None
ICMP_SIZE = None
ICMP_TYPE = None
IPV = 0
IP_PKT = None
MAX_PACKET_IN_SIZE = 194
```

**active**

`add_host_fib_route_from_pkt (now, pkt_meta)`

Add a host FIB route given packet from host.

**Parameters**

- `now (float)` – seconds since epoch.
- `pkt_meta (PacketMeta)` – received packet.

**Returns** OpenFlow messages.

**Return type** list

`add_route (vlan, ip_gw, ip_dst)`

Add a route to the RIB.

**Parameters**

- `vlan (vlan)` – VLAN containing this RIB.
- `ip_gw (ipaddress.ip_address)` – IP address of nexthop.
- `ip_dst (ipaddress.ip_network)` – destination IP network.

**Returns** OpenFlow messages.

**Return type** list

`add_vlan (vlan)`

install flows in response to a new VLAN

`advertise (vlan)`

`control_plane_handler (now, pkt_meta)`

`dec_ttl`

`del_route (vlan, ip_dst)`

Delete a route from the RIB.

Only one route with this exact destination is supported.

**Parameters**
• **vlan**(*vlan*) – VLAN containing this RIB.

• **ip_dst**(*ipaddress.ip_network*) – destination IP network.

Returns OpenFlow messages.

Return type list

**expire_port_nexthops**(*port*)

Expire all hosts on a port

**fib_table**

**flood_manager**

**global_routing**

**global_vlan**

**logger**

**max_host_fib_retry_count**

**max_hosts_per_resolve_cycle**

**max_resolve_backoff_time**

**multi_out**

**neighbor_timeout**

**nexthop_dead**(*nexthop_cache_entry*)

Returns true if the nexthop_cache_entry is considered dead

**notify**

**notify_learn**(*pkt_meta*)

**pipeline**

**proactive_learn**

**resolve_expire_hosts**(*vlan*, *now*, *resolve_all=True*)

Re/resolve hosts.

Parameters

• **vlan**(*vlan*) – VLAN containing this RIB/FIB.

• **now**(*float*) – seconds since epoch.

• **resolve_all**(*bool*) – attempt to resolve all unresolved gateways.

Returns OpenFlow messages.

Return type list

**resolve_gateways**(*vlan*, *now*, *resolve_all=True*)

Re/resolve gateways.

Parameters

• **vlan**(*vlan*) – VLAN containing this RIB/FIB.

• **now**(*float*) – seconds since epoch.

• **resolve_all**(*bool*) – attempt to resolve all unresolved gateways.

Returns OpenFlow messages.
Return type  list

route_priority

router_vlan_for_ip_gw(vlan, ip_gw)
Return router VLAN for IP gateway (or None).

Parameters
  • vlan(vlan) – VLAN containing this RIB.
  • ip_gw(ipaddress.ip_address) – IP address of nexthop.

Returns  VLAN for this gateway or None.

routers

vip_table

faucet.valve_ryuapp module

RyuApp base class for FAUCET/Gauge.

class faucet.valve_ryuapp.EventReconfigure
  Bases: ryu.controller.event.EventBase

Event sent to controller to cause config reload.

class faucet.valve_ryuapp.RyuAppBase(*args, **kwargs)
  Bases: ryu.base.app_manager.RyuApp

RyuApp base class for FAUCET/Gauge.

OFP_VERSIONS = [4]

connect_or_disconnect_handler(ryu_event)
Handle connection or disconnection of a datapath.

Parameters  ryu_event(ryu.controller.dpset.EventDP) – trigger.

exc_logname = ''

get_setting(setting, path_eval=False)
Return config setting prefaced with logname.

logname = ''

reconnect_handler(ryu_event)
Handle reconnection of a datapath.

Parameters  ryu_event(ryu.controller.dpset.EventDPReconnected) – trigger.

reload_config(_ryu_event)
Handle reloading configuration.

signal_handler(sigid, _)
Handle signals.

Parameters  sigid(int) – signal received.

start()
Start controller.
exception faucet.valve_ryuapp.ValveDeadThreadException
    Bases: Exception
    Exception raised when a dead thread is detected.

faucet.valve_table module

Abstraction of an OF table.

class faucet.valve_table.ValveGroupEntry (table, group_id, buckets)
    Bases: object
    Abstraction for a single OpenFlow group entry.
    add()
        Return flows to add this entry to the group table.
    delete()
        Return flow to delete an existing group entry.
    modify()
        Return flow to modify an existing group entry.
    update_buckets (buckets)
        Update entry with new buckets.

class faucet.valve_table.ValveGroupTable
    Bases: object
    Wrap access to group table.
    delete_all()
        Delete all groups.

entries = None

get_entry (group_id, buckets)
    Update entry with group_id with buckets, and return the entry.

static group_id_from_str (key_str)
    Return a group ID based on a string key.

class faucet.valve_table.ValveTable (name, table_config, flow_cookie, notify_flow_removed=False, next_tables=None)
    Bases: object
    Wrapper for an OpenFlow table.

flowcontroller (match=None, priority=None, inst=None, max_len=96)
    Add flow outputting to controller.

flowdel (match=None, priority=None, out_port=4294967295, strict=False)
    Delete matching flows from a table.

flowdrop (match=None, priority=None, hard_timeout=0)
    Add drop matching flow to a table.

flowmod (match=None, priority=None, inst=None, command=0, out_port=0, out_group=0, hard_timeout=0, idle_timeout=0, cookie=None)
    Helper function to construct a flow mod message with cookie.

goto (next_table)
    Add goto next table instruction.
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`goto_miss(next_table)`
Add miss goto table instruction.

`goto_this()`

`match`
Compose an OpenFlow match rule.

`set_external_forwarding_requested()`
Set field for external forwarding requested.

`set_field(**kwds)`
Return set field action.

`set_no_external_forwarding_requested()`
Set field for no external forwarding requested.

`set_vlan_vid(vlan_vid)`
Set VLAN VID with VID_PRESENT flag set.

Parameters

- `vid(int)` – VLAN VID
- `Returns` set VID with VID_PRESENT.
- `Return type` `ryu.ofproto.ofproto_v1_3_parser.OFPActionSetField`

**faucet.valve_util module**

Utility functions for FAUCET.

`faucet.valve_util.close_logger(logger)`
Close all handlers on logger object.

`faucet.valve_util.dpid_log(dpid)`
Log a DP ID as hex/decimal.

`faucet.valve_util.get_logger(logname, logfile, loglevel, propagate)`
Create and return a logger object.

`faucet.valve_util.get_setting(name, path_eval=False)`
Returns value of specified configuration setting.

`faucet.valve_util.get_sys_prefix()`
Returns an additional prefix for log and configuration files when used in a virtual environment.

`faucet.valve_util.kill_on_exception(logname)`
Decorator to ensure functions will kill ryu when an unhandled exception occurs.

`faucet.valve_util.stat_config_files(config_hashes)`
Return dict of a subset of stat attributes on config files.

`faucet.valve_util.utf8_decode(msg_str)`
Gracefully decode a possibly UTF-8 string.
faucet.valves_manager module

Manage a collection of Valves.

class faucet.valves_manager.ConfigWatcher
   Bases: object
   
   Watch config for file or content changes.
   
   config_file = None
   config_file_stats = None
   config_hashes = None
   
   content_changed(new_config_file)
      Return True if config file content actually changed.
   
   files_changed()
      Return True if any config files changed.
   
   update(new_config_file, new_config_hashes=None)
      Update state with new config file/hashes.

class faucet.valves_manager.MetaDPState
   Bases: object
   
   Contains state/config about all DPs.

class faucet.valves_manager.ValvesManager(logname, logger, metrics, notifier, bgp, dot1x, config_auto_revert, send_flows_to_dp_by_id)
   Bases: object
   
   Manage a collection of Valves.

   datapath_connect(now, valve, discovered_up_ports)
      Handle connection from DP.

   event_socket_heartbeat(now)
      raises event for event sock heartbeat

   healthy_stack_roots(now, candidate_dps)
      Return list of healthy stack root names.

   load_configs(now, new_config_file, delete_dp=None)
      Load/apply new config to all Valves.

   maintain_stack_root(now)
      Maintain current stack root and return True if stack root changes.

   new_valve(new_dp)

   parse_configs(new_config_file)
      Return parsed configs for Valves, or None.

   port_status_handler(valve, msg, now)
      Handle a port status change message.

   request_reload_configs(now, new_config_file, delete_dp=None)
      Process a request to load config changes.

   revert_config()
      Attempt to revert config to last known good version.
update_config_applied \( (\text{sent}=\text{None}, \text{reset}=\text{False}) \)

Update faucet_config_applied from \{dpid: sent\} dict, defining applied == sent == enqueued via Ryu

update_metrics \( (\text{now}) \)

Update metrics in all Valves.

valve_flow_services \( (\text{now}, \text{valve_service}) \)

Call a method on all Valves and send any resulting flows.

valve_packet_in \( (\text{now}, \text{valve}, \text{msg}) \)

Time a call to Valve packet in handler.

valves = None

faucet.vlan module

VLAN configuration.

class faucet.vlan.AnyVLAN

Bases: object

Placeholder any tagged VLAN.

name = 'Any VLAN'

vid = 4096

class faucet.vlan.HostCacheEntry (\text{eth}_\text{src}, \text{port}, \text{cache}\_\text{time})

Bases: object

Association of a host with a port.

cache\_\text{time}

eth\_\text{src}

eth\_\text{src}\_\text{int}

port

class faucet.vlan.NullVLAN

Bases: object

Placeholder null VLAN.

name = 'Null VLAN'

vid = 0

class faucet.vlan.OFVLAN (name, vid)

Bases: object

class faucet.vlan.VLAN (_id, dp_id, conf=None)

Bases: faucet.conf.Conf

Contains state for one VLAN, including its configuration.

add\_\text{cache}\_\text{host} (\text{eth}_\text{src}, \text{port}, \text{cache}\_\text{time})

Add/update a host to the cache on a port at at time.

add\_\text{route} (ip\_dst, ip\_gw)

Add an IP route.

all\_\text{ip}\_\text{gws} (ipv)

Return all IP gateways for specified IP version.
cached_host (eth_src)
   Return host from cache or None.

cached_host_on_port (eth_src, port)
   Return host cache entry if host in cache and on specified port.

cached_hosts_count_on_port (port)
   Return count of all hosts learned on a port.

cached_hosts_on_port (port)
   Return all hosts learned on a port.

clear_cache_hosts_on_port (port)
   Clear all hosts learned on a port.

defaults = {'acl_in': None, 'acl_out': None, 'acls_in': None, 'acls_out': None, 'description': None, 'dot1x_assigned': ... 0, 'reserved_internal_vlan': False, 'routes': None, 'targeted_gw_resolution': True, 'unicast_flood': True, 'vid': None}
defaults_types = {'acl_in': (<class 'int'>, <class 'str'>), 'acl_out': (<class 'int'>, <class 'str'>), 'acls_in': <class 'list'>, 'acls_out': <class 'list'>, 'description': <class 'str'>, 'dot1x_assigned': <class 'int'>, 'reserved_internal_vlan': <class 'bool'>, 'routes': <class 'list'>, 'targeted_gw_resolution': <class 'bool'>, 'unicast_flood': <class 'bool'>, 'vid': <class 'int'>}
del_route (ip_dst)
   Delete an IP route.

exclude_native_if_dot1x ()
   Don’t output on native vlan, if dynamic (1x) vlan is in use

excluded_lag_ports (in_port=None)
   Ensure output to SELECTED LAG ports & only one LAG member

expire_cache_host (eth_src)
   Expire a host from caches.

expire_cache_hosts (now, learn_timeout)
   Expire stale host entries.

faucet_vips_by_ipv (ipv)
   Return VIPs with specified IP version on this VLAN.

flood_pkt (packet_builder, multi_out=True, *args)
   Return Packet-out actions via flooding

static flood_ports (configured_ports, exclude_unicast)
   Return configured ports that allow flooding

from_connected_to_vip (src_ip, dst_ip)
   Return True if src_ip in connected network and dst_ip is a VIP.

   Parameters
   • src_ip (ipaddress.ip_address) – source IP.
   • dst_ip (ipaddress.ip_address) – destination IP

   Returns True if local traffic for a VIP.

get_ports ()
   Return all ports on this VLAN.

hairpin_ports ()
   Return all ports with hairpin enabled.

hosts_count ()
   Return number of hosts learned on this VLAN.
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`ip_dsts_for_ip_gw(ip_gw)`
Return list of IP destinations, for specified gateway.

`ip_in_vip_subnet(ipa, faucet_vip=None)`
Return faucet_vip if IP in same IP network as a VIP on this VLAN.

`ipvs()`
Return IP versions configured on this VLAN.

`is_faucet_vip(ipa, faucet_vip=None)`
Return True if IP is a VIP on this VLAN.

`is_host_fib_route(host_ip)`
Return True if IP destination is a host FIB route.

Parameters host_ip – (ipaddress.ip_address): potential host FIB route.

Returns True if a host FIB route (and not used as a gateway).

`lacp_ports()`
Return ports that have LACP on this VLAN.

`lacp_up_selected_ports()`
Return LACP ports that have been SELECTED and are UP.

`lags()`
Return dict of LAGs mapped to member ports.

`link_and_other_vips(ipv)`
Return link local and non-link local VIPs.

`loop_protect_external_ports()`
Return ports with external loop protection set.

`loop_protect_external_ports_up()`
Return up ports with external loop protection set.

`mirrored_ports()`
Return ports that are mirrored on this VLAN.

`mutable_attrs = frozenset({'dot1x_untagged', 'tagged', 'untagged'})`

`neigh_cache_by_ipv(ipv)`
Return neighbor cache for specified IP version on this VLAN.

`neigh_cache_count_by_ipv(ipv)`
Return number of hosts in neighbor cache for specified IP version on this VLAN.

`output_port(port, hairpin=False, output_table=None, external_forwarding_requested=None)`
Return packet-out actions with VLAN tag if port is tagged.

`pkt_out_port(packet_builder, port, *args)`
Return packet-out actions with VLAN tag if port is tagged.

`port_is_tagged(port)`
Return True if port number is an tagged port on this VLAN.

`port_is_untagged(port)`
Return True if port number is an untagged port on this VLAN.

`reset_caches()`
Reset dynamic caches.

`reset_ports(ports)`
Reset tagged and untagged port lists.
restricted_bcast_arpnd_ports()
    Return all ports with restricted broadcast enabled.

route_count_by_ipv(ipv)
    Return route table count for specified IP version on this VLAN.

routes_by_ipv(ipv)
    Return route table for specified IP version on this VLAN.

selected_up_lags()
    Return dict of LAGs mapped to member ports that have been selected

set_defaults()
    Set default values and run any basic sanity checks.

tagged_flood_ports(exclude_unicast)
untagged_flood_ports(exclude_unicast)
static vid_valid(vid)
    Return True if VID valid.

vip_map(ipa)
    Return the vip containing ipa

faucet.watcher module

Gauge watcher implementations.

class faucet.watcher.GaugeFlowTableLogger(conf, logname, prom_client)
    Bases: faucet.gauge_pollers.GaugeFlowTablePoller
    Periodically dumps the current datapath flow table as a yaml object.
    Includes a timestamp and a reference ($DATAPATHNAME-flowtables). The flow table is dumped as an OF-
        FlowStatsReply message (in yaml format) that matches all flows.
    optionally the output can be compressed by setting compressed: true in the config for this watcher

class faucet.watcher.GaugeMeterStatsLogger(conf, logname, prom_client)
    Bases: faucet.gauge_pollers.GaugeMeterStatsPoller
    Abstraction for meter statistics logger.

class faucet.watcher.GaugePortStateLogger(conf, logname, prom_client)
    Bases: faucet.gauge_pollers.GaugePortStatePoller
    Abstraction for port state logger.

static no_response()
    Called when a polling cycle passes without receiving a response.

static send_req()
    Send a stats request to a datapath.

class faucet.watcher.GaugePortStatsLogger(conf, logname, prom_client)
    Bases: faucet.gauge_pollers.GaugePortStatsPoller
    Abstraction for port statistics logger.

faucet.watcher.watcher_factory(conf)
    Return a Gauge object based on type.

Parameters conf(GaugeConf) – object with the configuration for this valve.
faucet.watcher_conf module

Gauge watcher configuration.

```python
class faucet.watcher_conf.WatcherConf(_id, dp_id, conf, prom_client)
    Bases: faucet.conf.Conf
```

Stores the state and configuration to monitor a single stat.

Watcher Config

Watchers are configured in the watchers config block in the config for gauge.

The following elements can be configured for each watcher, at the level of /watchers/<watcher name>/:

- **type (string):** The type of watcher (IE what stat this watcher monitors). The types are ‘port_state’, ‘port_stats’ or ‘flow_table’.
- **dps (list):** A list of dps that should be monitored with this watcher.
- **db (string):** The db that will be used to store the data once it is retrieved.
- **interval (int):** if this watcher requires polling the switch, it will monitor at this interval.

The config for a db should be created in the gauge config file under the dbs config block.

The following elements can be configured for each db, at the level of /dbs/<db name>/:

- **type (string):** the type of db. The available types are ‘text’ and ‘influx’ for port_state, ‘text’, ‘influx’ and ‘prometheus’ for port_stats and ‘text’ and flow_table.

The following config elements then depend on the type.

**For text:**

- **file (string):** the filename of the file to write output to.
- **path (string):** path where files should be written when writing to multiple files
- **compress (bool):** compress (with gzip) flow_table output while writing it

**For influx:**

- **influx_db (str):** The name of the influxdb database. Defaults to ‘faucet’.
- **influx_host (str):** The host where the influxdb is reachable. Defaults to ‘localhost’.
- **influx_port (int):** The port that the influxdb host will listen on. Defaults to 8086.
- **influx_user (str):** The username for accessing influxdb. Defaults to ‘’.  
- **influx_pwd (str):** The password for accessing influxdb. Defaults to ‘’.
- **influx_timeout (int):** The timeout in seconds for connecting to influxdb. Defaults to 10.
- **influx_retries (int):** The number of times to retry connecting to influxdb after failure. Defaults to 3.

**For Prometheus:**

- **prometheus_port (int):** The port used to export prometheus data. Defaults to 9303.
- **prometheus_addr (ip addr str):** The address used to export prometheus data. Defaults to ‘127.0.0.1’.

```python
add_db (db_conf)
    Add database config to this watcher.
```

```python
add_dp (dp)
    Add a datapath to this watcher.
```
check_config()

Check config at instantiation time for errors, typically via assert.

```
db_defaults = {'compress': False, 'file': None, 'influx_db': 'faucet', 'influx_host': 'localhost', 'influx_port': 8086, ...

db_defaults_types = {'compress': <class 'bool'>, 'file': <class 'str'>, 'influx_db': <class 'str'>, 'influx_host': ...

defaults = {'all_dps': False, 'db': None, 'db_type': 'text', 'dbs': None, 'dps': None}

defaults_types = {'all_dps': <class 'bool'>, 'db': <class 'str'>, 'db_type': <class 'str'>, 'dbs': <class 'list'>, 'dps': <class 'list'>}
```
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