
ryu Documentation

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ryu development team

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1.1 What's Ryu

Ryu is a component-based software defined networking framework.

Ryu provides software components with well defined API's that make it easy for developers to create new network management and control applications. Ryu supports various protocols for managing network devices, such as OpenFlow, Netconf, OF-config, etc. About OpenFlow, Ryu supports fully 1.0, 1.2, 1.3, 1.4, 1.5 and Nicira Extensions.

All of the code is freely available under the Apache 2.0 license. Ryu is fully written in Python.

1.2 Quick Start

Installing Ryu is quite easy:

```
% pip install ryu
```

If you prefer to install Ryu from the source code:

```
% git clone git://github.com/osrg/ryu.git
% cd ryu; pip install .
```

If you want to write your Ryu application, have a look at [Writing ryu application](#) document. After writing your application, just type:

```
% ryu-manager yourapp.py
```

1.3 Optional Requirements

Some functions of ryu require extra packages:

- OF-Config requires lxml and ncclient
- NETCONF requires paramiko
- BGP speaker (SSH console) requires paramiko
- Zebra protocol service (database) requires SQLAlchemy

If you want to use these functions, please install the requirements:

```
% pip install -r tools/optional-requirements
```

Please refer to tools/optional-requirements for details.

1.4 Prerequisites

If you got some error messages at the installation stage, please confirm dependencies for building the required Python packages.

On Ubuntu(16.04 LTS or later):

```
% apt install gcc python-dev libffi-dev libssl-dev libxml2-dev libxslt1-dev zlib1g-dev
```

1.5 Support

Ryu Official site is <http://osrg.github.io/ryu/>.

If you have any questions, suggestions, and patches, the mailing list is available at [ryu-devel ML](#). The [ML archive](#) at [Gmane](#) is also available.

Writing Your Ryu Application

2.1 The First Application

2.1.1 Whetting Your Appetite

If you want to manage network gear (switches, routers, etc) your own way, you just need to write your own Ryu application. Your application tells Ryu how you want to manage the gear. Then Ryu configures the gear by using OpenFlow protocol, etc.

Writing Ryu applications is easy. They're just Python scripts.

2.1.2 Start Writing

Here we show a Ryu application that makes an OpenFlow switch work as a dumb layer 2 switch.

Open a text editor and create a new file with the following content:

```
from ryu.base import app_manager

class L2Switch(app_manager.RyuApp):
    def __init__(self, *args, **kwargs):
        super(L2Switch, self).__init__(*args, **kwargs)
```

Ryu applications are just Python scripts so you can save the file with any name, any extension, and any place you want. Let's name the file 'l2.py' in your home directory.

This application does nothing useful yet, however it's a complete Ryu application. In fact, you can run this Ryu application:

```
% ryu-manager ~/l2.py
loading app /Users/fujita/l2.py
instantiating app /Users/fujita/l2.py
```

All you have to do is define a new subclass of RyuApp to run your Python script as a Ryu application.

Next let's add some functionality that sends a received packet to all the ports.

```
from ryu.base import app_manager
from ryu.controller import ofp_event
from ryu.controller.handler import MAIN_DISPATCHER
from ryu.controller.handler import set_ev_cls
from ryu.ofproto import ofproto_v1_0

class L2Switch(app_manager.RyuApp):
    OFP_VERSIONS = [ofproto_v1_0.OFP_VERSION]

    def __init__(self, *args, **kwargs):
        super(L2Switch, self).__init__(*args, **kwargs)

    @set_ev_cls(ofp_event.EventOFPPacketIn, MAIN_DISPATCHER)
    def packet_in_handler(self, ev):
        msg = ev.msg
        dp = msg.datapath
        ofp = dp.ofproto
        ofp_parser = dp.ofproto_parser

        actions = [ofp_parser.OFPActionOutput(ofp.OFPP_FLOOD)]
        out = ofp_parser.OFPPacketOut(
            datapath=dp, buffer_id=msg.buffer_id, in_port=msg.in_port,
            actions=actions)
        dp.send_msg(out)
```

A new method 'packet_in_handler' is added to the L2Switch class. This is called when Ryu receives an OpenFlow packet_in message. The trick is the 'set_ev_cls' decorator. This decorator tells Ryu when the decorated function should be called.

The first argument of the decorator indicates which type of event this function should be called for. As you might expect, every time Ryu gets a packet_in message, this function is called.

The second argument indicates the state of the switch. You probably want to ignore packet_in messages before the negotiation between Ryu and the switch is finished. Using 'MAIN_DISPATCHER' as the second argument means this function is called only after the negotiation completes.

Next let's look at the first half of the 'packet_in_handler' function.

- ev.msg is an object that represents a packet_in data structure.
- msg.dp is an object that represents a datapath (switch).
- dp.ofproto and dp.ofproto_parser are objects that represent the OpenFlow protocol that Ryu and the switch negotiated.

Ready for the second half.

- OFPActionOutput class is used with a packet_out message to specify a switch port that you want to send the packet out of. This application uses the OFPP_FLOOD flag to indicate that the packet should be sent out on all ports.
- OFPPacketOut class is used to build a packet_out message.
- If you call Datapath class's send_msg method with a OpenFlow message class object, Ryu builds and sends the on-wire data format to the switch.

There, you finished implementing your first Ryu application. You are ready to run a Ryu application that does something useful.

Is a dumb L2 switch is too dumb? You want to implement a learning L2 switch? Move to [the next step](#). You can learn from the existing Ryu applications at [ryu/app](#) directory and [integrated tests](#) directory.

2.2 Components of Ryu

2.2.1 Executables

`bin/ryu-manager`

The main executable.

2.2.2 Base components

`ryu.base.app_manager`

2.2.3 OpenFlow controller

`ryu.controller.controller`

`ryu.controller.dpset`

`ryu.controller.ofp_event`

`ryu.controller.ofp_handler`

2.2.4 OpenFlow wire protocol encoder and decoder

`ryu.ofproto.ofproto_v1_0`

`ryu.ofproto.ofproto_v1_0_parser`

`ryu.ofproto.ofproto_v1_2`

`ryu.ofproto.ofproto_v1_2_parser`

`ryu.ofproto.ofproto_v1_3`

`ryu.ofproto.ofproto_v1_3_parser`

`ryu.ofproto.ofproto_v1_4`

`ryu.ofproto.ofproto_v1_4_parser`

`ryu.ofproto.ofproto_v1_5`

`ryu.ofproto.ofproto_v1_5_parser`

2.2.5 Ryu applications

ryu.app.cbench

ryu.app.simple_switch

ryu.topology

Switch and link discovery module. Planned to replace ryu/controller/dpset.

2.2.6 Libraries

ryu.lib.packet

ryu.lib.ovs

ovsdb interaction library.

ryu.lib.of_config

OF-Config implementation.

ryu.lib.netconf

NETCONF definitions used by ryu/lib/of_config.

ryu.lib.xflow

An implementation of sFlow and NetFlow.

2.2.7 Third party libraries

ryu.contrib.ovs

Open vSwitch python binding. Used by ryu.lib.ovs.

ryu.contrib.oslo.config

Oslo configuration library. Used for ryu-manager's command-line options and configuration files.

ryu.contrib.ncclient

Python library for NETCONF client. Used by ryu.lib/of_config.

2.3 Ryu application API

2.3.1 Ryu application programming model

Threads, events, and event queues

Ryu applications are single-threaded entities which implement various functionalities in Ryu. Events are messages between them.

Ryu applications send asynchronous events to each other. Besides that, there are some Ryu-internal event sources which are not Ryu applications. One of examples of such event sources is OpenFlow controller. While an event can currently contain arbitrary python objects, it's discouraged to pass complex objects (eg. unpickleable objects) between Ryu applications.

Each Ryu application has a receive queue for events. The queue is FIFO and preserves the order of events. Each Ryu application has a thread for event processing. The thread keeps draining the receive queue by dequeuing an event and calling the appropriate event handler for the event type. Because the event handler is called in the context of the event processing thread, it should be careful when blocking. While an event handler is blocked, no further events for the Ryu application will be processed.

There are kinds of events which are used to implement synchronous inter-application calls between Ryu applications. While such requests uses the same machinery as ordinary events, their replies are put on a queue dedicated to the transaction to avoid deadlock.

While threads and queues is currently implemented with eventlet/greenlet, a direct use of them in a Ryu application is strongly discouraged.

Contexts

Contexts are ordinary python objects shared among Ryu applications. The use of contexts are discouraged for new code.

2.3.2 Create a Ryu application

A Ryu application is a python module which defines a subclass of `ryu.base.app_manager.RyuApp`. If two or more such classes are defined in a module, the first one (by name order) will be picked by `app_manager`. Ryu application is singleton: only single instance of a given Ryu application is supported.

2.3.3 Observe events

A Ryu application can register itself to listen for specific events using `ryu.controller.handler.set_ev_cls` decorator.

2.3.4 Generate events

A Ryu application can raise events by calling appropriate `ryu.base.app_manager.RyuApp`'s methods like `send_event` or `send_event_to_observers`.

2.3.5 Event classes

An event class describes a Ryu event generated in the system. By convention, event class names are prefixed by "Event". Events are generated either by the core part of Ryu or Ryu applications. A Ryu application can register its interest for a specific type of event by providing a handler method using `ryu.controller.handler.set_ev_cls` decorator.

OpenFlow event classes

`ryu.controller.ofp_event` module exports event classes which describe receptions of OpenFlow messages from connected switches. By convention, they are named as `ryu.controller.ofp_event.EventOFPxxxx` where `xxxx` is the name of the corresponding OpenFlow message. For example, `EventOFPPacketIn` for packet-in message. The OpenFlow controller part of Ryu automatically decodes OpenFlow messages received from switches and send these events to Ryu applications which expressed an interest using `ryu.controller.handler.set_ev_cls`. OpenFlow event classes are subclasses of the following class.

See *OpenFlow protocol API Reference* for more info about OpenFlow messages.

2.3.6 `ryu.base.app_manager.RyuApp`

See *Ryu API Reference*.

2.3.7 `ryu.controller.handler.set_ev_cls`

`ryu.controller.handler.set_ev_cls(ev_cls, dispatchers=None)`

A decorator for Ryu application to declare an event handler.

Decorated method will become an event handler. `ev_cls` is an event class whose instances this `RyuApp` wants to receive. `dispatchers` argument specifies one of the following negotiation phases (or a list of them) for which events should be generated for this handler. Note that, in case an event changes the phase, the phase before the change is used to check the interest.

Negotiation phase	Description
<code>ryu.controller.handler.HANDSHAKE_DISPATCHER</code>	Sending and waiting for hello message
<code>ryu.controller.handler.CONFIG_DISPATCHER</code>	Version negotiated and sent features-request message
<code>ryu.controller.handler.MAIN_DISPATCHER</code>	Switch-features message received and sent set-config message
<code>ryu.controller.handler.DEAD_DISPATCHER</code>	Disconnect from the peer. Or disconnecting due to some unrecoverable errors.

2.3.8 `ryu.controller.controller.Datapath`

2.3.9 `ryu.controller.event.EventBase`

class `ryu.controller.event.EventBase`

The base of all event classes.

A Ryu application can define its own event type by creating a subclass.

2.3.10 `ryu.controller.event.EventRequestBase`

class `ryu.controller.event.EventRequestBase`
The base class for synchronous request for `RyuApp.send_request`.

2.3.11 `ryu.controller.event.EventReplyBase`

class `ryu.controller.event.EventReplyBase` (*dst*)
The base class for synchronous request reply for `RyuApp.send_reply`.

2.3.12 `ryu.controller.ofp_event.EventOFPStateChange`

2.3.13 `ryu.controller.ofp_event.EventOFPPortStateChange`

2.3.14 `ryu.controller.dpset.EventDP`

2.3.15 `ryu.controller.dpset.EventPortAdd`

2.3.16 `ryu.controller.dpset.EventPortDelete`

2.3.17 `ryu.controller.dpset.EventPortModify`

2.3.18 `ryu.controller.network.EventNetworkPort`

2.3.19 `ryu.controller.network.EventNetworkDel`

2.3.20 `ryu.controller.network.EventMacAddress`

2.3.21 `ryu.controller.tunnels.EventTunnelKeyAdd`

2.3.22 `ryu.controller.tunnels.EventTunnelKeyDel`

2.3.23 `ryu.controller.tunnels.EventTunnelPort`

2.4 Library

Ryu provides some useful library for your network applications.

2.4.1 Packet library

Introduction

Ryu packet library helps you to parse and build various protocol packets. `dpkt` is the popular library for the same purpose, however it is not designed to handle protocols that are interleaved; `vlan`, `mpls`, `gre`, etc. So we implemented our own packet library.

Network Addresses

Unless otherwise specified, MAC/IPv4/IPv6 addresses are specified using human readable strings for this library. For example, '08:60:6e:7f:74:e7', '192.0.2.1', 'fe80::a60:6eff:fe7f:74e7'.

Parsing Packet

First, let's look at how we can use the library to parse the received packets in a handler for OFPPacketIn messages.

```
from ryu.lib.packet import packet

@handler.set_ev_cls(ofp_event.EventOFPPacketIn, handler.MAIN_DISPATCHER)
def packet_in_handler(self, ev):
    pkt = packet.Packet(array.array('B', ev.msg.data))
    for p in pkt.protocols:
        print p
```

You can create a Packet class instance with the received raw data. Then the packet library parses the data and creates protocol class instances included the data. The packet class 'protocols' has the protocol class instances.

If a TCP packet is received, something like the following is printed:

```
<ryu.lib.packet.ethernet.ethernet object at 0x107a5d790>
<ryu.lib.packet.vlan.vlan object at 0x107a5d7d0>
<ryu.lib.packet.ipv4.ipv4 object at 0x107a5d810>
<ryu.lib.packet.tcp.tcp object at 0x107a5d850>
```

If vlan is not used, you see something like:

```
<ryu.lib.packet.ethernet.ethernet object at 0x107a5d790>
<ryu.lib.packet.ipv4.ipv4 object at 0x107a5d810>
<ryu.lib.packet.tcp.tcp object at 0x107a5d850>
```

You can access to a specific protocol class instance by using the packet class iterator. Let's try to check VLAN id if VLAN is used:

```
from ryu.lib.packet import packet

@handler.set_ev_cls(ofp_event.EventOFPPacketIn, handler.MAIN_DISPATCHER)
def packet_in_handler(self, ev):
    pkt = packet.Packet(array.array('B', ev.msg.data))
    for p in pkt:
        print p.protocol_name, p
        if p.protocol_name == 'vlan':
            print 'vid = ', p.vid
```

You see something like:

```
ethernet <ryu.lib.packet.ethernet.ethernet object at 0x107a5d790>
vlan <ryu.lib.packet.vlan.vlan object at 0x107a5d7d0>
vid = 10
ipv4 <ryu.lib.packet.ipv4.ipv4 object at 0x107a5d810>
tcp <ryu.lib.packet.tcp.tcp object at 0x107a5d850>
```

Building Packet

You need to create protocol class instances that you want to send, add them to a packet class instance via `add_protocol` method, and then call `serialize` method. You have the raw data to send. The following example is building an arp packet.

```
from ryu.ofproto import ether
from ryu.lib.packet import ethernet, arp, packet

e = ethernet.ethernet(dst='ff:ff:ff:ff:ff:ff',
                      src='08:60:6e:7f:74:e7',
                      ethertype=ether.ETH_TYPE_ARP)
a = arp.arp(hwtype=1, proto=0x0800, hlen=6, plen=4, opcode=2,
           src_mac='08:60:6e:7f:74:e7', src_ip='192.0.2.1',
           dst_mac='00:00:00:00:00:00', dst_ip='192.0.2.2')
p = packet.Packet()
p.add_protocol(e)
p.add_protocol(a)
p.serialize()
print repr(p.data)  # the on-wire packet
```

2.4.2 Packet library API Reference

Packet class

Stream Parser class

List of the sub-classes:

- `ryu.lib.packet.bgp.StreamParser`

Protocol Header classes

Packet Base Class

class `ryu.lib.packet.packet_base.PacketBase`

A base class for a protocol (ethernet, ipv4, ...) header.

classmethod `get_packet_type` (*type_*)

Per-protocol dict-like get method.

Provided for convenience of protocol implementers. Internal use only.

classmethod `parser` (*buf*)

Decode a protocol header.

This method is used only when decoding a packet.

Decode a protocol header at offset 0 in bytearray *buf*. Returns the following three objects.

- An object to describe the decoded header.
- A `packet_base.PacketBase` subclass appropriate for the rest of the packet. None when the rest of the packet should be considered as raw payload.
- The rest of packet.

classmethod `register_packet_type(cls_, type_)`

Per-protocol dict-like set method.

Provided for convenience of protocol implementers. Internal use only.

serialize (*payload*, *prev*)

Encode a protocol header.

This method is used only when encoding a packet.

Encode a protocol header. Returns a bytearray which contains the header.

payload is the rest of the packet which will immediately follow this header.

prev is a packet_base.PacketBase subclass for the outer protocol header. *prev* is None if the current header is the outer-most. For example, *prev* is ipv4 or ipv6 for tcp.serialize.

ARP

BFD

BGP

BMP

BPDU

CFM

DHCP

DHCP6

Ethernet

Geneve

GRE

ICMP

ICMPv6

IGMP

IPv4

IPv6

LLC

LLDP

MPLS

OpenFlow

OSPF

PBB

SCTP

Slow

TCP

UDP

VLAN

VRRP

VXLAN

Zebra

2.4.3 PCAP file library

Introduction

Ryu PCAP file library helps you to read/write PCAP file which file format are described in [The Wireshark Wiki](#).

Reading PCAP file

For loading the packet data containing in PCAP files, you can use `pcaplib.Reader`.

```
class ryu.lib.pcaplib.Reader (file_obj)
    PCAP file reader
```

Argument	Description
<code>file_obj</code>	File object which reading PCAP file in binary mode

Example of usage:

```
from ryu.lib import pcaplib
from ryu.lib.packet import packet

frame_count = 0
```

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```
# iterate pcaplib.Reader that yields (timestamp, packet_data)
# in the PCAP file
for ts, buf in pcaplib.Reader(open('test.pcap', 'rb')):
    frame_count += 1
    pkt = packet.Packet(buf)
    print("%d, %f, %s" % (frame_count, ts, pkt))
```

Writing PCAP file

For dumping the packet data which your RyuApp received, you can use `pcaplib.Writer`.

class `ryu.lib.pcaplib.Writer` (*file_obj*, *snaplen=65535*, *network=1*)
PCAP file writer

Argument	Description
<code>file_obj</code>	File object which writing PCAP file in binary mode
<code>snaplen</code>	Max length of captured packets (in octets)
<code>network</code>	Data link type. (e.g. 1 for Ethernet, see tcpdump.org for details)

Example of usage:

```
...
from ryu.lib import pcaplib

class SimpleSwitch13(app_manager.RyuApp):
    OFP_VERSIONS = [ofproto_v1_3.OFP_VERSION]

    def __init__(self, *args, **kwargs):
        super(SimpleSwitch13, self).__init__(*args, **kwargs)
        self.mac_to_port = {}

        # Create pcaplib.Writer instance with a file object
        # for the PCAP file
        self.pcap_writer = pcaplib.Writer(open('mypcap.pcap', 'wb'))

    ...

    @set_ev_cls(ofp_event.EventOFPPacketIn, MAIN_DISPATCHER)
    def _packet_in_handler(self, ev):
        # Dump the packet data into PCAP file
        self.pcap_writer.write_pkt(ev.msg.data)

    ...
```

2.4.4 OF-Config support

Ryu has a library for OF-Config support.

XML schema files for NETCONFIG and OFConfig

XML schema files for NETCONF and OFConfig are stolen from LINC whose licence is Apache 2.0. It supports only part of OFConfig so that its schema files are (intentionally) limited such that operation attributes are allowed only in several limited places. Once our library is tested with other OFConfig switches, the schema files should be updated to allow operation attribute in more places.

References

- [NETCONF ietf](#),
- [NETCONF ietf wiki](#),
- [OF-Config spec](#),
- [ncclient](#),
- [ncclient repo](#),
- [LINC git repo](#)

2.4.5 BGP speaker library

Introduction

Ryu BGP speaker library helps you to enable your code to speak BGP protocol. The library supports IPv4, IPv4 MPLS-labeled VPN, IPv6 MPLS-labeled VPN and L2VPN EVPN address families.

Example

The following simple code creates a BGP instance with AS number 64512 and Router ID 10.0.0.1. It tries to establish a bgp session with a peer (its IP is 192.168.177.32 and the AS number is 64513). The instance advertizes some prefixes.

```
import eventlet

# BGPSpeaker needs sockets patched
eventlet.monkey_patch()

# initialize a log handler
# this is not strictly necessary but useful if you get messages like:
# No handlers could be found for logger "ryu.lib.hub"
import logging
import sys
log = logging.getLogger()
log.addHandler(logging.StreamHandler(sys.stderr))

from ryu.services.protocols.bgp.bgpspeaker import BGPSpeaker

def dump_remote_best_path_change(event):
    print 'the best path changed:', event.remote_as, event.prefix, \
        event.nexthop, event.is_withdraw

def detect_peer_down(remote_ip, remote_as):
    print 'Peer down:', remote_ip, remote_as
```

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```
if __name__ == "__main__":
    speaker = BGPSpeaker(as_number=64512, router_id='10.0.0.1',
                        best_path_change_handler=dump_remote_best_path_change,
                        peer_down_handler=detect_peer_down)

    speaker.neighbor_add('192.168.177.32', 64513)
    # uncomment the below line if the speaker needs to talk with a bmp server.
    # speaker.bmp_server_add('192.168.177.2', 11019)
    count = 1
    while True:
        eventlet.sleep(30)
        prefix = '10.20.' + str(count) + '.0/24'
        print "add a new prefix", prefix
        speaker.prefix_add(prefix)
        count += 1
        if count == 4:
            speaker.shutdown()
            break
```

2.4.6 BGP speaker library API Reference

BGPSpeaker class

2.4.7 MRT file library

Introduction

Ryu MRT file library helps you to read/write MRT (Multi-Threaded Routing Toolkit) Routing Information Export Format [RFC6396].

Reading MRT file

For loading the routing information contained in MRT files, you can use `mrtlib.Reader`.

Writing MRT file

For dumping the routing information which your RyuApp generated, you can use `mrtlib.Writer`.

2.4.8 OVSDb Manager library

Path: `ryu.services.protocols.ovsdb`

Introduction

Ryu OVSDb Manager library allows your code to interact with devices speaking the OVSDb protocol. This enables your code to perform remote management of the devices and react to topology changes on them.

Please note this library will spawn a server listening on the port 6640 (the IANA registered for OVSDb protocol), but does not initiate connections from controller side. Then, to make your devices connect to Ryu, you need to tell the controller IP address and port to your devices.

```
# Show current configuration
$ ovs-vsctl get-manager

# Set manager (controller) address
$ ovs-vsctl set-manager "tcp:127.0.0.1:6640"

# If you want to specify IPv6 address, wrap ip with brackets
$ ovs-vsctl set-manager "tcp:[::1]:6640"
```

Also this library identifies the devices by "system-id" which should be unique, persistent identifier among all devices connecting to a single controller. Please make sure "system-id" is configured before connecting.

```
# Show current configuration
$ ovs-vsctl get Open_vSwitch . external_ids:system-id

# Set system-id manually
$ ovs-vsctl set Open_vSwitch . external_ids:system-id=<SYSTEM-ID>
```

Example

The following logs all new OVSDb connections in "handle_new_ovsdb_connection" and also provides the API "create_port" for creating a port on a bridge.

```
import uuid

from ryu.base import app_manager
from ryu.controller.handler import set_ev_cls
from ryu.services.protocols.ovsdb import api as ovsdb
from ryu.services.protocols.ovsdb import event as ovsdb_event

class MyApp(app_manager.RyuApp):
    @set_ev_cls(ovsdb_event.EventNewOVSDbConnection)
    def handle_new_ovsdb_connection(self, ev):
        system_id = ev.system_id
        address = ev.client.address
        self.logger.info(
            'New OVSDb connection from system-id=%s, address=%s',
            system_id, address)

        # Example: If device has bridge "s1", add port "s1-eth99"
        if ovsdb.bridge_exists(self, system_id, "s1"):
            self.create_port(system_id, "s1", "s1-eth99")

    def create_port(self, system_id, bridge_name, name):
        new_iface_uuid = uuid.uuid4()
        new_port_uuid = uuid.uuid4()

        bridge = ovsdb.row_by_name(self, system_id, bridge_name)

        def _create_port(tables, insert):
            iface = insert(tables['Interface'], new_iface_uuid)
            iface.name = name
            iface.type = 'internal'

            port = insert(tables['Port'], new_port_uuid)
```

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```
port.name = name
port.interfaces = [iface]

bridge.ports = bridge.ports + [port]

    return new_port_uuid, new_iface_uuid

req = ovsdb_event.EventModifyRequest(system_id, _create_port)
rep = self.send_request(req)

if rep.status != 'success':
    self.logger.error('Error creating port %s on bridge %s: %s',
                      name, bridge, rep.status)
    return None

return rep.insert_uuids[new_port_uuid]
```

2.4.9 OVSDb library

Path: `ryu.lib.ovs`

Similar to the *OVSDb Manager library*, this library enables your application to speak the OVSDb protocol (RFC7047), but differ from the *OVSDb Manager library*, this library will initiate connections from controller side as `ovs-vsctl` command does. Please make sure that your devices are listening on either the Unix domain socket or TCP/SSL port before calling the APIs of this library.

```
# Show current configuration
$ ovs-vsctl get-manager

# Set TCP listen address
$ ovs-vsctl set-manager "tcp:6640"
```

See manpage of `ovs-vsctl` command for more details.

Basic Usage

1. Instantiate `ryu.lib.ovs.vsctl.VSctl`.
2. Construct commands with `ryu.lib.ovs.vsctl.VSctlCommand`. The syntax is almost the same as `ovs-vsctl` command.
3. Execute commands via `ryu.lib.ovs.vsctl.VSctl.run_command`.

Example

```
from ryu.lib.ovs import vsctl

OVSDb_ADDR = 'tcp:127.0.0.1:6640'
ovs_vsctl = vsctl.VSctl(OVSDb_ADDR)

# Equivalent to
# $ ovs-vsctl show
command = vsctl.VSctlCommand('show')
```

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```

ovs_vsctl.run_command([command])
print(command)
# >>> VSctlCommand(args=[], command='show', options=[], result='830d781f-c3c8-4b4f-837e-
↪106e1b33d058\n      ovs_version: "2.8.90"\n')

# Equivalent to
# $ ovs-vsctl list Port s1-eth1
command = vsctl.VSctlCommand('list', ('Port', 's1-eth1'))
ovs_vsctl.run_command([command])
print(command)
# >>> VSctlCommand(args=('Port', 's1-eth1'), command='list', options=[], result=[<ovs.db.
↪idl.Row object at 0x7f525fb682e8>])
print(command.result[0].name)
# >>> s1-eth1

```

API Reference

ryu.lib.ovs.vswitch

ryu.lib.ovs.bridge

2.5 OpenFlow protocol API Reference

2.5.1 OpenFlow version independent classes and functions

Base class for OpenFlow messages

Functions

2.5.2 OpenFlow v1.0 Messages and Structures

Controller-to-Switch Messages

Handshake

Switch Configuration

Modify State Messages

Queue Configuration Messages

Read State Messages

Send Packet Message

Barrier Message

Asynchronous Messages

Packet-In Message

Flow Removed Message

Port Status Message

Error Message

Symmetric Messages

Hello

Echo Request

Echo Reply

Vendor

Port Structures

Flow Match Structure

Action Structures

2.5.3 OpenFlow v1.2 Messages and Structures

Controller-to-Switch Messages

Handshake

Switch Configuration

Flow Table Configuration

Modify State Messages

Read State Messages

Queue Configuration Messages

Packet-Out Message

Barrier Message

Role Request Message

Asynchronous Messages

Packet-In Message

Flow Removed Message

Port Status Message

Error Message

Symmetric Messages

Hello

Echo Request

Echo Reply

Experimenter

Port Structures

Flow Match Structure

Flow Instruction Structures

Action Structures

2.5.4 OpenFlow v1.3 Messages and Structures

Controller-to-Switch Messages

Handshake

Switch Configuration

Flow Table Configuration

Modify State Messages

Multipart Messages

Queue Configuration Messages

Packet-Out Message

Barrier Message

Role Request Message

Set Asynchronous Configuration Message

Asynchronous Messages

Packet-In Message

Flow Removed Message

Port Status Message

Error Message

Symmetric Messages

Hello

Echo Request

Echo Reply

Experimenter

Port Structures

Flow Match Structure

Flow Instruction Structures

Action Structures

2.5.5 OpenFlow v1.4 Messages and Structures

Controller-to-Switch Messages

Handshake

Switch Configuration

Modify State Messages

Multipart Messages

Packet-Out Message

Barrier Message

Role Request Message

Bundle Messages

Set Asynchronous Configuration Message

Asynchronous Messages

Packet-In Message

Flow Removed Message

Port Status Message

Controller Role Status Message

Table Status Message

Request Forward Message

Symmetric Messages

Hello

Echo Request

Echo Reply

Error Message

Experimenter

Port Structures

Flow Match Structure

Flow Instruction Structures

Action Structures

2.5.6 OpenFlow v1.5 Messages and Structures

Controller-to-Switch Messages

Handshake

Switch Configuration

Modify State Messages

Multipart Messages

Packet-Out Message

Barrier Message

Role Request Message

Bundle Messages

Set Asynchronous Configuration Message

Asynchronous Messages

Packet-In Message

Flow Removed Message

Port Status Message

Controller Role Status Message

Table Status Message

Request Forward Message

Controller Status Message

Symmetric Messages

Hello

Echo Request

Echo Reply

Error Message

Experimenter

Port Structures

Flow Match Structure

Flow Stats Structures

Flow Instruction Structures

Action Structures

Controller Status Structure

2.6 Nicira Extension Structures

2.6.1 Nicira Extension Actions Structures

The followings shows the supported NXAction classes only in OpenFlow1.0

The followings shows the supported NXAction classes in OpenFlow1.0 or later

2.6.2 Nicira Extended Match Structures

2.7 Ryu API Reference

3.1 Setup TLS Connection

If you want to use secure channel to connect OpenFlow switches, you need to use TLS connection. This document describes how to setup Ryu to connect to the Open vSwitch over TLS.

3.1.1 Configuring a Public Key Infrastructure

If you don't have a PKI, the ovs-pki script included with Open vSwitch can help you. This section is based on the INSTALL.SSL in the Open vSwitch source code.

NOTE: How to install Open vSwitch isn't described in this document. Please refer to the Open vSwitch documents.

Create a PKI by using ovs-pki script:

```
% ovs-pki init
(Default directory is /usr/local/var/lib/openvswitch/pki)
```

The pki directory consists of controllerca and switchca subdirectories. Each directory contains CA files.

Create a controller private key and certificate:

```
% ovs-pki req+sign ctl controller
```

ctl-privkey.pem and ctl-cert.pem are generated in the current directory.

Create a switch private key and certificate:

```
% ovs-pki req+sign sc switch
```

sc-privkey.pem and sc-cert.pem are generated in the current directory.

3.1.2 Testing TLS Connection

Configuring ovs-vswitchd to use CA files using the ovs-vsctl "set-ssl" command, e.g.:

```
% ovs-vsctl set-ssl /etc/openvswitch/sc-privkey.pem \  
/etc/openvswitch/sc-cert.pem \  
/usr/local/var/lib/openvswitch/pki/controllerca/cacert.pem  
% ovs-vsctl add-br br0  
% ovs-vsctl set-controller br0 ssl:127.0.0.1:6633
```

Substitute the correct file names, if they differ from the ones used above. You should use absolute file names.

Run Ryu with CA files:

```
% ryu-manager --ctl-privkey ctl-privkey.pem \  
--ctl-cert ctl-cert.pem \  
--ca-certs /usr/local/var/lib/openvswitch/pki/switchca/cacert.pem \  
--verbose
```

You can see something like:

```
loading app ryu.controller.ofp_handler  
instantiating app ryu.controller.ofp_handler  
BRICK ofp_event  
  CONSUMES EventOFPSwitchFeatures  
  CONSUMES EventOFPErrormsg  
  CONSUMES EventOFPHello  
  CONSUMES EventOFPEchoRequest  
connected socket:<SSLSocket fileno=4 sock=127.0.0.1:6633 peer=127.0.0.1:61302> a  
ddress:('127.0.0.1', 61302)  
hello ev <ryu.controller.ofp_event.EventOFPHello object at 0x1047806d0>  
move onto config mode  
switch features ev version: 0x1 msg_type 0x6 xid 0xb0bb34e5 port OFPPhyPort(port  
_no=65534, hw_addr='\x16\xdc\xa2\xe2}K', name='br0\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00\x00',  
config=0, state=0, curr=0, advertised=0, supported=0, p  
eer=0)  
move onto main mode
```

3.2 Topology Viewer

ryu.app.gui_topology.gui_topology provides topology visualization.

This depends on following ryu applications.

ryu.app.rest_topology	Get node and link data.
ryu.app.ws_topology	Being notified change of link up/down.
ryu.app.ofctl_rest	Get flows of datapaths.

3.2.1 Usage

Run mininet (or join your real environment):

```
$ sudo mn --controller remote --topo tree,depth=3
```

Run GUI application:

```
$ PYTHONPATH=. ./bin/ryu run --observe-links ryu/app/gui_topology/gui_topology.py
```

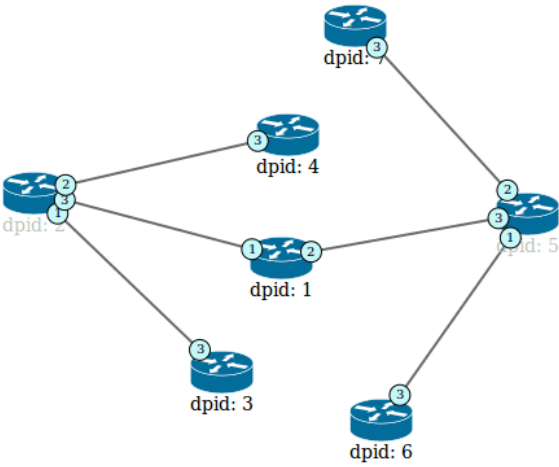
Access <http://<ip address of ryu host>:8080> with your web browser.

3.2.2 Screenshot

Mozilla Firefox (Private Browsing)

<http://192.168.31.202:8080/>

Ryu Topology Viewer



- { "actions": ["OUTPUT:65533"], "idle_timeout": 0, "cookie": 0, "packet_count": 18270, "hard_timeout": 0, "byte_count": 931770, "duration_nsec": 119000000, "priority": 65535, "duration_sec": 6114, "table_id": 0, "match": { "dl_type": 35020, "nw_dst": "0.0.0.0", "dl_vlan_pcp": 0, "dl_src": "00:00:00:00:00:00", "tp_src": 0, "dl_vlan": 0, "nw_src": "0.0.0.0", "nw_proto": 0, "tp_dst": 0, "dl_dst": "01:80:c2:00:00:0e", "in_port": 0 } }

4.1 Testing VRRP Module

This page describes how to test Ryu VRRP service

4.1.1 Running integrated tests

Some testing scripts are available.

- `ryu/tests/integrated/test_vrrp_linux_multi.py`
- `ryu/tests/integrated/test_vrrp_multi.py`

Each files include how to run in the comment. Please refer to it.

4.1.2 Running multiple Ryu VRRP in network namespace

The following command lines set up necessary bridges and interfaces.

And then run RYU-VRRP:

```
# ip netns add gateway1
# ip netns add gateway2

# brctl addbr vrrp-br0
# brctl addbr vrrp-br1

# ip link add veth0 type veth peer name veth0-br0
# ip link add veth1 type veth peer name veth1-br0
# ip link add veth2 type veth peer name veth2-br0
# ip link add veth3 type veth peer name veth3-br1
# ip link add veth4 type veth peer name veth4-br1
# ip link add veth5 type veth peer name veth5-br1
```

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```

# brctl addif vrrp-br0 veth0-br0
# brctl addif vrrp-br0 veth1-br0
# brctl addif vrrp-br0 veth2-br0
# brctl addif vrrp-br1 veth3-br1
# brctl addif vrrp-br1 veth4-br1
# brctl addif vrrp-br1 veth5-br1

# ip link set vrrp-br0 up
# ip link set vrrp-br1 up

# ip link set veth0 up
# ip link set veth0-br0 up
# ip link set veth1-br0 up
# ip link set veth2-br0 up
# ip link set veth3-br1 up
# ip link set veth4-br1 up
# ip link set veth5 up
# ip link set veth5-br1 up

# ip link set veth1 netns gateway1
# ip link set veth2 netns gateway2
# ip link set veth3 netns gateway1
# ip link set veth4 netns gateway2

# ip netns exec gateway1 ip link set veth1 up
# ip netns exec gateway2 ip link set veth2 up
# ip netns exec gateway1 ip link set veth3 up
# ip netns exec gateway2 ip link set veth4 up

# ip netns exec gateway1 .ryu-vrrp veth1 '10.0.0.2' 254
# ip netns exec gateway2 .ryu-vrrp veth2 '10.0.0.3' 100

```

Caveats

Please make sure that all interfaces and bridges are UP. Don't forget interfaces in netns gateway1/gateway2.

```

      ^ veth5
      |
      V veth5-br1
-----
|Linux Bridge vrrp-br1|
-----
veth3-br1^          ^ veth4-br1
  |              |
  veth3V          V veth4
-----          -----
|netns  |          |netns  |
|gateway1|        |gateway2|
|ryu-vrrp|        |ryu-vrrp|
-----          -----
veth1^            ^ veth2
  |              |
veth1-br0V        V veth2-br0
-----

```

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```
|Linux Brirge vrrp-br0|
|-----|
|      ^ veth0-br0    |
|      |              |
|      V veth0        |
```

Here's the helper executable, `ryu-vrrp`:

```
#!/usr/bin/env python
#
# Copyright (C) 2013 Nippon Telegraph and Telephone Corporation.
# Copyright (C) 2013 Isaku Yamahata <yamahata at valinux co jp>
#
# Licensed under the Apache License, Version 2.0 (the "License");
# you may not use this file except in compliance with the License.
# You may obtain a copy of the License at
#
#     http://www.apache.org/licenses/LICENSE-2.0
#
# Unless required by applicable law or agreed to in writing, software
# distributed under the License is distributed on an "AS IS" BASIS,
# WITHOUT WARRANTIES OR CONDITIONS OF ANY KIND, either express or
# implied.
# See the License for the specific language governing permissions and
# limitations under the License.

from ryu.lib import hub
hub.patch()

# TODO:
#   Right now, we have our own patched copy of ovs python bindings
#   Once our modification is upstreamed and widely deployed,
#   use it
#
# NOTE: this modifies sys.path and thus affects the following imports.
# eg. oslo.config.cfg.
import ryu.contrib

from oslo.config import cfg
import logging
import netaddr
import sys
import time

from ryu import log
log.early_init_log(logging.DEBUG)

from ryu import flags
from ryu import version
from ryu.base import app_manager
from ryu.controller import controller
from ryu.lib import mac as lib_mac
from ryu.lib.packet import vrrp
from ryu.services.protocols.vrrp import api as vrrp_api
from ryu.services.protocols.vrrp import event as vrrp_event
```

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```

CONF = cfg.CONF

_VRID = 7
_IP_ADDRESS = '10.0.0.1'
_PRIORITY = 100

class VRRPTestRouter(app_manager.RyuApp):
    def __init__(self, *args, **kwargs):
        super(VRRPTestRouter, self).__init__(*args, **kwargs)
        print args
        self.logger.debug('vrrp_config %s', args)
        self._ifname = args[0]
        self._primary_ip_address = args[1]
        self._priority = int(args[2])

    def start(self):
        print 'start'
        hub.spawn(self._main)

    def _main(self):
        print self
        interface = vrrp_event.VRRPInterfaceNetworkDevice(
            lib_mac.DONTCARE, self._primary_ip_address, None, self._ifname)
        self.logger.debug('%s', interface)

        ip_addresses = [_IP_ADDRESS]
        config = vrrp_event.VRRPConfig(
            version=vrrp.VRRP_VERSION_V3, vrid=_VRID, priority=self._priority,
            ip_addresses=ip_addresses)
        self.logger.debug('%s', config)

        rep = vrrp_api.vrrp_config(self, interface, config)
        self.logger.debug('%s', rep)

def main():
    vrrp_config = sys.argv[-3:]
    sys.argv = sys.argv[:-3]
    CONF(project='ryu', version='ryu-vrrp %s' % version)

    log.init_log()
    # always enable ofp for now.
    app_lists = ['ryu.services.protocols.vrrp.manager',
                 'ryu.services.protocols.vrrp.dumper',
                 'ryu.services.protocols.vrrp.sample_manager']

    app_mgr = app_manager.AppManager.get_instance()
    app_mgr.load_apps(app_lists)
    contexts = app_mgr.create_contexts()
    app_mgr.instantiate_apps(**contexts)
    vrrp_router = app_mgr.instantiate(VRRPTestRouter, *vrrp_config, **contexts)
    vrrp_router.start()

    while True:
        time.sleep(999999)

```

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```

app_mgr.close()

if __name__ == "__main__":
    main()

```

4.2 Testing OF-config support with LINC

This page describes how to setup LINC and test Ryu OF-config with it.

The procedure is as follows. Although all the procedure is written for reader's convenience, please refer to LINC document for latest informations of LINC.

<https://github.com/FlowForwarding/LINC-Switch>

The test procedure

- install Erlang environment
- build LINC
- configure LINC switch
- setup for LINC
- run LINC switch
- run Ryu test_of_config app

For getting/installing Ryu itself, please refer to <http://osrg.github.io/ryu/>

4.2.1 Install Erlang environment

Since LINC is written in Erlang, you need to install Erlang execution environment. Required version is R15B+.

The easiest way is to use binary package from <https://www.erlang-solutions.com/downloads/download-erlang-otp>

The distribution may also provide Erlang package.

4.2.2 build LINC

install necessary packages for build

install necessary build tools

On Ubuntu:

```
# apt-get install git-core bridge-utils libpcap0.8 libpcap-dev libcap2-bin uml-utilities
```

On RedHat/CentOS:

```
# yum install git sudo bridge-utils libpcap libpcap-devel libcap tuncctl
```

Note that on RedHat/CentOS 5.x you need a newer version of libpcap:

```
# yum erase libpcap libpcap-devel
# yum install flex byacc
# wget http://www.tcpdump.org/release/libpcap-1.2.1.tar.gz
# tar xzf libpcap-1.2.1.tar.gz
# cd libpcap-1.2.1
# ./configure
# make && make install
```

get LINC repo and built

Clone LINC repo:

```
% git clone git://github.com/FlowForwarding/LINC-Switch.git
```

Then compile everything:

```
% cd LINC-Switch
% make
```

Note: At the time of this writing, `test_of_config` fails due to a bug of LINC. You can try this test with LINC which is built by the following methods.

```
% cd LINC-Switch
% make
% cd deps/of_config
% git reset --hard f772af4b765984381ad024ca8e5b5b8c54362638
% cd ../../
% make offline
```

4.2.3 Setup LINC

edit LINC switch configuration file. `rel/linc/releases/0.1/sys.config` Here is the sample `sys.config` for `test_of_config.py` to run.

```
[{linc,
  [{of_config,enabled},
   {capable_switch_ports,
    [{port,1,[{interface,"linc-port"}]},
     {port,2,[{interface,"linc-port2"}]},
     {port,3,[{interface,"linc-port3"}]},
     {port,4,[{interface,"linc-port4"}]}]},
   {capable_switch_queues,
    [
      {queue,991,[{min_rate,10},{max_rate,120}]},
      {queue,992,[{min_rate,10},{max_rate,130}]},
      {queue,993,[{min_rate,200},{max_rate,300}]},
      {queue,994,[{min_rate,400},{max_rate,900}]}
    ]},
   {logical_switches,
    [{switch,0,
      [{backend,linc_us4},
```

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```

        {controllers, [{"Switch0-Default-Controller", "127.0.0.1", 6633, tcp}]},
        {controllers_listener, {"127.0.0.1", 9998, tcp}},
        {queues_status, enabled},
        {ports, [{port, 1, {queues, []}}, {port, 2, {queues, [991, 992]}}]}]}},
    },
    {switch, 7,
     [{backend, linc_us3},
      {controllers, [{"Switch7-Controller", "127.0.0.1", 6633, tcp}]},
      {controllers_listener, disabled},
      {queues_status, enabled},
      {ports, [{port, 4, {queues, []}}, {port, 3, {queues, [993, 994]}}]}]}},
    ]}],
{enetconf,
 [{capabilities,
  [{base, {1, 0}},
   {base, {1, 1}},
   {startup, {1, 0}},
   {'writable-running', {1, 0}}]},
 {callback_module, linc_ofconfig},
 {sshd_ip, {127, 0, 0, 1}},
 {sshd_port, 1830},
 {sshd_user_passwords, [{"linc", "linc"}]}]},
{lager,
 [{handlers,
  [{lager_console_backend, debug},
   {lager_file_backend,
    [{"log/error.log", error, 10485760, "$D0", 5},
     {"log/console.log", info, 10485760, "$D0", 5}]}]}]},
{sasl,
 [{sasl_error_logger, {file, "log/sasl-error.log"}},
 {errlog_type, error},
 {error_logger_mf_dir, "log/sasl"},
 {error_logger_mf_maxbytes, 10485760},
 {error_logger_mf_maxfiles, 5}]},
{sync, [{excluded_modules, [procket]}]}].

```

4.2.4 setup for LINC

As the above sys.config requires some network interface, create them:

```

# ip link add linc-port type veth peer name linc-port-peer
# ip link set linc-port up
# ip link add linc-port2 type veth peer name linc-port-peer2
# ip link set linc-port2 up
# ip link add linc-port3 type veth peer name linc-port-peer3
# ip link set linc-port3 up
# ip link add linc-port4 type veth peer name linc-port-peer4
# ip link set linc-port4 up

```

After stopping LINC, those created interfaces can be deleted:

```

# ip link delete linc-port
# ip link delete linc-port2
# ip link delete linc-port3
# ip link delete linc-port4

```

4.2.5 Starting LINC OpenFlow switch

Then run LINC:

```
# rel/linc/bin/linc console
```

4.2.6 Run Ryu test_of_config app

Run test_of_config app:

```
# ryu-manager --verbose ryu.tests.integrated.test_of_config ryu.app.rest
```

If you don't install ryu and are working in the git repo directly:

```
# PYTHONPATH=. ./bin/ryu-manager --verbose ryu.tests.integrated.test_of_config ryu.  
↪ app.rest
```

Snort Intergration

This document describes how to integrate Ryu with Snort.

5.1 Overview

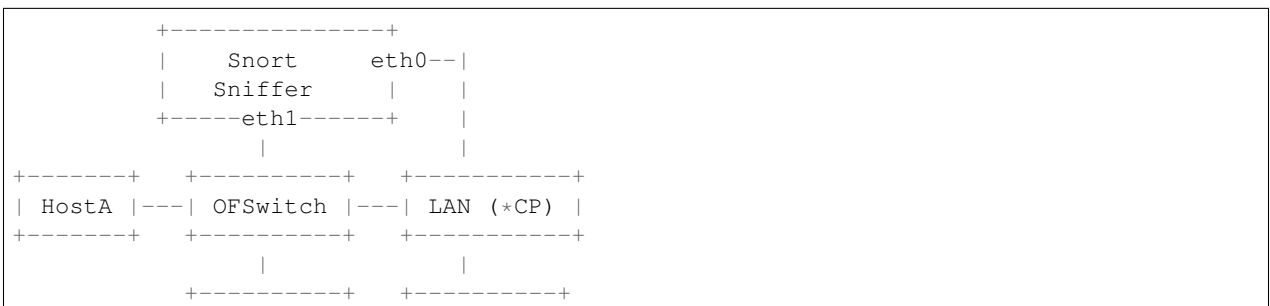
There are two options can send alert to Ryu controller. The Option 1 is easier if you just want to demonstrate or test. Since Snort need very large computation power for analyzing packets you can choose Option 2 to separate them.

[Option 1] Ryu and Snort are on the same machine



The above depicts Ryu and Snort architecture. Ryu receives Snort alert packet via **Unix Domain Socket** . To monitor packets between HostA and HostB, installing a flow that mirrors packets to Snort.

[Option 2] Ryu and Snort are on the different machines



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*CP: Control Plane

The above depicts Ryu and Snort architecture. Ryu receives Snort alert packet via **Network Socket** . To monitor packets between HostA and HostB, installing a flow that mirrors packets to Snort.

5.2 Installation Snort

Snort is an open source network intrusion prevention and detectionsystem developed by Sourcefire. If you are not familiar with installing/setting up Snort, please referto snort setup guides.

<http://www.snort.org/documents>

5.3 Configure Snort

The configuration example is below:

- Add a snort rules file into `/etc/snort/rules` named `Myrules.rules`

```
alert icmp any any -> any any (msg:"Pinging...";sid:1000004;)
alert tcp any any -> any 80 (msg:"Port 80 is accessing"; sid:1000003;)
```

- Add the custom rules in `/etc/snort/snort.conf`

```
include $RULE_PATH/Myrules.rules
```

Configure NIC as a promiscuous mode.

```
$ sudo ifconfig eth1 promisc
```

5.4 Usage

[Option 1]

1. Modify the `simple_switch_snort.py`:

```
socket_config = {'unixsock': True}
# True: Unix Domain Socket Server [Option1]
# False: Network Socket Server [Option2]
```

2. Run Ryu with sample application:

```
$ sudo ./bin/ryu-manager ryu/app/simple_switch_snort.py
```

The incoming packets will all mirror to **port 3** which should be connect to Snort network interface. You can modify the mirror port by assign a new value in the `self.snort_port = 3` of `simple_switch_snort.py`

3. Run Snort:

```
$ sudo -i
$ snort -i eth1 -A unsock -l /tmp -c /etc/snort/snort.conf
```

4. Send an ICMP packet from HostA (192.168.8.40) to HostB (192.168.8.50):

```
$ ping 192.168.8.50
```

5. You can see the result under next section.

[Option 2]

1. Modify the `simple_switch_snort.py`:

```
socket_config = {'unixsock': False}
# True: Unix Domain Socket Server [Option1]
# False: Network Socket Server [Option2]
```

2. Run Ryu with sample application (On the Controller):

```
$ ./bin/ryu-manager ryu/app/simple_switch_snort.py
```

3. Run Snort (On the Snort machine):

```
$ sudo -i
$ snort -i eth1 -A unsock -l /tmp -c /etc/snort/snort.conf
```

4. Run `pigrelay.py` (On the Snort machine):

```
$ sudo python pigrelay.py
```

This program listening snort alert messages from unix domain socket and sending it to Ryu using network socket.

You can clone the source code from this repo. <https://github.com/John-Lin/pigrelay>

5. Send an ICMP packet from HostA (192.168.8.40) to HostB (192.168.8.50):

```
$ ping 192.168.8.50
```

6. You can see the alert message below:

```
alertmsg: Pinging...
icmp(code=0,csum=19725,data=echo(data=array('B', [97, 98, 99, 100, 101, 102, 103,
↪104, 105, 106, 107, 108, 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119,
↪97, 98, 99, 100, 101, 102, 103, 104, 105])),id=1,seq=78),type=8)

ipv4(csum=42562,dst='192.168.8.50',flags=0,header_length=5,identification=724,
↪offset=0,option=None,proto=1,src='192.168.8.40',tos=0,total_length=60,ttl=128,
↪version=4)

ethernet(dst='00:23:54:5a:05:14',ethertype=2048,src='00:23:54:6c:1d:17')
```

```
alertmsg: Pinging...
icmp(code=0,csum=21773,data=echo(data=array('B', [97, 98, 99, 100, 101, 102, 103,
↪104, 105, 106, 107, 108, 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119,
↪97, 98, 99, 100, 101, 102, 103, 104, 105])),id=1,seq=78),type=0)

ipv4(csum=52095,dst='192.168.8.40',flags=0,header_length=5,identification=7575,
↪offset=0,option=None,proto=1,src='192.168.8.50',tos=0,total_length=60,ttl=64,
↪version=4)
```

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Built-in Ryu applications

Ryu has some built-in Ryu applications. Some of them are examples. Others provide some functionalities to other Ryu applications.

6.1 ryu.app.ofctl

ryu.app.ofctl provides a convenient way to use OpenFlow messages synchronously.

OfctlService ryu application is automatically loaded if your Ryu application imports ofctl.api module.

Example:

```
import ryu.app.ofctl.api
```

OfctlService application internally uses OpenFlow barrier messages to ensure message boundaries. As OpenFlow messages are asynchronous and some of messages does not have any replies on success, barriers are necessary for correct error handling.

6.1.1 api module

6.1.2 exceptions

exception ryu.app.ofctl.exception.InvalidDatapath(*result*)

Datapath is invalid.

This can happen when the bridge disconnects.

exception ryu.app.ofctl.exception.OFError(*result*)

OFErrorMsg is received.

exception ryu.app.ofctl.exception.UnexpectedMultiReply(*result*)

Two or more replies are received for reply_muiti=False request.

6.2 ryu.app.ofctl_rest

ryu.app.ofctl_rest provides REST APIs for retrieving the switch stats and Updating the switch stats. This application helps you debug your application and get various statistics.

This application supports OpenFlow version 1.0, 1.2, 1.3, 1.4 and 1.5.

Contents

- *ryu.app.ofctl_rest*
 - *Retrieve the switch stats*
 - * *Get all switches*
 - * *Get the desc stats*
 - * *Get all flows stats*
 - * *Get flows stats filtered by fields*
 - * *Get aggregate flow stats*
 - * *Get aggregate flow stats filtered by fields*
 - * *Get table stats*
 - * *Get table features*
 - * *Get ports stats*
 - * *Get ports description*
 - * *Get queues stats*
 - * *Get queues config*
 - * *Get queues description*
 - * *Get groups stats*
 - * *Get group description stats*
 - * *Get group features stats*
 - * *Get meters stats*
 - * *Get meter config stats*
 - * *Get meter description stats*
 - * *Get meter features stats*
 - * *Get role*
 - *Update the switch stats*
 - * *Add a flow entry*
 - * *Modify all matching flow entries*
 - * *Modify flow entry strictly*
 - * *Delete all matching flow entries*
 - * *Delete flow entry strictly*

- * *Delete all flow entries*
- * *Add a group entry*
- * *Modify a group entry*
- * *Delete a group entry*
- * *Modify the behavior of the port*
- * *Add a meter entry*
- * *Modify a meter entry*
- * *Delete a meter entry*
- * *Modify role*
- *Support for experimenter multipart*
 - * *Send a experimenter message*
- *Reference: Description of Match and Actions*
 - * *Description of Match on request messages*
 - * *Description of Actions on request messages*

6.2.1 Retrieve the switch stats

Get all switches

Get the list of all switches which connected to the controller.

Usage:

Method	GET
URI	/stats/switches

Response message body:

Attribute	Description	Example
dpid	Datapath ID	1

Example of use:

```
$ curl -X GET http://localhost:8080/stats/switches
```

```
[
  1,
  2,
  3
]
```

Note: The result of the REST command is formatted for easy viewing.

Get the desc stats

Get the desc stats of the switch which specified with Datapath ID in URI.

Usage:

Method	GET
URI	/stats/desc/<dpid>

Response message body:

Attribute	Description	Example
dpid	Datapath ID	"1"
mfr_desc	Manufacturer description	"Nicira, Inc.",
hw_desc	Hardware description	"Open vSwitch",
sw_desc	Software description	"2.3.90",
serial_num	Serial number	"None",
dp_desc	Human readable description of datapath	"None"

Example of use:

```
$ curl -X GET http://localhost:8080/stats/desc/1
```

```
{
  "1": {
    "mfr_desc": "Nicira, Inc.",
    "hw_desc": "Open vSwitch",
    "sw_desc": "2.3.90",
    "serial_num": "None",
    "dp_desc": "None"
  }
}
```

Get all flows stats

Get all flows stats of the switch which specified with Datapath ID in URI.

Usage:

Method	GET
URI	/stats/flow/<dpid>

Response message body(OpenFlow1.3 or earlier):

Attribute	Description	Example
dpid	Datapath ID	"1"
length	Length of this entry	88
table_id	Table ID	0
duration_sec	Time flow has been alive in seconds	2
duration_nsec	Time flow has been alive in nanoseconds beyond duration_sec	6.76e+08
priority	Priority of the entry	11111
idle_timeout	Number of seconds idle before expiration	0
hard_timeout	Number of seconds before expiration	0
flags	Bitmap of OFPFF_* flags	1
cookie	Opaque controller-issued identifier	1
packet_count	Number of packets in flow	0
byte_count	Number of bytes in flow	0
match	Fields to match	{"in_port": 1}
actions	Instruction set	["OUTPUT:2"]

Response message body(OpenFlow1.4 or later):

Attribute	Description	Example
dpid	Datapath ID	"1"
length	Length of this entry	88
table_id	Table ID	0
duration_sec	Time flow has been alive in seconds	2
duration_nsec	Time flow has been alive in nanoseconds beyond duration_sec	6.76e+08
priority	Priority of the entry	11111
idle_timeout	Number of seconds idle before expiration	0
hard_timeout	Number of seconds before expiration	0
flags	Bitmap of OFPFF_* flags	1
cookie	Opaque controller-issued identifier	1
packet_count	Number of packets in flow	0
byte_count	Number of bytes in flow	0
importance	Eviction precedence	0
match	Fields to match	{"eth_type": 2054}
instructions	struct ofp_instruction_header	[{"type":GOTO_TABLE", "table_id":1}]

Example of use:

```
$ curl -X GET http://localhost:8080/stats/flow/1
```

Response (OpenFlow1.3 or earlier):

```
{
  "1": [
    {
      "length": 88,
```

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```
    "table_id": 0,
    "duration_sec": 2,
    "duration_nsec": 6.76e+08,
    "priority": 11111,
    "idle_timeout": 0,
    "hard_timeout": 0,
    "flags": 1,
    "cookie": 1,
    "packet_count": 0,
    "byte_count": 0,
    "match": {
        "in_port": 1
    },
    "actions": [
        "OUTPUT:2"
    ]
  }
]
```

Response (OpenFlow1.4 or later):

```
{
  "1": [
    {
      "length": 88,
      "table_id": 0,
      "duration_sec": 2,
      "duration_nsec": 6.76e+08,
      "priority": 11111,
      "idle_timeout": 0,
      "hard_timeout": 0,
      "flags": 1,
      "cookie": 1,
      "packet_count": 0,
      "byte_count": 0,
      "match": {
        "eth_type": 2054
      },
      "importance": 0,
      "instructions": [
        {
          "type": "APPLY_ACTIONS",
          "actions": [
            {
              "port": 2,
              "max_len": 0,
              "type": "OUTPUT"
            }
          ]
        }
      ]
    }
  ]
}
```

Get flows stats filtered by fields

Get flows stats of the switch filtered by the OFPFlowStats fields. This is POST method version of *Get all flows stats*.

Usage:

Method	POST
URI	/stats/flow/<dpid>

Request message body:

Attribute	Description	Example	Default
table_id	Table ID (int)	0	OF-PTT_ALL
out_port	Require matching entries to include this as an output port (int)	2	OFPP_ANY
out_group	Require matching entries to include this as an output group (int)	1	OFPG_ANY
cookie	Require matching entries to contain this cookie value (int)	1	0
cookie_mask	Mask used to restrict the cookie bits that must match (int)	1	0
match	Fields to match (dict)	{"in_port": 1}	{ } #wild-carded
priority	Priority of the entry (int) (See Note)	1111	#wild-carded

Note: OpenFlow Spec does not allow to filter flow entries by priority, but when with a large amount of flow entries, filtering by priority is convenient to get statistics efficiently. So, this app provides priority field for filtering.

Response message body: The same as *Get all flows stats*

Example of use:

```
$ curl -X POST -d '{
  "table_id": 0,
  "out_port": 2,
  "cookie": 1,
  "cookie_mask": 1,
  "match": {
    "in_port": 1
  }
}' http://localhost:8080/stats/flow/1
```

Response (OpenFlow1.3 or earlier):

```
{
  "1": [
    {
      "length": 88,
      "table_id": 0,
```

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```
"duration_sec": 2,
"duration_nsec": 6.76e+08,
"priority": 11111,
"idle_timeout": 0,
"hard_timeout": 0,
"flags": 1,
"cookie": 1,
"packet_count": 0,
"byte_count": 0,
"match": {
    "in_port": 1
},
"actions": [
    "OUTPUT:2"
]
}
]
```

Response (OpenFlow1.4 or later):

```
{
  "1": [
    {
      "length": 88,
      "table_id": 0,
      "duration_sec": 2,
      "duration_nsec": 6.76e+08,
      "priority": 11111,
      "idle_timeout": 0,
      "hard_timeout": 0,
      "flags": 1,
      "cookie": 1,
      "packet_count": 0,
      "byte_count": 0,
      "match": {
        "eth_type": 2054
      },
      "importance": 0,
      "instructions": [
        {
          "type": "APPLY_ACTIONS",
          "actions": [
            {
              "port": 2,
              "max_len": 0,
              "type": "OUTPUT"
            }
          ]
        }
      ]
    }
  ]
}
```

Get aggregate flow stats

Get aggregate flow stats of the switch which specified with Datapath ID in URI.

Usage:

Method	GET
URI	/stats/aggregateflow/<dpid>

Response message body:

Attribute	Description	Example
dpid	Datapath ID	"1"
packet_count	Number of packets in flows	18
byte_count	Number of bytes in flows	756
flow_count	Number of flows	3

Example of use:

```
$ curl -X GET http://localhost:8080/stats/aggregateflow/1
```

```
{
  "1": [
    {
      "packet_count": 18,
      "byte_count": 756,
      "flow_count": 3
    }
  ]
}
```

Get aggregate flow stats filtered by fields

Get aggregate flow stats of the switch filtered by the OFPAggregateStats fields. This is POST method version of *Get aggregate flow stats*.

Usage:

Method	POST
URI	/stats/aggregateflow/<dpid>

Request message body:

Attribute	Description	Example	Default
table_id	Table ID (int)	0	OF-PTT_ALL
out_port	Require matching entries to include this as an output port (int)	2	OFPP_ANY
out_group	Require matching entries to include this as an output group (int)	1	OFPG_ANY
cookie	Require matching entries to contain this cookie value (int)	1	0
cookie_mask	Mask used to restrict the cookie bits that must match (int)	1	0
match	Fields to match (dict)	{"in_port": 1}	{ } #wild-carded

Response message body: The same as *Get aggregate flow stats*

Example of use:

```
$ curl -X POST -d '{
  "table_id": 0,
  "out_port": 2,
  "cookie": 1,
  "cookie_mask": 1,
  "match": {
    "in_port": 1
  }
}' http://localhost:8080/stats/aggregateflow/1
```

```
{
  "1": [
    {
      "packet_count": 18,
      "byte_count": 756,
      "flow_count": 3
    }
  ]
}
```

Get table stats

Get table stats of the switch which specified with Datapath ID in URI.

Usage:

Method	GET
URI	/stats/table/<dpid>

Response message body(OpenFlow1.0):

Attribute	Description	Example
dpid	Datapath ID	"1"
table_id	Table ID	0
name	Name of Table	"classifier"
max_entries	Max number of entries supported	1e+06
wildcards	Bitmap of OFPFW_* wildcards that are supported by the table	["IN_PORT","DL_VLAN"]
active_count	Number of active entries	0
lookup_count	Number of packets looked up in table	8
matched_count	Number of packets that hit table	0

Response message body(OpenFlow1.2):

Attribute	Description	Example
dpid	Datapath ID	"1"
table_id	Table ID	0
name	Name of Table	"classifier"
match	Bitmap of (1 << OFPXMT_*) that indicate the fields the table can match on	["OFB_IN_PORT","OFB_METADATA"]
wildcards	Bitmap of (1 << OFPXMT_*) wildcards that are supported by the table	["OFB_IN_PORT","OFB_METADATA"]
write_actions	Bitmap of OFPAT_* that are supported by the table with OFPIT_WRITE_ACTIONS	["OUTPUT","SET_MPLS_TTL"]
apply_actions	Bitmap of OFPAT_* that are supported by the table with OFPIT_APPLY_ACTIONS	["OUTPUT","SET_MPLS_TTL"]
write_setfields	Bitmap of (1 << OFPXMT_*) header fields that can be set with OFPIT_WRITE_ACTIONS	["OFB_IN_PORT","OFB_METADATA"]
apply_setfields	Bitmap of (1 << OFPXMT_*) header fields that can be set with OFPIT_APPLY_ACTIONS	["OFB_IN_PORT","OFB_METADATA"]
meta-data_match	Bits of metadata table can match	18446744073709552000
meta-data_write	Bits of metadata table can write	18446744073709552000
instructions	Bitmap of OFPIT_* values supported	["GOTO_TABLE","WRITE_METADATA"]
config	Bitmap of OFPTC_* values	[]
max_entries	Max number of entries supported	1e+06
active_count	Number of active entries	0
lookup_count	Number of packets looked up in table	0
matched_count	Number of packets that hit table	8

Response message body(OpenFlow1.3):

Attribute	Description	Example
dpid	Datapath ID	"1"
table_id	Table ID	0
active_count	Number of active entries	0
lookup_count	Number of packets looked up in table	8
matched_count	Number of packets that hit table	0

Example of use:

```
$ curl -X GET http://localhost:8080/stats/table/1
```

Response (OpenFlow1.0):

```
{
  "1": [
    {
      "table_id": 0,
      "lookup_count": 8,
      "max_entries": 1e+06,
      "active_count": 0,
      "name": "classifier",
      "matched_count": 0,
      "wildcards": [
        "IN_PORT",
        "DL_VLAN"
      ]
    },
    ...
    {
      "table_id": 253,
      "lookup_count": 0,
      "max_entries": 1e+06,
      "active_count": 0,
      "name": "table253",
      "matched_count": 0,
      "wildcards": [
        "IN_PORT",
        "DL_VLAN"
      ]
    }
  ]
}
```

Response (OpenFlow1.2):

```
{
  "1": [
    {
      "apply_setfields": [
        "OFB_IN_PORT",
        "OFB_METADATA"
      ],
      "match": [
        "OFB_IN_PORT",
        "OFB_METADATA"
      ],
    },
  ],
}
```

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```

    "metadata_write": 18446744073709552000,
    "config": [],
    "instructions": [
        "GOTO_TABLE",
        "WRITE_METADATA"
    ],
    "table_id": 0,
    "metadata_match": 18446744073709552000,
    "lookup_count": 8,
    "wildcards": [
        "OFB_IN_PORT",
        "OFB_METADATA"
    ],
    "write_setfields": [
        "OFB_IN_PORT",
        "OFB_METADATA"
    ],
    "write_actions": [
        "OUTPUT",
        "SET_MPLS_TTL"
    ],
    "name": "classifier",
    "matched_count": 0,
    "apply_actions": [
        "OUTPUT",
        "SET_MPLS_TTL"
    ],
    "active_count": 0,
    "max_entries": 1e+06
},
...
{
    "apply_setfields": [
        "OFB_IN_PORT",
        "OFB_METADATA"
    ],
    "match": [
        "OFB_IN_PORT",
        "OFB_METADATA"
    ],
    "metadata_write": 18446744073709552000,
    "config": [],
    "instructions": [
        "GOTO_TABLE",
        "WRITE_METADATA"
    ],
    "table_id": 253,
    "metadata_match": 18446744073709552000,
    "lookup_count": 0,
    "wildcards": [
        "OFB_IN_PORT",
        "OFB_METADATA"
    ],
    "write_setfields": [
        "OFB_IN_PORT",
        "OFB_METADATA"
    ],
    "write_actions": [
        "OUTPUT",
        "SET_MPLS_TTL"
    ],
    "name": "classifier",
    "matched_count": 0,
    "apply_actions": [
        "OUTPUT",
        "SET_MPLS_TTL"
    ],
    "active_count": 0,
    "max_entries": 1e+06
}

```

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```

        "write_actions": [
            "OUTPUT",
            "SET_MPLS_TTL"
        ],
        "name": "table253",
        "matched_count": 0,
        "apply_actions": [
            "OUTPUT",
            "SET_MPLS_TTL"
        ],
        "active_count": 0,
        "max_entries": 1e+06
    }
]
}

```

Response (OpenFlow1.3):

```

{
  "1": [
    {
      "active_count": 0,
      "table_id": 0,
      "lookup_count": 8,
      "matched_count": 0
    },
    ...
    {
      "active_count": 0,
      "table_id": 253,
      "lookup_count": 0,
      "matched_count": 0
    }
  ]
}

```

Get table features

Get table features of the switch which specified with Datapath ID in URI.

Usage:

Method	GET
URI	/stats/tablefeatures/<dpid>

Response message body:

Attribute	Description	Example
dpid	Datapath ID	"1"
table_id	Table ID	0
name	Name of Table	"table_0"
meta-data_match	Bits of metadata table can match	18446744073709552000
meta-data_write	Bits of metadata table can write	18446744073709552000
config	Bitmap of OFPTC_* values	0
max_entries	Max number of entries supported	4096
properties	struct ofp_table_feature_prop_header	["type": "INSTRUC-TIONS", "instruction_ids": [...],...]

Example of use:

```
$ curl -X GET http://localhost:8080/stats/tablefeatures/1
```

```
{
  "1": [
    {
      "metadata_write": 18446744073709552000,
      "config": 0,
      "table_id": 0,
      "metadata_match": 18446744073709552000,
      "max_entries": 4096,
      "properties": [
        {
          "type": "INSTRUCTIONS",
          "instruction_ids": [
            {
              "len": 4,
              "type": 1
            },
            ...
          ]
        },
        ...
      ],
      "name": "table_0"
    },
    {
      "metadata_write": 18446744073709552000,
      "config": 0,
      "table_id": 1,
      "metadata_match": 18446744073709552000,
      "max_entries": 4096,
      "properties": [
        {
          "type": "INSTRUCTIONS",
          "instruction_ids": [
            {
              "len": 4,
              "type": 1
            },
            ...
          ]
        },
        ...
      ]
    }
  ]
}
```

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```
        ...
    ],
    },
    ...
],
    "name": "table_1"
},
    ...
]
}
```

Get ports stats

Get ports stats of the switch which specified with Datapath ID in URI.

Usage:

Method	GET
URI	/stats/port/<dpid>[/<port>]

Note: Specification of port number is optional.

Response message body(OpenFlow1.3 or earlier):

Attribute	Description	Example
dpid	Datapath ID	"1"
port_no	Port number	1
rx_packets	Number of received packets	9
tx_packets	Number of transmitted packets	6
rx_bytes	Number of received bytes	738
tx_bytes	Number of transmitted bytes	252
rx_dropped	Number of packets dropped by RX	0
tx_dropped	Number of packets dropped by TX	0
rx_errors	Number of receive errors	0
tx_errors	Number of transmit errors	0
rx_frame_err	Number of frame alignment errors	0
rx_over_err	Number of packets with RX overrun	0
rx_crc_err	Number of CRC errors	0
collisions	Number of collisions	0
duration_sec	Time port has been alive in seconds	12
duration_nsec	Time port has been alive in nanoseconds beyond duration_sec	9.76e+08

Response message body(OpenFlow1.4 or later):

Attribute	Description	Example
dpid	Datapath ID	"1"
port_no	Port number	1
rx_packets	Number of received packets	9
tx_packets	Number of transmitted packets	6
rx_bytes	Number of received bytes	738
tx_bytes	Number of transmitted bytes	252
rx_dropped	Number of packets dropped by RX	0
tx_dropped	Number of packets dropped by TX	0
rx_errors	Number of receive errors	0
tx_errors	Number of transmit errors	0
duration_sec	Time port has been alive in seconds	12
duration_nsec	Time port has been alive in nanoseconds beyond duration_sec	9.76e+08
properties	struct of p_port_desc_prop_header	[{"rx_frame_err": 0, "rx_over_err": 0, "rx_crc_err": 0, "collisions": 0,...},...]

Example of use:

```
$ curl -X GET http://localhost:8080/stats/port/1
```

Response (OpenFlow1.3 or earlier):

```
{
  "1": [
    {
      "port_no": 1,
      "rx_packets": 9,
      "tx_packets": 6,
      "rx_bytes": 738,
      "tx_bytes": 252,
      "rx_dropped": 0,
      "tx_dropped": 0,
      "rx_errors": 0,
      "tx_errors": 0,
      "rx_frame_err": 0,
      "rx_over_err": 0,
      "rx_crc_err": 0,
      "collisions": 0,
      "duration_sec": 12,
      "duration_nsec": 9.76e+08
    },
    {
      :
      :
    }
  ]
}
```

Response (OpenFlow1.4 or later):

```
{
  "1": [
    {
      "port_no": 1,
      "rx_packets": 9,
      "tx_packets": 6,
      "rx_bytes": 738,
      "tx_bytes": 252,
      "rx_dropped": 0,
      "tx_dropped": 0,
      "rx_errors": 0,
      "tx_errors": 0,
      "duration_nsec": 12,
      "duration_sec": 9.76e+08,
      "properties": [
        {
          "rx_frame_err": 0,
          "rx_over_err": 0,
          "rx_crc_err": 0,
          "collisions": 0,
          "type": "ETHERNET"
        },
        {
          "bias_current": 300,
          "flags": 3,
          "rx_freq_lmda": 1500,
          "rx_grid_span": 500,
          "rx_offset": 700,
          "rx_pwr": 2000,
          "temperature": 273,
          "tx_freq_lmda": 1500,
          "tx_grid_span": 500,
          "tx_offset": 700,
          "tx_pwr": 2000,
          "type": "OPTICAL"
        },
        {
          "data": [],
          "exp_type": 0,
          "experimenter": 101,
          "type": "EXPERIMENTER"
        },
        {
          :
          :
        }
      ]
    }
  ]
}
```

Get ports description

Get ports description of the switch which specified with Datapath ID in URI.

Usage(OpenFlow1.4 or earlier):

Method	GET
URI	/stats/portdesc/<dpid>

Usage(OpenFlow1.5 or later):

Method	GET
URI	/stats/portdesc/<dpid>/[<port>]

Note: Specification of port number is optional.

Response message body(OpenFlow1.3 or earlier):

Attribute	Description	Example
dpid	Datapath ID	"1"
port_no	Port number	1
hw_addr	Ethernet hardware address	"0a:b6:d0:0c:e1:d7"
name	Name of port	"s1-eth1"
config	Bitmap of OFPPC_* flags	0
state	Bitmap of OFPPS_* flags	0
curr	Current features	2112
advertised	Features being advertised by the port	0
supported	Features supported by the port	0
peer	Features advertised by peer	0
curr_speed	Current port bitrate in kbps	1e+07
max_speed	Max port bitrate in kbps	0

Response message body(OpenFlow1.4 or later):

Attribute	Description	Example
dpid	Datapath ID	"1"
port_no	Port number	1
hw_addr	Ethernet hardware address	"0a:b6:d0:0c:e1:d7"
name	Name of port	"s1-eth1"
config	Bitmap of OFPPC_* flags	0
state	Bitmap of OFPPS_* flags	0
length	Length of this entry	168
properties	struct ofp_port_desc_prop_header	[{"length": 32, "curr": 10248,...}]

Example of use:

```
$ curl -X GET http://localhost:8080/stats/portdesc/1
```

Response (OpenFlow1.3 or earlier):

```
{
  "1": [
    {
      "port_no": 1,
      "hw_addr": "0a:b6:d0:0c:e1:d7",
```

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```
    "name": "s1-eth1",
    "config": 0,
    "state": 0,
    "curr": 2112,
    "advertised": 0,
    "supported": 0,
    "peer": 0,
    "curr_speed": 1e+07,
    "max_speed": 0
  },
  {
    :
    :
  }
]
```

Response (OpenFlow1.4 or later):

```
{
  "1": [
    {
      "port_no": 1,
      "hw_addr": "0a:b6:d0:0c:e1:d7",
      "name": "s1-eth1",
      "config": 0,
      "state": 0,
      "length": 168,
      "properties": [
        {
          "length": 32,
          "curr": 10248,
          "advertised": 10240,
          "supported": 10248,
          "peer": 10248,
          "curr_speed": 5000,
          "max_speed": 5000,
          "type": "ETHERNET"
        },
        {
          "length": 40,
          "rx_grid_freq_lmda": 1500,
          "tx_grid_freq_lmda": 1500,
          "rx_max_freq_lmda": 2000,
          "tx_max_freq_lmda": 2000,
          "rx_min_freq_lmda": 1000,
          "tx_min_freq_lmda": 1000,
          "tx_pwr_max": 2000,
          "tx_pwr_min": 1000,
          "supported": 1,
          "type": "OPTICAL"
        }
      ],
      {
        "data": [],
        "exp_type": 0,
        "experimenter": 101,
        "length": 12,
```

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```

        "type": "EXPERIMENTER"
    },
    {
        :
        :
    }
]
}
]
}

```

Get queues stats

Get queues stats of the switch which specified with Datapath ID in URI.

Usage:

Method	GET
URI	/stats/queue/<dpid>[/<port>[/<queue_id>]]

Note: Specification of port number and queue id are optional.

If you want to omitting the port number and setting the queue id, please specify the keyword "ALL" to the port number.

e.g. GET <http://localhost:8080/stats/queue/1/ALL/1>

Response message body(OpenFlow1.3 or earlier):

Attribute	Description	Example
dpid	Datapath ID	"1"
port_no	Port number	1
queue_id	Queue ID	0
tx_bytes	Number of transmitted bytes	0
tx_packets	Number of transmitted packets	0
tx_errors	Number of packets dropped due to overrun	0
duration_sec	Time queue has been alive in seconds	4294963425
dura- tion_nsec	Time queue has been alive in nanoseconds beyond dura- tion_sec	3912967296

Response message body(OpenFlow1.4 or later):

Attribute	Description	Example
dpid	Datapath ID	"1"
port_no	Port number	1
queue_id	Queue ID	0
tx_bytes	Number of transmitted bytes	0
tx_packets	Number of transmitted packets	0
tx_errors	Number of packets dropped due to overrun	0
duration_sec	Time queue has been alive in seconds	4294963425
duration_nsec	Time queue has been alive in nanoseconds beyond duration_sec	3912967296
length	Length of this entry	104
properties	struct ofp_queue_stats_prop_header	[{"type": 65535,"length": 12,...},...]

Example of use:

```
$ curl -X GET http://localhost:8080/stats/queue/1
```

Response (OpenFlow1.3 or earlier):

```
{
  "1": [
    {
      "port_no": 1,
      "queue_id": 0,
      "tx_bytes": 0,
      "tx_packets": 0,
      "tx_errors": 0,
      "duration_sec": 4294963425,
      "duration_nsec": 3912967296
    },
    {
      "port_no": 1,
      "queue_id": 1,
      "tx_bytes": 0,
      "tx_packets": 0,
      "tx_errors": 0,
      "duration_sec": 4294963425,
      "duration_nsec": 3912967296
    }
  ]
}
```

Response (OpenFlow1.4 or later):

```
{
  "1": [
    {
      "port_no": 1,
      "queue_id": 0,
      "tx_bytes": 0,
      "tx_packets": 0,
      "tx_errors": 0,
      "duration_sec": 4294963425,
```

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```

    "duration_nsec": 3912967296,
    "length": 104,
    "properties": [
      {
        "OFPQueueStatsPropExperimenter": {
          "type": 65535,
          "length": 16,
          "data": [
            1
          ],
          "exp_type": 1,
          "experimenter": 101
        }
      },
      {
        :
        :
      }
    ]
  },
  {
    "port_no": 2,
    "queue_id": 1,
    "tx_bytes": 0,
    "tx_packets": 0,
    "tx_errors": 0,
    "duration_sec": 4294963425,
    "duration_nsec": 3912967296,
    "length": 48,
    "properties": []
  }
]
}

```

Get queues config

Get queues config of the switch which specified with Datapath ID and Port in URI.

Usage:

Method	GET
URI	/stats/queueconfig/<dpid>/[<port>]

Note: Specification of port number is optional.

Caution: This message is deprecated in Openflow1.4. If OpenFlow 1.4 or later is in use, please refer to *Get queues description* instead.

Response message body:

Attribute	Description	Example
dpid	Datapath ID	"1"
port	Port which was queried	1
queues	struct ofp_packet_queue	
– queue_id	ID for the specific queue	2
– port	Port this queue is attached to	0
– properties	struct ofp_queue_prop_header properties	[{"property": "MIN_RATE", "rate": 80}]

Example of use:

```
$ curl -X GET http://localhost:8080/stats/queueconfig/1/1
```

```
{
  "1": [
    {
      "port": 1,
      "queues": [
        {
          "properties": [
            {
              "property": "MIN_RATE",
              "rate": 80
            }
          ],
          "port": 0,
          "queue_id": 1
        },
        {
          "properties": [
            {
              "property": "MAX_RATE",
              "rate": 120
            }
          ],
          "port": 2,
          "queue_id": 2
        },
        {
          "properties": [
            {
              "property": "EXPERIMENTER",
              "data": [],
              "experimenter": 999
            }
          ],
          "port": 3,
          "queue_id": 3
        }
      ]
    }
  ]
}
```

Get queues description

Get queues description of the switch which specified with Datapath ID, Port and Queue_id in URI.

Usage:

Method	GET
URI	/stats/queuedesc/<dpid>[/<port>[/<queue_id>]]

Note: Specification of port number and queue id are optional.

If you want to omitting the port number and setting the queue id, please specify the keyword "ALL" to the port number.

e.g. GET <http://localhost:8080/stats/queuedesc/1/ALL/1>

Caution: This message is available in OpenFlow1.4 or later. If Openflow1.3 or earlier is in use, please refer to *Get queues config* instead.

Response message body:

Attribute	Description	Example
dpid	Datapath ID	"1"
len	Length in bytes of this queue desc	88
port_no	Port which was queried	1
queue_id	Queue ID	1
properties	struct ofp_queue_desc_prop_header	[{"length": 8, ...},...]

Example of use:

```
$ curl -X GET http://localhost:8080/stats/queuedesc/1/1/1
```

```
{
  "1": [
    {
      "len": 88,
      "port_no": 1,
      "queue_id": 1,
      "properties": [
        {
          "length": 8,
          "rate": 300,
          "type": "MIN_RATE"
        },
        {
          "length": 8,
          "rate": 900,
          "type": "MAX_RATE"
        },
        {
          "length": 16,
          "exp_type": 0,

```

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```

        "experimenter": 101,
        "data": [1],
        "type": "EXPERIMENTER"
    },
    {
        :
        :
    }
]
}
}

```

Get groups stats

Get groups stats of the switch which specified with Datapath ID in URI.

Usage:

Method	GET
URI	/stats/group/<dpid>[/<group_id>]

Note: Specification of group id is optional.

Response message body:

Attribute	Description	Example
dpid	Datapath ID	"1"
length	Length of this entry	56
group_id	Group ID	1
ref_count	Number of flows or groups that directly forward to this group	1
packet_count	Number of packets processed by group	0
byte_count	Number of bytes processed by group	0
duration_sec	Time group has been alive in seconds	161
duration_nsec	Time group has been alive in nanoseconds beyond duration_sec	3.03e+08
bucket_stats	struct ofp_bucket_counter	
– packet_count	Number of packets processed by bucket	0
– byte_count	Number of bytes processed by bucket	0

Example of use:

```
$ curl -X GET http://localhost:8080/stats/group/1
```

```
{
  "1": [
    {
      "length": 56,
      "group_id": 1,
      "ref_count": 1,
      "packet_count": 0,
      "byte_count": 0,
      "duration_sec": 161,
      "duration_nsec": 3.03e+08,
      "bucket_stats": [
        {
          "packet_count": 0,
          "byte_count": 0
        }
      ]
    }
  ]
}
```

Get group description stats

Get group description stats of the switch which specified with Datapath ID in URI.

Usage(Openflow1.4 or earlier):

Method	GET
URI	/stats/groupdesc/<dpid>

Usage(Openflow1.5 or later):

Method	GET
URI	/stats/groupdesc/<dpid>/[<group_id>]

Note: Specification of group id is optional.

Response message body(Openflow1.3 or earlier):

Attribute	Description	Example
dpid	Datapath ID	"1"
type	One of OFPGT_*	"ALL"
group_id	Group ID	1
buckets	struct ofp_bucket	
– weight	Relative weight of bucket (Only defined for select groups)	0
– watch_port	Port whose state affects whether this bucket is live (Only required for fast failover groups)	4294967295
– watch_group	Group whose state affects whether this bucket is live (Only required for fast failover groups)	4294967295
– actions	0 or more actions associated with the bucket	["OUT-PUT:1"]

Response message body(Openflow1.4 or later):

At-tribute	Description	Example
dpid	Datapath ID	"1"
type	One of OFPGT_*	"ALL"
group_id	Group ID	1
length	Length of this entry	40
buckets	struct ofp_bucket	
– weight	Relative weight of bucket (Only defined for select groups)	0
– watch_port	Port whose state affects whether this bucket is live (Only required for fast failover groups)	4294967295
– watch_group	Group whose state affects whether this bucket is live (Only required for fast failover groups)	4294967295
– len	Length the bucket in bytes, including this header and any adding to make it 64-bit aligned.	32
– actions	0 or more actions associated with the bucket	[{"OUTPUT:1", "max_len": 65535,...}]

Example of use:

```
$ curl -X GET http://localhost:8080/stats/groupdesc/1
```

Response (Openflow1.3 or earlier):

```
{
  "1": [
    {
      "type": "ALL",
      "group_id": 1,
      "buckets": [
        {
          "weight": 0,
          "watch_port": 4294967295,
          "watch_group": 4294967295,
          "actions": [
            "OUTPUT:1"
          ]
        }
      ]
    }
  ]
}
```

Response (Openflow1.4 or later):

```
{
  "1": [
    {
      "type": "ALL",
      "group_id": 1,
      "length": 40,
      "buckets": [
```

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```

    {
      "weight": 1,
      "watch_port": 1,
      "watch_group": 1,
      "len": 32,
      "actions": [
        {
          "type": "OUTPUT",
          "max_len": 65535,
          "port": 2
        }
      ]
    }
  ]
}

```

Get group features stats

Get group features stats of the switch which specified with Datapath ID in URI.

Usage:

Method	GET
URI	/stats/groupfeatures/<dpid>

Response message body:

At-tribute	Description	Example
dpid	Datapath ID	"1"
types	Bitmap of (1 << OFPGT_*) values supported	[]
capabilities	Bitmap of OFPGFC_* capability supported	["SELECT_WEIGHT", "SELECT_LIVENESS", "CHAINING"]
max_groups	Maximum number of groups for each type	[{"ALL": 4294967040},...]
actions	Bitmaps of (1 << OFPAT_*) values supported	[{"ALL": ["OUTPUT",...]},...]

Example of use:

```
$ curl -X GET http://localhost:8080/stats/groupfeatures/1
```

```

{
  "1": [
    {
      "types": [],
      "capabilities": [
        "SELECT_WEIGHT",

```

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```
    "SELECT_LIVENESS",
    "CHAINING"
  ],
  "max_groups": [
    {
      "ALL": 4294967040
    },
    {
      "SELECT": 4294967040
    },
    {
      "INDIRECT": 4294967040
    },
    {
      "FF": 4294967040
    }
  ],
  "actions": [
    {
      "ALL": [
        "OUTPUT",
        "COPY_TTL_OUT",
        "COPY_TTL_IN",
        "SET_MPLS_TTL",
        "DEC_MPLS_TTL",
        "PUSH_VLAN",
        "POP_VLAN",
        "PUSH_MPLS",
        "POP_MPLS",
        "SET_QUEUE",
        "GROUP",
        "SET_NW_TTL",
        "DEC_NW_TTL",
        "SET_FIELD"
      ]
    },
    {
      "SELECT": []
    },
    {
      "INDIRECT": []
    },
    {
      "FF": []
    }
  ]
}
```

Get meters stats

Get meters stats of the switch which specified with Datapath ID in URI.

Usage:

Method	GET
URI	/stats/meter/<dpid>[/<meter_id>]

Note: Specification of meter id is optional.

Response message body:

Attribute	Description	Example
dpid	Datapath ID	"1"
meter_id	Meter ID	1
len	Length in bytes of this stats	56
flow_count	Number of flows bound to meter	0
packet_in_count	Number of packets in input	0
byte_in_count	Number of bytes in input	0
duration_sec	Time meter has been alive in seconds	37
duration_nsec	Time meter has been alive in nanoseconds beyond duration_sec	988000
band_stats	struct of p_meter_band_stats	
– packet_band_count	Number of packets in band	0
– byte_band_count	Number of bytes in band	0

Example of use:

```
$ curl -X GET http://localhost:8080/stats/meter/1
```

```
{
  "1": [
    {
      "meter_id": 1,
      "len": 56,
      "flow_count": 0,
      "packet_in_count": 0,
      "byte_in_count": 0,
      "duration_sec": 37,
      "duration_nsec": 988000,
      "band_stats": [
        {
          "packet_band_count": 0,
          "byte_band_count": 0
        }
      ]
    }
  ]
}
```

Get meter config stats

Get meter description stats

Get meter config stats of the switch which specified with Datapath ID in URI.

Caution: This message has been renamed in openflow 1.5. If Openflow 1.4 or earlier is in use, please used as Get meter description stats. If Openflow 1.5 or later is in use, please used as Get meter description stats.

Usage(Openflow1.4 or earlier):

Method	GET
URI	/stats/meterconfig/<dpid>[/<meter_id>]

Usage(Openflow1.5 or later):

Method	GET
URI	/stats/meterdesc/<dpid>[/<meter_id>]

Note: Specification of meter id is optional.

Response message body:

Attribute	Description	Example
dpid	Datapath ID	"1"
flags	All OFPMC_* that apply	"KBPS"
meter_id	Meter ID	1
bands	struct ofp_meter_band_header	
– type	One of OFPMBT_*	"DROP"
– rate	Rate for this band	1000
– burst_size	Size of bursts	0

Example of use:

```
$ curl -X GET http://localhost:8080/stats/meterconfig/1
```

```
{
  "1": [
    {
      "flags": [
        "KBPS"
      ],
      "meter_id": 1,
      "bands": [
        {
          "type": "DROP",
          "rate": 1000,
          "burst_size": 0
        }
      ]
    }
  ]
}
```

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```
    ]
}
```

Get meter features stats

Get meter features stats of the switch which specified with Datapath ID in URI.

Usage:

Method	GET
URI	/stats/meterfeatures/<dpid>

Response message body:

Attribute	Description	Example
dpid	Datapath ID	"1"
max_meter	Maximum number of meters	256
band_types	Bitmaps of (1 << OFPMBT_*) values supported	["DROP"]
capabilities	Bitmaps of "ofp_meter_flags"	["KBPS", "BURST", "STATS"]
max_bands	Maximum bands per meters	16
max_color	Maximum color value	8

Example of use:

```
$ curl -X GET http://localhost:8080/stats/meterfeatures/1
```

```
{
  "1": [
    {
      "max_meter": 256,
      "band_types": [
        "DROP"
      ],
      "capabilities": [
        "KBPS",
        "BURST",
        "STATS"
      ],
      "max_bands": 16,
      "max_color": 8
    }
  ]
}
```

Get role

Get the current role of the controller from the switch.

Usage:

Method	GET
URI	/stats/role/<dpid>

Response message body(Openflow1.4 or earlier):

Attribute	Description	Example
dpid	Datapath ID	1
role	One of OFPCR_ROLE_*	"EQUAL"
generation_id	Master Election Generation Id	0

Response message body(Openflow1.5 or later):

Attribute	Description	Example
dpid	Datapath ID	1
role	One of OFPCR_ROLE_*	"EQUAL"
short_id	ID number for the controller	0
generation_id	Master Election Generation Id	0

Example of use:

```
$ curl -X GET http://localhost:8080/stats/role/1
```

Response (Openflow1.4 or earlier):

```
{
  "1": [
    {
      "generation_id": 0,
      "role": "EQUAL"
    }
  ]
}
```

Response (Openflow1.5 or later):

```
{
  "1": [
    {
      "generation_id": 0,
      "role": "EQUAL",
      "short_id": 0
    }
  ]
}
```

6.2.2 Update the switch stats

Add a flow entry

Add a flow entry to the switch.

Usage:

Method	POST
URI	/stats/flowentry/add

Request message body(Openflow1.3 or earlier):

At-tribute	Description	Example	Default
dpid	Datapath ID (int)	1	(Mandatory)
cookie	Opaque controller-issued identifier (int)	1	0
cookie_mask	Mask used to restrict the cookie bits (int)	1	0
table_id	Table ID to put the flow in (int)	0	0
idle_timeout	Idle time before discarding (seconds) (int)	30	0
hard_timeout	Max time before discarding (seconds) (int)	30	0
priority	Priority level of flow entry (int)	11111	0
buffer_id	Buffered packet to apply to, or OFP_NO_BUFFER (int)	1	OFP_NO_BUFFER
flags	Bitmap of OFPFF_* flags (int)	1	0
match	Fields to match (dict)	{"in_port":1}	{ } #wild-carded
actions	Instruction set (list of dict)	[{"type":"OUTPUT", "port":2}]	[] #DROP

Request message body(Openflow1.4 or later):

At-tribute	Description	Example	Default
dpid	Datapath ID (int)	1	(Mandatory)
cookie	Opaque controller-issued identifier (int)	1	0
cookie_mask	Mask used to restrict the cookie bits (int)	1	0
table_id	Table ID to put the flow in (int)	0	0
idle_timeout	Idle time before discarding (seconds) (int)	30	0
hard_timeout	Max time before discarding (seconds) (int)	30	0
priority	Priority level of flow entry (int)	11111	0
buffer_id	Buffered packet to apply to, or OFP_NO_BUFFER (int)	1	OFP_NO_BUFFER
flags	Bitmap of OFPFF_* flags (int)	1	0
match	Fields to match (dict)	{"in_port":1}	{ } #wild-carded
instructions	Instruction set (list of dict)	[{"type":"METER", "meter_id":2}]	[] #DROP

Note: For description of match and actions, please see *Reference: Description of Match and Actions*.

Example of use(Openflow1.3 or earlier):

```
$ curl -X POST -d '{
  "dpid": 1,
  "cookie": 1,
  "cookie_mask": 1,
  "table_id": 0,
  "idle_timeout": 30,
  "hard_timeout": 30,
  "priority": 11111,
  "flags": 1,
  "match":{
    "in_port":1
  },
  "actions":[
    {
      "type":"OUTPUT",
      "port": 2
    }
  ]
}' http://localhost:8080/stats/flowentry/add
```

```
$ curl -X POST -d '{
  "dpid": 1,
  "priority": 22222,
  "match":{
    "in_port":1
  },
  "actions":[
    {
      "type":"GOTO_TABLE",
      "table_id": 1
    }
  ]
}' http://localhost:8080/stats/flowentry/add
```

```
$ curl -X POST -d '{
  "dpid": 1,
  "priority": 33333,
  "match":{
    "in_port":1
  },
  "actions":[
    {
      "type":"WRITE_METADATA",
      "metadata": 1,
      "metadata_mask": 1
    }
  ]
}' http://localhost:8080/stats/flowentry/add
```

```
$ curl -X POST -d '{
  "dpid": 1,
```

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```
"priority": 44444,
"match":{
    "in_port":1
},
"actions":[
    {
        "type":"METER",
        "meter_id": 1
    }
]
}' http://localhost:8080/stats/flowentry/add
```

Example of use(Openflow1.4 or later):

```
$ curl -X POST -d '{
    "dpid": 1,
    "cookie": 1,
    "cookie_mask": 1,
    "table_id": 0,
    "idle_timeout": 30,
    "hard_timeout": 30,
    "priority": 11111,
    "flags": 1,
    "match":{
        "in_port":1
    },
    "instructions": [
        {
            "type": "APPLY_ACTIONS",
            "actions": [
                {
                    "max_len": 65535,
                    "port": 2,
                    "type": "OUTPUT"
                }
            ]
        }
    ]
}' http://localhost:8080/stats/flowentry/add
```

```
$ curl -X POST -d '{
    "dpid": 1,
    "priority": 22222,
    "match":{
        "in_port":1
    },
    "instructions": [
        {
            "type":"GOTO_TABLE",
            "table_id": 1
        }
    ]
}' http://localhost:8080/stats/flowentry/add
```

```
$ curl -X POST -d '{
    "dpid": 1,
```

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```
"priority": 33333,
"match":{
  "in_port":1
},
"instructions": [
  {
    "type":"WRITE_METADATA",
    "metadata": 1,
    "metadata_mask": 1
  }
]
}' http://localhost:8080/stats/flowentry/add
```

```
$ curl -X POST -d '{
  "dpid": 1,
  "priority": 44444,
  "match":{
    "in_port":1
  },
  "instructions": [
    {
      "type":"METER",
      "meter_id": 1
    }
  ]
}' http://localhost:8080/stats/flowentry/add
```

Note: To confirm flow entry registration, please see *Get all flows stats* or *Get flows stats filtered by fields*.

Modify all matching flow entries

Modify all matching flow entries of the switch.

Usage:

Method	POST
URI	/stats/flowentry/modify

Request message body:

Attribute	Description	Example	Default
dpid	Datapath ID (int)	1	(Mandatory)
cookie	Opaque controller-issued identifier (int)	1	0
cookie_mask	Mask used to restrict the cookie bits (int)	1	0
table_id	Table ID to put the flow in (int)	0	0
idle_timeout	Idle time before discarding (seconds) (int)	30	0
hard_timeout	Max time before discarding (seconds) (int)	30	0
priority	Priority level of flow entry (int)	11111	0
buffer_id	Buffered packet to apply to, or OFP_NO_BUFFER (int)	1	OFP_NO_BUFFER
flags	Bitmap of OFPFF_* flags (int)	1	0
match	Fields to match (dict)	{"in_port":1}	{ } #wild-carded
actions	Instruction set (list of dict)	[{"type":"OUTPUT", "port":2}]	[] #DROP

Example of use:

```
$ curl -X POST -d '{
  "dpid": 1,
  "cookie": 1,
  "cookie_mask": 1,
  "table_id": 0,
  "idle_timeout": 30,
  "hard_timeout": 30,
  "priority": 11111,
  "flags": 1,
  "match":{
    "in_port":1
  },
  "actions":[
    {
      "type":"OUTPUT",
      "port": 2
    }
  ]
}' http://localhost:8080/stats/flowentry/modify
```

Modify flow entry strictly

Modify flow entry strictly matching wildcards and priority

Usage:

Method	POST
URI	/stats/flowentry/modify_strict

Request message body:

Attribute	Description	Example	Default
dpid	Datapath ID (int)	1	(Mandatory)
cookie	Opaque controller-issued identifier (int)	1	0
cookie_mask	Mask used to restrict the cookie bits (int)	1	0
table_id	Table ID to put the flow in (int)	0	0
idle_timeout	Idle time before discarding (seconds) (int)	30	0
hard_timeout	Max time before discarding (seconds) (int)	30	0
priority	Priority level of flow entry (int)	11111	0
buffer_id	Buffered packet to apply to, or OFP_NO_BUFFER (int)	1	OFP_NO_BUFFER
flags	Bitmap of OFPFF_* flags (int)	1	0
match	Fields to match (dict)	{"in_port":1}	{ } #wild-carded
actions	Instruction set (list of dict)	[{"type":"OUTPUT", "port":2}]	[] #DROP

Example of use:

```
$ curl -X POST -d '{
  "dpid": 1,
  "cookie": 1,
  "cookie_mask": 1,
  "table_id": 0,
  "idle_timeout": 30,
  "hard_timeout": 30,
  "priority": 11111,
  "flags": 1,
  "match":{
    "in_port":1
  },
  "actions":[
    {
      "type":"OUTPUT",
      "port": 2
    }
  ]
}' http://localhost:8080/stats/flowentry/modify_strict
```

Delete all matching flow entries

Delete all matching flow entries of the switch.

Usage:

Method	POST
URI	/stats/flowentry/delete

Request message body:

Attribute	Description	Example	Default
dpid	Datapath ID (int)	1	(Mandatory)
cookie	Opaque controller-issued identifier (int)	1	0
cookie_mask	Mask used to restrict the cookie bits (int)	1	0
table_id	Table ID to put the flow in (int)	0	0
idle_timeout	Idle time before discarding (seconds) (int)	30	0
hard_timeout	Max time before discarding (seconds) (int)	30	0
priority	Priority level of flow entry (int)	11111	0
buffer_id	Buffered packet to apply to, or OFP_NO_BUFFER (int)	1	OFP_NO_BUFFER
out_port	Output port (int)	1	OFPF_ANY
out_group	Output group (int)	1	OFPG_ANY
flags	Bitmap of OFPFF_* flags (int)	1	0
match	Fields to match (dict)	{"in_port":1}	{ } #wild-carded
actions	Instruction set (list of dict)	[{"type":"OUTPUT", "port":2}]	[] #DROP

Example of use:

```
$ curl -X POST -d '{
  "dpid": 1,
  "cookie": 1,
  "cookie_mask": 1,
  "table_id": 0,
  "idle_timeout": 30,
  "hard_timeout": 30,
  "priority": 11111,
  "flags": 1,
  "match":{
    "in_port":1
  },
  "actions":[
    {
      "type":"OUTPUT",
      "port": 2
    }
  ]
}' http://localhost:8080/stats/flowentry/delete
```

Delete flow entry strictly

Delete flow entry strictly matching wildcards and priority.

Usage:

Method	POST
URI	/stats/flowentry/delete_strict

Request message body:

Attribute	Description	Example	Default
dpid	Datapath ID (int)	1	(Mandatory)
cookie	Opaque controller-issued identifier (int)	1	0
cookie_mask	Mask used to restrict the cookie bits (int)	1	0
table_id	Table ID to put the flow in (int)	0	0
idle_timeout	Idle time before discarding (seconds) (int)	30	0
hard_timeout	Max time before discarding (seconds) (int)	30	0
priority	Priority level of flow entry (int)	11111	0
buffer_id	Buffered packet to apply to, or OFP_NO_BUFFER (int)	1	OFP_NO_BUFFER
out_port	Output port (int)	1	OFPF_ANY
out_group	Output group (int)	1	OFPG_ANY
flags	Bitmap of OFPFF_* flags (int)	1	0
match	Fields to match (dict)	{"in_port":1}	{ } #wild-carded
actions	Instruction set (list of dict)	[{"type":"OUTPUT", "port":2}]	[] #DROP

Example of use:

```
$ curl -X POST -d '{
  "dpid": 1,
  "cookie": 1,
  "cookie_mask": 1,
  "table_id": 0,
  "idle_timeout": 30,
  "hard_timeout": 30,
  "priority": 11111,
  "flags": 1,
  "match":{
    "in_port":1
  },
  "actions":[
    {
      "type":"OUTPUT",
      "port": 2
    }
  ]
}' http://localhost:8080/stats/flowentry/delete_strict
```

Delete all flow entries

Delete all flow entries of the switch which specified with Datapath ID in URI.

Usage:

Method	DELETE
URI	/stats/flowentry/clear/<dpid>

Example of use:

```
$ curl -X DELETE http://localhost:8080/stats/flowentry/clear/1
```

Add a group entry

Add a group entry to the switch.

Usage:

Method	POST
URI	/stats/groupentry/add

Request message body:

Attribute	Description	Example	Default
dpid	Datapath ID (int)	1	(Mandatory)
type	One of OFPGT_* (string)	"ALL"	"ALL"
group_id	Group ID (int)	1	0
buckets	struct ofp_bucket		
– weight	Relative weight of bucket (Only defined for select groups)	0	0
– watch_port	Port whose state affects whether this bucket is alive (Only required for fast failover groups)	4294967295	OFPP_ANY
– watch_group	Group whose state affects whether this bucket is alive (Only required for fast failover groups)	4294967295	OFPG_ANY
– actions	0 or more actions associated with the bucket (list of dict)	[[{"type": "OUTPUT", "port": 1}]]	[] #DROP

Example of use:

```
$ curl -X POST -d '{
  "dpid": 1,
  "type": "ALL",
  "group_id": 1,
  "buckets": [
    {
      "actions": [
        {
          "type": "OUTPUT",
          "port": 1
        }
      ]
    }
  ]
}'
```

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```

    }
  ]
}
]
}' http://localhost:8080/stats/groupentry/add

```

Note: To confirm group entry registration, please see [Get group description stats](#).

Modify a group entry

Modify a group entry to the switch.

Usage:

Method	POST
URI	/stats/groupentry/modify

Request message body:

At-tribute	Description	Example	De-fault
dpid	Datapath ID (int)	1	(Mandatory)
type	One of OFPGT_* (string)	"ALL"	"ALL"
group_id	Group ID (int)	1	0
buckets	struct ofp_bucket		
– weight	Relative weight of bucket (Only defined for select groups)	0	0
– watch_port	Port whose state affects whether this bucket is alive (Only required for fast failover groups)	4294967295	OFPP_ANY
– watch_group	Group whose state affects whether this bucket is alive (Only required for fast failover groups)	4294967295	OFPG_ANY
– actions	0 or more actions associated with the bucket (list of dict)	[{"type": "OUTPUT", "port": 1}]	[] #DROP

Example of use:

```

$ curl -X POST -d '{
  "dpid": 1,
  "type": "ALL",
  "group_id": 1,
  "buckets": [
    {
      "actions": [
        {
          "type": "OUTPUT",
          "port": 1
        }
      ]
    }
  ]
}'

```

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```

    ]
  }' http://localhost:8080/stats/groupentry/modify

```

Delete a group entry

Delete a group entry to the switch.

Usage:

Method	POST
URI	/stats/groupentry/delete

Request message body:

Attribute	Description	Example	Default
dpid	Datapath ID (int)	1	(Mandatory)
group_id	Group ID (int)	1	0

Example of use:

```

$ curl -X POST -d '{
  "dpid": 1,
  "group_id": 1
}' http://localhost:8080/stats/groupentry/delete

```

Modify the behavior of the port

Modify the behavior of the physical port.

Usage:

Method	POST
URI	/stats/portdesc/modify

Request message body:

Attribute	Description	Example	Default
dpid	Datapath ID (int)	1	(Mandatory)
port_no	Port number (int)	1	0
config	Bitmap of OFPPC_* flags (int)	1	0
mask	Bitmap of OFPPC_* flags to be changed (int)	1	0

Example of use:

```

$ curl -X POST -d '{
  "dpid": 1,
  "port_no": 1,
  "config": 1,
  "mask": 1
}' http://localhost:8080/stats/portdesc/modify

```

Note: To confirm port description, please see [Get ports description](#).

Add a meter entry

Add a meter entry to the switch.

Usage:

Method	POST
URI	/stats/meterentry/add

Request message body:

Attribute	Description	Example	Default
dpid	Datapath ID (int)	1	(Mandatory)
flags	Bitmap of OFPMF_* flags (list)	["KBPS"]	[] #Empty
meter_id	Meter ID (int)	1	0
bands	struct ofp_meter_band_header		
– type	One of OFPMBT_* (string)	"DROP"	None
– rate	Rate for this band (int)	1000	None
– burst_size	Size of bursts (int)	100	None

Example of use:

```
$ curl -X POST -d '{
  "dpid": 1,
  "flags": "KBPS",
  "meter_id": 1,
  "bands": [
    {
      "type": "DROP",
      "rate": 1000
    }
  ]
}' http://localhost:8080/stats/meterentry/add
```

Note: To confirm meter entry registration, please see [Get meter config stats](#).

Modify a meter entry

Modify a meter entry to the switch.

Usage:

Method	POST
URI	/stats/meterentry/modify

Request message body:

Attribute	Description	Example	Default
dpid	Datapath ID (int)	1	(Mandatory)
flags	Bitmap of OFPMF_* flags (list)	["KBPS"]	[] #Empty
meter_id	Meter ID (int)	1	0
bands	struct ofp_meter_band_header		
- type	One of OFPMBT_* (string)	"DROP"	None
- rate	Rate for this band (int)	1000	None
- burst_size	Size of bursts (int)	100	None

Example of use:

```
$ curl -X POST -d '{
  "dpid": 1,
  "meter_id": 1,
  "flags": "KBPS",
  "bands": [
    {
      "type": "DROP",
      "rate": 1000
    }
  ]
}' http://localhost:8080/stats/meterentry/modify
```

Delete a meter entry

Delete a meter entry to the switch.

Usage:

Method	POST
URI	/stats/meterentry/delete

Request message body:

Attribute	Description	Example	Default
dpid	Datapath ID (int)	1	(Mandatory)
meter_id	Meter ID (int)	1	0

Example of use:

```
$ curl -X POST -d '{
  "dpid": 1,
  "meter_id": 1
}' http://localhost:8080/stats/meterentry/delete
```

Modify role

modify the role of the switch.

Usage:

Method	POST
URI	/stats/role

Request message body:

Attribute	Description	Example	Default
dpid	Datapath ID (int)	1	(Mandatory)
role	One of OFPCR_ROLE_*(string)	"MASTER"	OFPCR_ROLE_EQUAL

Example of use:

```
$ curl -X POST -d '{
  "dpid": 1,
  "role": "MASTER"
}' http://localhost:8080/stats/role
```

6.2.3 Support for experimenter multipart

Send a experimenter message

Send a experimenter message to the switch which specified with Datapath ID in URI.

Usage:

Method	POST
URI	/stats/experimenter/<dpid>

Request message body:

Attribute	Description	Example	Default
dpid	Datapath ID (int)	1	(Mandatory)
experimenter	Experimenter ID (int)	1	0
exp_type	Experimenter defined (int)	1	0
data_type	Data format type ("ascii" or "base64")	"ascii"	"ascii"
data	Data to send (string)	"data"	"" #Empty

Example of use:

```
$ curl -X POST -d '{
  "dpid": 1,
  "experimenter": 1,
  "exp_type": 1,
  "data_type": "ascii",
  "data": "data"
}' http://localhost:8080/stats/experimenter/1
```

6.2.4 Reference: Description of Match and Actions

Description of Match on request messages

List of Match fields (OpenFlow1.0):

Match field	Description	Example
in_port	Input switch port (int)	{"in_port": 7}
dl_src	Ethernet source address (string)	{"dl_src": "aa:bb:cc:11:22:33"}
dl_dst	Ethernet destination address (string)	{"dl_dst": "aa:bb:cc:11:22:33"}
dl_vlan	Input VLAN id (int)	{"dl_vlan": 5}
dl_vlan_pcp	Input VLAN priority (int)	{"dl_vlan_pcp": 3, "dl_vlan": 3}
dl_type	Ethernet frame type (int)	{"dl_type": 123}
nw_tos	IP ToS (int)	{"nw_tos": 16, "dl_type": 2048}
nw_proto	IP protocol or lower 8 bits of ARP opcode (int)	{"nw_proto": 5, "dl_type": 2048}
nw_src	IPv4 source address (string)	{"nw_src": "192.168.0.1", "dl_type": 2048}
nw_dst	IPv4 destination address (string)	{"nw_dst": "192.168.0.1/24", "dl_type": 2048}
tp_src	TCP/UDP source port (int)	{"tp_src": 1, "nw_proto": 6, "dl_type": 2048}
tp_dst	TCP/UDP destination port (int)	{"tp_dst": 2, "nw_proto": 6, "dl_type": 2048}

Note: IPv4 address field can be described as IP Prefix like as follows.

IPv4 address:

```
"192.168.0.1"
"192.168.0.2/24"
```

List of Match fields (OpenFlow1.2 or later):

Match field	Description	Example
in_port	Switch input port (int)	{"in_port": 7}
in_phy_port	Switch physical input port (int)	{"in_phy_port": 5, "in_port": 3}
metadata	Metadata passed between tables (int or string)	{"metadata": 12345} or {"metadata": "0x1212"}
eth_dst	Ethernet destination address (string)	{"eth_dst": "aa:bb:cc:11:22:33/00:00:00:00:ff"}
eth_src	Ethernet source address (string)	{"eth_src": "aa:bb:cc:11:22:33"}
eth_type	Ethernet frame type (int)	{"eth_type": 2048}
vlan_vid	VLAN id (int or string)	See Example of VLAN ID match field
vlan_pcp	VLAN priority (int)	{"vlan_pcp": 3, "vlan_vid": 3}
ip_dscp	IP DSCP (6 bits in ToS field) (int)	{"ip_dscp": 3, "eth_type": 2048}
ip_ecn	IP ECN (2 bits in ToS field) (int)	{"ip_ecn": 0, "eth_type": 34525}
ip_proto	IP protocol (int)	{"ip_proto": 5, "eth_type": 34525}
ipv4_src	IPv4 source address (string)	{"ipv4_src": "192.168.0.1", "eth_type": 2048}
ipv4_dst	IPv4 destination address (string)	{"ipv4_dst": "192.168.10.10/255.255.255.0", "eth_type": 2048}
tcp_src	TCP source port (int)	{"tcp_src": 3, "ip_proto": 6, "eth_type": 2048}
tcp_dst	TCP destination port (int)	{"tcp_dst": 5, "ip_proto": 6, "eth_type": 2048}
udp_src	UDP source port (int)	{"udp_src": 2, "ip_proto": 17, "eth_type": 2048}
udp_dst	UDP destination port (int)	{"udp_dst": 6, "ip_proto": 17, "eth_type": 2048}
sctp_src	SCTP source port (int)	{"sctp_src": 99, "ip_proto": 132, "eth_type": 2048}
sctp_dst	SCTP destination port (int)	{"sctp_dst": 99, "ip_proto": 132, "eth_type": 2048}

Table 1 – continued from previous page

Match field	Description	Example
icmpv4_type	ICMP type (int)	{"icmpv4_type": 5, "ip_proto": 1, "eth_type": 2054}
icmpv4_code	ICMP code (int)	{"icmpv4_code": 6, "ip_proto": 1, "eth_type": 2054}
arp_op	ARP opcode (int)	{"arp_op": 3, "eth_type": 2054}
arp_spa	ARP source IPv4 address (string)	{"arp_spa": "192.168.0.11", "eth_type": 2054}
arp_tpa	ARP target IPv4 address (string)	{"arp_tpa": "192.168.0.44/24", "eth_type": 2054}
arp_sha	ARP source hardware address (string)	{"arp_sha": "aa:bb:cc:11:22:33", "eth_type": 2054}
arp_tha	ARP target hardware address (string)	{"arp_tha": "aa:bb:cc:11:22:33/00:00:00:00:ff:ff", "eth_type": 2054}
ipv6_src	IPv6 source address (string)	{"ipv6_src": "2001::aaaa:bbbb:cccc:1111", "eth_type": 34525}
ipv6_dst	IPv6 destination address (string)	{"ipv6_dst": "2001::ffff:cccc:bbbb:1111/64", "eth_type": 34525}
ipv6_flabel	IPv6 Flow Label (int)	{"ipv6_flabel": 2, "eth_type": 34525}
icmpv6_type	ICMPv6 type (int)	{"icmpv6_type": 3, "ip_proto": 58, "eth_type": 34525}
icmpv6_code	ICMPv6 code (int)	{"icmpv6_code": 4, "ip_proto": 58, "eth_type": 34525}
ipv6_nd_target	Target address for Neighbor Discovery (string)	{"ipv6_nd_target": "2001::ffff:cccc:bbbb:1111", "eth_type": 34525}
ipv6_nd_sll	Source link-layer for Neighbor Discovery (string)	{"ipv6_nd_sll": "aa:bb:cc:11:22:33", "eth_type": 34525}
ipv6_nd_tll	Target link-layer for Neighbor Discovery (string)	{"ipv6_nd_tll": "aa:bb:cc:11:22:33", "eth_type": 34525}
mpls_label	MPLS label (int)	{"mpls_label": 3, "eth_type": 34888}
mpls_tc	MPLS Traffic Class (int)	{"mpls_tc": 2, "eth_type": 34888}
mpls_bos	MPLS BoS bit (int) (Openflow1.3+)	{"mpls_bos": 1, "eth_type": 34888}
pbb_isid	PBB I-SID (int or string) (Openflow1.3+)	{"pbb_isid": 5, "eth_type": 35047} or {"pbb_isid": "5", "eth_type": 35047}
tunnel_id	Logical Port Metadata (int or string) (Openflow1.3+)	{"tunnel_id": 7} or {"tunnel_id": "0x07/0xff", "eth_type": 35047}
ipv6_exthdr	IPv6 Extension Header pseudo-field (int or string) (Openflow1.3+)	{"ipv6_exthdr": 3, "eth_type": 34525} or {"ipv6_exthdr": "3", "eth_type": 34525}
pbb_uca	PBB UCA handler field(int) (Openflow1.4+)	{"pbb_uca": 1, "eth_type": 35047}
tcp_flags	TCP flags(int) (Openflow1.5+)	{"tcp_flags": 2, "ip_proto": 6, "eth_type": 2054}
actset_output	Output port from action set metadata(int) (Openflow1.5+)	{"actset_output": 3}
packet_type	Packet type value(int) (Openflow1.5+)	{"packet_type": [1, 2048]}

Note: Some field can be described with mask like as follows.

Ethernet address:

```
"aa:bb:cc:11:22:33"
"aa:bb:cc:11:22:33/00:00:00:00:ff:ff"
```

IPv4 address:

```
"192.168.0.11"
"192.168.0.44/24"
"192.168.10.10/255.255.255.0"
```

IPv6 address:

```
"2001::ffff:cccc:bbbb:1111"
"2001::ffff:cccc:bbbb:2222/64"
"2001::ffff:cccc:bbbb:2222/ffff:ffff:ffff:ffff::0"
```

Metadata:

```
"0x1212121212121212"
"0x3434343434343434/0x0101010101010101"
```

Example of VLAN ID match field

The following is available in OpenFlow1.0 or later.

- To match only packets with VLAN tag and VLAN ID equal value 5:

```
$ curl -X POST -d '{
  "dpid": 1,
  "match":{
    "dl_vlan": 5
  },
  "actions":[
    {
      "type":"OUTPUT",
      "port": 1
    }
  ]
}' http://localhost:8080/stats/flowentry/add
```

Note: When "dl_vlan" field is described as decimal int value, OFPVID_PRESENT(0x1000) bit is automatically applied.

The following is available in OpenFlow1.2 or later.

- To match only packets without a VLAN tag:

```
$ curl -X POST -d '{
  "dpid": 1,
  "match":{
    "dl_vlan": "0x0000"    # Describe OFPVID_NONE(0x0000)
  },
  "actions":[
    {
      "type":"OUTPUT",
      "port": 1
    }
  ]
}' http://localhost:8080/stats/flowentry/add
```

- To match only packets with a VLAN tag regardless of its value:

```
$ curl -X POST -d '{
  "dpid": 1,
  "match":{
    "dl_vlan": "0x1000/0x1000"    # Describe OFPVID_PRESENT(0x1000/
↪0x1000)
  },
  "actions":[
    {
      "type":"OUTPUT",
      "port": 1
    }
  ]
}' http://localhost:8080/stats/flowentry/add
```

- To match only packets with VLAN tag and VLAN ID equal value 5:

```
$ curl -X POST -d '{
  "dpid": 1,
  "match":{
    "dl_vlan": "0x1005"    # Describe sum of VLAN-ID(e.g. 5) | OFFVID_
    ↪PRESENT(0x1000)
  },
  "actions":[
    {
      "type":"OUTPUT",
      "port": 1
    }
  ]
}' http://localhost:8080/stats/flowentry/add
```

Note: When using the descriptions for OpenFlow1.2 or later, please describe "dl_vlan" field as hexadecimal string value, and OFFVID_PRESENT(0x1000) bit is NOT automatically applied.

Description of Actions on request messages

List of Actions (OpenFlow1.0):

Actions	Description	Example
OUTPUT	Output packet from "port"	{"type": "OUTPUT", "port": 3}
SET_VLAN_VID	Set the 802.1Q VLAN ID using "vlan_vid"	{"type": "SET_VLAN_VID", "vlan_vid": 5}
SET_VLAN_PCP	Set the 802.1Q priority using "vlan_pcp"	{"type": "SET_VLAN_PCP", "vlan_pcp": 3}
STRIP_VLAN	Strip the 802.1Q header	{"type": "STRIP_VLAN"}
SET_DL_SRC	Set ethernet source address using "dl_src"	{"type": "SET_DL_SRC", "dl_src": "aa:bb:cc:11:22:33"}
SET_DL_DST	Set ethernet destination address using "dl_dst"	{"type": "SET_DL_DST", "dl_dst": "aa:bb:cc:11:22:33"}
SET_NW_SRC	Set IP source address using "nw_src"	{"type": "SET_NW_SRC", "nw_src": "10.0.0.1"}
SET_NW_DST	Set IP destination address using "nw_dst"	{"type": "SET_NW_DST", "nw_dst": "10.0.0.1"}
SET_NW_TOS	Set IP ToS (DSCP field, 6 bits) using "nw_tos"	{"type": "SET_NW_TOS", "nw_tos": 184}
SET_TP_SRC	Set TCP/UDP source port using "tp_src"	{"type": "SET_TP_SRC", "tp_src": 8080}
SET_TP_DST	Set TCP/UDP destination port using "tp_dst"	{"type": "SET_TP_DST", "tp_dst": 8080}
ENQUEUE	Output to queue with "queue_id" attached to "port"	{"type": "ENQUEUE", "queue_id": 3, "port": 1}

List of Actions (OpenFlow1.2 or later):

Ac-tions	Description	Example
OUT-PUT	Output packet from "port"	{"type": "OUTPUT", "port": 3}
COPY_TTL_OUT	Copy TTL outwards	{"type": "COPY_TTL_OUT"}
COPY_TTL_IN	Copy TTL inwards	{"type": "COPY_TTL_IN"}
SET_MPLS_TTL	Set MPLS TTL using "mpls_ttl"	{"type": "SET_MPLS_TTL", "mpls_ttl": 64}
DEC_MPLS_TTL	Decrement MPLS TTL	{"type": "DEC_MPLS_TTL"}
PUSH_VLAN	Push a new VLAN tag with "ethertype"	{"type": "PUSH_VLAN", "ethertype": 33024}
POP_VLAN	Pop the outer VLAN tag	{"type": "POP_VLAN"}
PUSH_MPLS	Push a new MPLS tag with "ethertype"	{"type": "PUSH_MPLS", "ethertype": 34887}
POP_MPLS	Pop the outer MPLS tag with "ethertype"	{"type": "POP_MPLS", "ethertype": 2054}
SET_QUEUE	Set queue id using "queue_id" when outputting to a port	{"type": "SET_QUEUE", "queue_id": 7}
GROUP	Apply group identified by "group_id"	{"type": "GROUP", "group_id": 5}
SET_NW_TTL	Set IP TTL using "nw_ttl"	{"type": "SET_NW_TTL", "nw_ttl": 64}
DEC_NW_TTL	Decrement IP TTL	{"type": "DEC_NW_TTL"}
SET_FIELD	Set a "field" using "value" (The set of keywords available for "field" is the same as match field)	See <i>Example of set-field action</i>
PUSH_PBB	Push a new PBB service tag with "ethertype" (Openflow1.3+)	{"type": "PUSH_PBB", "ethertype": 35047}
POP_PBB	Pop the outer PBB service tag (Openflow1.3+)	{"type": "POP_PBB"}
COPY_FIELD	Copy value between header and register (Openflow1.5+)	{"type": "COPY_FIELD", "n_bits": 32, "src_offset": 1, "dst_offset": 2, "src_oxm_id": "eth_src", "dst_oxm_id": "eth_dst"}
METER	Apply meter identified by "meter_id" (Openflow1.5+)	{"type": "METER", "meter_id": 3}
EXPERIMENTER	Extensible action for the experimenter (Set "base64" or "ascii" to "data_type" field)	{"type": "EXPERIMENTER", "experimenter": 101, "data": "AAECAwQFBgc=", "data_type": "base64"}
GOTO_TABLE	(Instruction) Setup the next table identified by "table_id"	{"type": "GOTO_TABLE", "table_id": 8}
WRITE_METADATA	(Instruction) Setup the metadata field using "metadata" and "metadata_mask"	{"type": "WRITE_METADATA", "metadata": 0x3, "metadata_mask": 0x3}
METER	(Instruction) Apply meter identified by "meter_id" (deprecated in Openflow1.5)	{"type": "METER", "meter_id": 3}
WRITE_ACTIONS	(Instruction) Write the action(s) onto the datapath action set	{"type": "WRITE_ACTIONS", "actions": [{"type": "POP_VLAN"}, {"type": "OUTPUT", "port": 2}]}
CLEAR_ACTIONS	(Instruction) Clears all actions from the datapath action set	{"type": "CLEAR_ACTIONS"}

Example of set-field action

To set VLAN ID to non-VLAN-tagged frame:

```
$ curl -X POST -d '{
  "dpid": 1,
  "match":{
    "dl_type": "0x8000"
  },
  "actions":[
    {
      "type": "PUSH_VLAN",      # Push a new VLAN tag if a input frame
      ↪is non-VLAN-tagged      # Ethertype 0x8100(=33024): IEEE 802.1Q
      "ethertype": 33024      ↪VLAN-tagged frame
    },
    {
      "type": "SET_FIELD",
      "field": "vlan_vid",     # Set VLAN ID
      "value": 4102           # Describe sum of vlan_id(e.g. 6) |
      ↪OFFVID_PRESENT(0x1000=4096)
    },
    {
      "type": "OUTPUT",
      "port": 2
    }
  ]
}' http://localhost:8080/stats/flowentry/add
```

6.3 ryu.app.rest_vtep

6.3.1 REST API

6.4 ryu.services.protocols.bgp.application

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