HP Switch Software

OpenFlow Supplement

3500 switches
3500yl switches
5400zl switches
6200yl switches
6600 switches
8200zl switches

Software version K.15.06.5008
February 2012

HP Networking
3500 Switches
3500yl Switches
5400zl Switches
6200yl Switch
6600 Switches
8200zl Switches

February 2012
K.15.06.5008

OpenFlow Supplement

Publication Number

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Applicable Products

HP 3500-24 Switch	(J9470A)
HP 3500-24-PoE Switch	(J9471A)
HP 3500-48 Switch	(J9472A)
HP 3500-48-PoE Switch	(J9473A)
HP 3500yl-24G-PWR Intelligent Edge Switch	(J8692A)
HP 3500yl-48G-PWR Intelligent Edge Switch	(J8693A)
HP 3500yl-24G-PoE+ Switch	(J9310A)
HP 3500yl-48G-PoE+ Switch	(J9311A)
HP 5406zl Intelligent Edge Switch	(J8697A)
HP 5406 zl Switch with Premium SW	(J9642A)
HP 5412zl Intelligent Edge Switch	(J8698A)
HP 5412 zl Switch with Premium SW	(J9643A)
HP 5406zl-48G Intelligent Edge Switch	(J8699A)
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HP 5412-92G-PoE+/4G-SFP v2 zl Switch	(J9540A)
HP 6200yl-24G-mGBIC Switch	(J8992A)
HP 6600-24G Switch	(J9263A)
HP 6600-24G-4XG Switch	(J9264A)
HP 6600-24XG Switch	(J9265A)
HP 6600-48G Switch	(J9451A)
HP 6600-48G-4XG Switch	(J9452A)
HP 8206zl Switch	(J9475A)
HP 8206 v2 zl Switch with Premium SW	(J9640A)
HP 8212zl Switch	(J8715A/B)
HP 8212 v2 zl Switch with Premium SW	(J9641A)
HP 8206-44G-PoE+/2XG v2 zl Switch with Premium SW	(J9638A)
HP 8212-92G-PoE+/2XG v2 zl Switch with Premium SW	(J9639A)

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OpenFlow on HP Switches

Overview

OpenFlow is a software environment that allows for experimentation of networking protocols and traffic flows without interrupting the operation of the "production" network.

This document describes the operation of the OpenFlow feature on the HP switches that use software version K.15.06.5008 or later. Those switches are listed on the Copyright page near the beginning of this document.

For more information on OpenFlow, access these web pages:

http://www.openflow.org/wp/downloads/

http://openvswitch.org/cgi-bin/gitweb.cgi?p=openvswitch;a=summary

http://noxrepo.org/cgi-bin/gitweb.cgi

http://www.openflow.org/wk/index.php/OpenFlow_Tutorial#Running_the_Tutorial_Controller

Disclaimer: The CLI command set and display format for the OpenFlow Module is subject to revision in future releases, without prior notification.

OpenFlow Module Status and Capabilities

Current OpenFlow version: v2.02w (K.15.06.5008)

The OpenFlow module is included in the HP switch software for the HP Switch 8200zl, 6600, 6200zl, 5400zl, and 3500/3500yl products. The current OpenFlow module has been implemented in switch software revision K.15.06.5008 for those switches. Other revisions are not available.

Version v2.02w of the OpenFlow module implements OpenFlow protocol version 1.0. A prior version of this module, Version v1.09, implements OpenFlow 0.8.9, and is available in older switch software.

Note: The current module has seen limited testing and does not yet fully pass the conformance tests. The current implementation has various limitations (see below).

What's New for the OpenFlow Module

The following changes have been implemented in recent versions of the OpenFlow module:

- New in release K.15.06.5008:

  Fixes to the following issues have been implemented:
  - The state of previous switch software crashes lost upon reboot. [CR107764]
  - Switch interface module crashes under heavy load of flow setup via the OpenFlow agent in the switch. [CR108858]

- New in release K.15.06.5006:
  - Removed the **show openflow rules** command and output.
  - Augmented the **show openflow** command output to indicate flows that are implemented in hardware.
  - Added a **filter** option to the **show openflow flows** command. The **filter** option filters the information for the flows appearing in the status display.
  - The **show debug ip** command output no longer includes debug information for the OpenFlow module by default.

- The **show openflow** command output now displays the active OpenFlow controller, rather than the primary OpenFlow controller.
- The **show openflow <vlan-id>** command output now shows all configured OpenFlow controllers, and displays an asterisk (*) next to the currently active controller.
- Added a **no vlan <vlan-id> openflow listener** command, to disable the OpenFlow listener for auxiliary operations.
- Fixed a bug that caused the connection to the OpenFlow controller to be lost when ports are removed from the corresponding OpenFlow VLAN.

■ New in release K.15.05.5001:

Fixed a bug in the re-application of non-volatile OpenFlow configuration after a switch reboot.

■ New in release K.15.05.5000:

- Support for Version 2 chassis modules (model numbers J9534A, J9535A).
- Support for inclusion of OpenFlow configuration commands in the **show config** display.
- Addition of a **no openflow** configuration negation command.
- Addition of a **show openflow flows** command.
- Addition of a **show openflow rules** command.

Known Issues

These issues are known to exist in the current implementation of the OpenFlow module.

- Some parts of the OpenFlow v1.0 specification are not yet fully implemented.
- Trunks are not supported.
- The HP Networking meshing should not be enabled on OpenFlow switches.
- Q-in-Q has not been tested. It should not be used on OpenFlow switches.

Software Limitations

These software limitations are known to exist in the current implementation of the OpenFlow module:

- OpenFlow 0.8.2 - SSL controller connection: not supported.
- OpenFlow 0.8.9 - Explicit Handling of IP Fragments: OFPC_IP_REASM is not supported.
- OpenFlow 0.8.9 - 802.1D Spanning Tree: OpenFlow does not allow full interaction with the switch Spanning Tree. OpenFlow is confined to the switch Spanning Tree.
- OpenFlow 0.9 - Emergency Flow Cache: not supported.
- OpenFlow 0.9 - Barrier Command: not supported.
- OpenFlow 1.0 - Slicing: not implemented. The hardware can not support the slicing specification. HP provides its own QoS API instead.

Hardware Acceleration Limitations

These hardware limitations are known to exist for the OpenFlow module implementation on the supported HP switches:

- All flows can not be executed in the switch hardware, because of hardware limitations. Flows not executed in hardware are processed in switch software, which is a slower path.
- For a rule to be executed in hardware:
  - The flow must be IPv4 (L2 type == 0x800)
  - The main action is output to a single port or drop
  - Optional actions: set pcp, set ToS, and rate limit

- When a rule is executed in hardware, the following fields of the predicate are ignored:
  - dl_src
  - dl_dst
  - dl_vlan_pcp
  - flow_mod priority (wildcard flows)
- When a rule is executed in hardware, full statistics are no longer available for that rule. The following restrictions apply:
  - byte_count is not available (software byte count only)
  - Statistics are updated at a large period interval (approximately 7 seconds)
  - flow_duration value is larger than the actual flow duration, because of sample rate quantization.

Summary of Features Supported in Hardware:

Feature	Current OpenFlow Operation
Header Fields:	
Ingress Port	Matched.
MAC source	Not matched; ignored.
MAC dst	Not matched; ignored.
Ethertype	Must be 0x800.
VLAN id	Forced to the OpenFlow VLAN in the VLAN virtualization mode. Matched straight in the aggregation mode.
VLAN priority	Not matched; ignored.
IP src	Matched.
IP dst	Matched.
IP proto	Matched.
IP ToS bits	Matched.
TCP/ UDP src port	Matched.
TCP/ UDP dst port	Matched.

Feature	Current OpenFlow Operation
Actions:	
forward	Only one physical or logical port.
forward ALL	Not supported.
forward CONTROLLER	Not supported.
forward LOCAL	Not supported.
forward TABLE	Not supported
forward IN_PORT	Not supported.
forward NORMAL	Supported.
forward FLOOD	Not supported.
enqueue	Not supported (use HP QoS extensions instead).
drop	Supported.
set vlan-id	Not supported.
set vlan-priority	Supported.
strip vlan	Not supported.
modify eth src	Not supported.
modify eth dst	Not supported.
modify ipv4 src	Not supported.
modify ipv4 dst	Not supported.
modify ipv4 ToS	Supported.
modify tcp srcport	Not supported.
modify tcp dstport	Not supported.
Per Flow Counters:	
Received Packets	Maintained correctly.
Received Bytes	Not maintained correctly.
Duration (sec)	Maintained by software.
Duration (nsec)	Maintained by software.

Rules Executed in Switch Software:

The following types of rules will be processed in switch software:

- Output to multiple ports
- All header rewrites except ToS and PCP
- Non-IP
- Output to OFPP_IN_PORT
- Output to OFPP_FLOOD

Using OpenFlow on HP Switches

Saving the Switch Software to Flash

The switch has primary and secondary flash memory. HP advises you to always keep a tested version of an original HP Networking software in the primary flash, and to put the OpenFlow-enabled software in the secondary flash. When you boot the switch, it is possible to select which software version to use (primary or secondary) from the switch serial console (9600 baud).

Only on HP Networking switch software version K.13.58 and later can the OpenFlow-enabled software be saved in flash. Earlier switch software will return an error. HP therefore recommends that you keep software version K.13.58 or later in primary flash.

The switch software upload can be done via the switch console, either via the serial console or telnet/ssh. To do so, the OpenFlow-enabled software needs to be added on a TFTP server accessible from the switch.

To save the OpenFlow-enabled software (K.15.06.5008) that is on the TFTP server with IP address 10.10.10.1 to the switch secondary flash:

```
# copy tftp flash 10.10.10.1
     K_15_06_5008.swi secondary
```

To boot the switch into that software:

```
# boot system flash secondary
```

OpenFlow on a VLAN (VLAN Virtualization)

The default operating mode of the OpenFlow module is VLAN virtualization. A number of VLANs are designated as OpenFlow instances. Each of these OpenFlow VLANs is independent and has its own OpenFlow configuration and controller connection. Each OpenFlow instance runs logically within the corresponding VLAN.

Normal operation also requires the presence of at least one VLAN that is not managed by OpenFlow. The non-OpenFlow VLAN(s) are used to run the OpenFlow controller connections and to configure the OpenFlow instances via SNMP. Non-OpenFlow VLANs can also be used for any traffic that is not supposed to be managed by OpenFlow.

Typical networks use VLAN 1 as the management VLAN. HP recommends that you never use OpenFlow on the management VLAN, and to never associate an OpenFlow configuration with the management VLAN.

VLAN Configuration

Each OpenFlow instance will only act on the traffic within a specific VLAN. This means that you need to create a VLAN for OpenFlow use and assign some ports to it.

For more information about configuring VLANs, please refer to the chapter titled “Static Virtual LANs (VLANs)” in the *Advanced Traffic Management Guide* for your HP switch.

To display the current VLANS that are configured on the switch:

```
# show vlan
```

To create and name a VLAN (VLAN 10, for example), from the switch CLI config context:

```
(config)# vlan 10 name openflow
```

To display the configuration and ports of VLAN 10, for example:

```
# show vlan 10
```

To add untagged ports to a VLAN:

```
(config)# vlan 10 untagged A14,B7
```

To remove untagged ports from a VLAN, assign them to another VLAN (for example, VLAN 1 to return them to the default VLAN):

```
(config)# vlan 1 untagged A14,B7
```

To add tagged ports to a VLAN:

```
(config)# vlan 10 tagged A24,B8
```

To remove tagged ports from a VLAN:

```
(config)# no vlan 10 tagged A24,B8
```

Port Configuration

Switch ports are assigned to VLANs (see "VLAN Configuration" on page 10), but ports can not be assigned directly to an OpenFlow instance. A port can be part of multiple VLANs when using tagged mode, which means that a port can be part of multiple OpenFlow instances and non-OpenFlow VLANs.

For more information about configuring interfaces (ports), please refer to the chapter titled "Port Status and Configuration" in the *Management and Configuration Guide* for your HP switch.

To display the status of all ports:

```
# show interfaces brief
```

To display the configuration of all ports:

```
# show interfaces config
```

To display the port statistics counters:

```
# show interfaces
```

To display the port statistics counters live:

```
# show interfaces display
```

To display the VLANs associated with a port:

```
# show vlans port A14
```

OpenFlow Configuration

Configuration of the OpenFlow module is mainly done via the switch CLI. To change the configuration, it is necessary to be in the configuration context (`config` command).

There can be multiple OpenFlow instances, and each instance is bound to a specific VLAN. Therefore, the configuration of OpenFlow is done on a per-VLAN basis.

Note: Ensure that the VLAN used in the commands below is already defined. See "VLAN Configuration" on page 10 for information on how to create a VLAN or check currently defined VLANs.

To show the OpenFlow configuration of all VLANs:

```
# show openflow
```

To show the OpenFlow configuration and status for VLAN 10:

```
# show openflow 10
```

To enter the CLI configuration context:

```
# config
```

To enable/start OpenFlow on VLAN 10 (for example):

```
(config)# vlan 10 openflow enable
```

To disable/stop OpenFlow on VLAN 10:

```
(config)# vlan 10 openflow disable
```

To set the switch to use 10.11.12.1 as the OpenFlow controller and communicate via TCP port 975:

```
(config)# vlan 10 openflow controller
             tcp:10.11.12.1:975
```

To enter the VLAN 10 context and add a passive listener for dpctl (OpenFlow data paths) on port 975:

```
(config)# vlan 10

(config)# openflow listener ptcp:975
```

To do everything via a single command:

```
(config)# vlan 10 openflow controller
     tcp:10.11.12.1:975 listener ptcp:975 enable
```

The switch has many configuration files. All OpenFlow configuration that is done via the CLI affects only the "running-config", which is not persistent across reboots. For more information about managing the switch configuration files, see the chapter titled "Switch Memory and Configuration" in the *Basic Operation Guide* for your HP switch.

The simplest way to have the configuration persist across boots is to save the current "running-config" to the "startup-config". To do so, enter this command:

```
# write memory
```

Non-OpenFlow software does not recognize OpenFlow parameters from configuration files and will discard them. When booting a switch from non-OpenFlow software, all OpenFlow configuration is removed from the "startup-config" and needs to be restored when booting OpenFlow software. For more information on saving and restoring switch configurations, see the chapter titled "Switch Memory and Configuration" in the *Basic Operation Guide* for your HP switch.

OpenFlow module configuration may be removed, without erasing the entire switch configuration.

To remove the OpenFlow configuration on VLAN 10 (for example):

```
(config)# no openflow vlan 10
```

To remove OpenFlow configuration on aggregate VLANs:

```
(config)# no openflow aggregate_vlans
```

Controller Connection

The OpenFlow controller traffic can not be "in-band". It can not transit on a VLAN managed by OpenFlow, and must transit on a VLAN not managed by OpenFlow. On the other hand, the controller traffic and OpenFlow traffic can transit on the same port, as long as they use different VLANs.

The VLAN chosen for the controller traffic depends entirely on the IP address of the controller, and no specific configuration is needed. For this reason, the switch should have a proper IP configuration, and the controller address must be part of a subnet that is not on an OpenFlow VLAN.

For information on how to either manually assign an IP address to the switch or set it up to perform DHCP queries, please refer to the chapter titled "Configuring IP Addressing" in the *Basic Operation Guide* for your HP switch.

OpenFlow Interfaces

By design, the OpenFlow module user interface on the switch is minimal, and mostly offers configuration or status information not available through the OpenFlow protocol. The proper way to control and monitor the OpenFlow module is to use the OpenFlow protocol itself. The OpenFlow module has two OpenFlow interfaces: the controller interface and the listener interface.

Controller Interface: The controller interface is an active connection to a single controller IP address. The controller can be monolithic, but it can also be a proxy, such as FlowVisor, or a framework, such as NoX, enabling multiple applications to interact with the switch via the controller connection.

To set the switch to use 10.11.12.1 as the OpenFlow controller and communicate via TCP port 975:

```
(config)# vlan 10 openflow controller
             tcp:10.11.12.1:975
```

Listener Interface: The listener interface is a passive connection enabling any number of OpenFlow applications to connect directly to the switch, but does not offer the full controller functionality.

To add a passive listener interface:

```
(config)# vlan 10 openflow listener ptcp:975
```

To disable the passive listener interface:

```
(config)# no vlan 10 openflow listener
```

Debugging the OpenFlow Module

The most common way to debug and monitor the OpenFlow module is to use a utility running on a Linux system and connecting remotely to the listener socket on the switch. The OpenFlow Reference System software contains such a utility called “dpctl”. Open vSwitch contains its own version of this utility called “ovs-ofctl”.

The syntax of dpctl and ovs-ofctl are identical. These four commands expose the full state of the OpenFlow module (using the OpenFlow controller with IP address 10.11.12.1 and using port 975 for communication with the switch):

```
# dpctl show tcp:10.11.12.1:975
# dpctl dump-tables tcp:10.11.12.1:975
# dpctl dump-flows tcp:10.11.12.1:975
# dpctl dump-ports tcp:10.11.12.1:975
```

Adding a permanent flow can also be done:

```
# dpctl add-flow tcp:10.11.12.1:975
  "priority=32769,idle_timeout=0,ip,nw_dst=10.0.0.3,
  nw_src=10.0.0.2,action=output:23"
```

Rate Limiters Configuration

The OpenFlow module can be configured with rate limiters to control OpenFlow experiments and to prevent them from consuming a significant portion of the switch resources. Two rate limiters can be implemented for each OpenFlow instance. The rate limiters have different purposes, are completely independent for each OpenFlow instance, and can be set independently.

The **first rate limiter** is the software rate limiter. It limits the number of packets that each fixed-port switch or switch interface module can send to the software path on the switch's CPU. It indirectly controls the number of packet_in messages sent by the switch to the controller. This rate limiter is always enabled and its default value is 100 pps.

To change the software rate limiter's limit:

```
(config)# vlan 10 openflow sw-rate 10000
```

(the valid range is 10 to 10000)

The **second rate limiter** is the hardware rate limiter. It controls the bandwidth for that OpenFlow instance on each fixed-port switch or switch interface module.

This rate limiter is disabled by default. Enabling this rate limiter disables per-flow rate limiters on that OpenFlow instance. See "Per-Flow Rate Limiters" on page 25.

To set the hardware rate limiter:

```
(config)# vlan 10 openflow hw-rate 1000000
```

To disable the hardware rate limiter:

```
(config)# vlan 10 openflow hw-rate 0
```

OpenFlow Configuration via SNMP

It is also possible to configure the OpenFlow module via SNMP, like the rest of the switch configuration. However, to do so you must have SNMP access with sufficient permissions to allow that configuration.

To enable OpenFlow on VLAN 99 and using OpenFlow controller 10.11.12.1 (for example):

```
# snmpset -v2c -c public 10.11.12.1 iso.org.dod.
  internet.private.enterprises.
  11.2.14.11.5.1.7.1.35.1.1.2.99 i 1
```

To disable OpenFlow:

```
# snmpset -v2c -c public 10.11.12.1 iso.org.dod.
  internet.private.enterprises.
  11.2.14.11.5.1.7.1.35.1.1.2.99 i 2
```

Displaying OpenFlow Information

Showing OpenFlow Configuration

OpenFlow configuration may be extracted and saved for later restoration on the switch (or some other switch) using the standard switch **show config** command. The OpenFlow related display will be formatted as follows:

```
openflow
  vlan 9
    enable
    controller "tcp:172.22.18.193:6633" listener "ptcp:6633"
    exit
  exit
```

Showing OpenFlow Status

The current version information for the OpenFlow Module can be displayed using the following command:

```
# show openflow version
```

Here's an example of the output from this command:

```
Openflow Version

  HP Networking OpenFlow Agent Version 2.02w.
  Based on Open vSwitch Reference Source code Version 1.0.0.
  Switch software Version K.15.06.5008.
```

The current summary configuration operating status of the OpenFlow Module can be displayed using the following command:

```
# show openflow
```

Here's an example of the output from this command:

```
Openflow Configuration

 Openflow aggregate VLANs [Disabled] :
 Openflow aggregate management VlanId [0] : 0
 Openflow second aggregate management VlanId [0] : 0
 Openflow aggregate configuration VlanId [0] : 0

 VID  State HW  Active controller Pseudo-URL                        Conn
 ---- ----- --- ------------------------------------------------- ----
 9    On    On  tcp:172.22.17.21:6633                               Yes
```

The current configuration operating status of an OpenFlow VLAN instance can be displayed using the following command:

```
# show openflow <vlan-id>
```

Here's an example of the output from this command with VLAN 10 specified:

```
Openflow Configuration - VLAN 10

  Openflow state [Disabled] : Enabled
  Controller pseudo-URL : tcp:172.22.17.20:6633
  Listener pseudo-URL : ptcp:6633
  Openflow software rate limit [100] : 100
  Openflow connecting max backoff [60] : 3
  Openflow hardware acceleration [Enabled] : Enabled
  Openflow hardware rate limit [0] : 0
  Openflow hardware stats max refresh rate [0] : 0
  Openflow fail-secure [Disabled] : Disabled
  Second Controller pseudo-URL : tcp:172.22.17.21:6633 *
  Third Controller pseudo-URL : tcp:172.22.17.22.6633

Openflow Status - VLAN 10

  Switch MAC address : B4:99:BA:52:02:00
  Openflow datapath ID : 0009B499BA520200
  Controller connection status (2/3) : connected ; state: ACTIVE
  Listening connection status : listening (3 connections)
  SW Dpif n_flows: 0 ; cur_capacity:1 ; n_lost: 0
           n_hit: 0 ; n_missed: 47 ; n_frags: 0
  Number of hardware rules: 0
```

The currently active OpenFlow controller is indicated by the adjacent asterisk (*). In the above example, the Second Controller is active.

Showing OpenFlow Flows

The current (volatile) status of OpenFlow flows may be displayed using the command:

```
# show openflow [vlan <vlan-id>] [flows [FILTER <value>]]
```

To display the OpenFlow flow table for VLAN 9 with no filters applied (for example):

```
# show openflow vlan 9 flows
```

The display is formatted as follows:

```
Flow 1:

 Incoming Port   : 0                 HW acceleration  : Yes
 Destination MAC : 001b21-22edd8     Source MAC       : 001b21-239552
 VLAN ID         : 9                 VLAN Priority    : 0
 Source IP       : 192.16.200.4      Destination IP   : 192.16.200.4
 IP Protocol     : IP                IP ToS bits      : 0
 Source Port     : 0                 Destination Port : 0
 Duration        : 16s secs          Priority         : 32769
 Idle Timeout    : 0 secs            Hard Timeout     : 0 secs
 Packet Count    : 0                 Bytes Count      : 0
 Actions         : output:23
```

Filtering Display Information

To manage the volume of display information, use one of the filter options to limit those flows displayed to a subset of interest. Only those flows that match the filter `value` will be displayed.

The currently supported filter options for the above command are:

`dest-ip`	The destination IP address of the flow(s) to be matched.
`dest-mac`	The destination MAC address of the flow(s) to be matched.
`dest-port`	The destination IP port on the flow(s) to be matched.
`ip-protocol`	The IP protocol of the flow(s) to be matched. The possible values are those defined for the IP field by the Internet Assigned Numbers Authority.
`ip-tos-bits`	The IP Type-of-Service (TOS) flags of the flow(s) to be matched, expressed as a hexadecimal number.
`source-ip`	The source IP address of the flows to be matched.

`source-mac`	The source MAC address of the flow(s) to be matched.
`source-port`	The source TCP/UDP port of the flow(s) to be matched.
`vlan-id`	The VLAN ID of the flow(s) to be matched.
`vlan-priority`	The VLAN priority of the flow(s) to be matched.

The values for each filter type are entered in the standard format for the corresponding element as used elsewhere in the switch CLI. An example command with the `source-mac` filter is:

```
# show openflow vlan 9 flows source-mac 080001-020304
```

(Any MAC address format supported by the CLI can be used. The same applies to IP addresses.)

Showing OpenFlow via SNMP

To show the OpenFlow configuration via SNMP for the switch with IP address 172.16.10.10 (for example):

```
# snmpwalk -v2c -c public 172.16.10.10 iso.org.
  dod.internet.private.enterprises.
  11.2.14.11.5.1.7.1.35
```

OpenFlow Configuration Commands (CLI, SNMP)

This is the full list of commands available through CLI and SNMP.

Note:

In the following SNMP commands, `*` represents the string:

```
iso.org.dod.internet.private.enterprises.
   11.2.14.11.5.1.7.1.35
```

- To enable and start the OpenFlow module:

  CLI `vlan <vlan-id> openflow enable`

  SNMP `*.1.1.2.<vlan-id> i 1`

- To disable and stop the OpenFlow module:

  CLI `vlan <vlan-id> openflow disable`

  SNMP `*.1.1.2.<vlan-id> i 2`

- To disable the OpenFlow module in the non-volatile configuration file store:

  CLI `no openflow vlan <vlan-id>`

  SNMP NA

- To set the controller pseudo-URL that OpenFlow connects to:

  CLI `vlan <vlan-id> openflow controller <string>`

  SNMP `*.1.1.3.<vlan-id> s <"STRING">`

- To set the listener pseudo-URL where OpenFlow receives auxiliary requests:

  CLI `vlan <vlan-id> openflow listener ptcp:<tcp-port>`

  SNMP `*.1.1.4.<vlan-id> s <"STRING">`

- To clear the listener pseudo-URL where OpenFlow receives auxiliary requests:

  CLI `no vlan <vlan-id> openflow listener`

  SNMP NA

- To set the packet rate limit for OpenFlow's software path (packets per seconds per line card).

  CLI `vlan <vlan-id> openflow sw-rate <10-10000>`

  SNMP `*.1.1.5.<vlan-id> i <10-10000>`

- To set the maximum backoff when connecting to the controller (seconds):

  CLI `vlan <vlan-id> openflow backoff <1-3600>`

  SNMP `*.1.1.6.<vlan-id> i <1-3600>`

- To Enable/Disable Hardware Acceleration:

  CLI `vlan <vlan-id> openflow hw-accel <on | off>`

  SNMP `*.1.1.7.<vlan-id> i <1 | 2>`

- To set the rate limit for OpenFlow's hardware path (Kilobit per seconds per interface module):

  CLI `vlan <vlan-id> openflow hw-rate <0-2147483647>`

  SNMP `*.1.1.8.<vlan-id> i <0-2147483647>`

- To set the maximum time before refreshing statistics from the hardware (seconds):

  CLI `vlan <vlan-id> openflow hw-refresh-max <1-3600>`

  SNMP `*.1.1.9.<vlan-id> i <1-3600>`

- To enable fail-secure mode, disable fail-standalone mode:

  CLI `vlan <vlan-id> openflow fail-secure`

  SNMP `*.1.1.11.<vlan-id> i <1 | 2>]`

- To set the second controller pseudo-URL that OpenFlow connects to:

  CLI
  ```
  vlan <vlan-id> openflow
       second_controller <STRING>
  ```

  SNMP `*.1.1.12.<vlan-id> s <"STRING">`

- To set the third controller pseudo-URL that OpenFlow connects to:

  CLI
  ```
  vlan <vlan-id> openflow
       third_controller <STRING>
  ```

  SNMP `*.1.1.13.<vlan-id> s <"STRING">`

- To enable aggregation of OpenFlow VLANs:

  CLI `openflow aggregate_vlans enable`

  SNMP `*.2.1.0 i 1`

- To disable aggregation of OpenFlow VLANs:

  CLI `openflow aggregate_vlans disable`

  SNMP `*.2.1.0 i 2`

- To disable aggregation of OpenFlow VLANs in the non-volatile configuration file store:

  CLI `no openflow aggregate_vlans`

  SNMP NA

- To set the VLAN ID for the non-aggregated VLAN:

  CLI
  ```
  openflow aggregate_vlans
       management_vlan <vlan-ID>
  ```

  SNMP `*.2.2.0 i <vlan-id>`

- To set the VLAN ID for the VLAN configuration to use when doing aggregation.

  CLI
  ```
  openflow aggregate_vlans
       configuration_vlan <vlan-id>
  ```

  SNMP `*.2.3.0 i <vlan-id>`

Aggregation Mode Configuration

Aggregation is an EXPERIMENTAL feature. Few people really need aggregation mode, and most people are encouraged to use VLAN virtualization and ignore this section.

Aggregation is the opposite of VLAN virtualization in that it enables the switch to have a single OpenFlow instance managing all the VLANs within the switch. It impacts the whole way OpenFlow is managed inside the switch. It is not possible to mix aggregation and virtualization, which means that when aggregation is enabled, a single OpenFlow instance can be run: the aggregated one.

In aggregated mode, all VLANs on the switch are managed by a single OpenFlow instance, regardless of their individual OpenFlow configuration or lack of OpenFlow configuration. Because the OpenFlow control traffic can not be “in-band”, a specific “OpenFlow Management VLAN” is defined and excluded from aggregation. In other words, the OpenFlow instance manages all VLANs except the “OpenFlow Management VLAN”. The “OpenFlow Management VLAN” can be used for running the OpenFlow control traffic, but also to access the switch console or MIB, or for any other purpose.

To define VLAN 1 (for example) as the OpenFlow Management VLAN:

```
(config)# openflow aggregate_vlans management_vlan 1
```

(Note that the OpenFlow management VLAN is not necessarily the same as the switch management VLAN and that there is a separate switch command to configure the switch management VLAN.)

The “Configuration VLAN” defines which OpenFlow VLAN configuration is used by the aggregated instance. Any VLAN number can be picked, apart from the “OpenFlow Management VLAN”, and it won't change the overall behavior of the switch.

To configure an aggregated OpenFlow, for example on VLAN 10 using OpenFlow controller 10.11.12.1:

```
(config)# openflow aggregate_vlans
     configuration_vlan 10

(config)# vlan 10 openflow controller
     tcp:10.11.12.1:975 listener ptcp:975

(config)# openflow aggregate_vlans enable
```

To enable/start the aggregated OpenFlow:

```
(config)# vlan 10 openflow enable
```

To show the configuration and status for the aggregated OpenFlow:

```
# show openflow 10
```

HP Extensions

The HP OpenFlow module is the first implementation to provide QoS support in OpenFlow. The HP QoS extensions were included in version 1.09 of the OpenFlow module, and are also available in version 2.02.

Priority Queues

For those HP Networking switches that have 8 priority queues per port, the queuing mechanism is a strict priority with guaranteed minimum bandwidth (GMB). The GMB parameter can be configured per port. Please refer to the chapter titled “Port Traffic Controls” in the *Management and Configuration Guide* for your HP switch.

OpenFlow flows can be mapped to the priority queues using either the VLAN PCP or the IP ToS/DSCP. The VLAN PCP offers a direct mapping, whereas IP ToS/DSCP is indirect. Please refer to the chapter titled “Quality of Service” in the *Advanced Traffic Management Guide* for your HP switch.

There is no need to use the classifier feature. The only need is for the OpenFlow rule to specify the chosen PCP or ToS as part of the action list.

To map a flow to the third priority class:

```
# dpctl add-flow tcp:10.11.12.1:975 "priority=32769,
  idle_timeout=0,ip,nw_dst=10.0.0.3,nw_src=10.0.0.2,
  action=mod_vlan_pcp:3,output:23"
```

Per-Flow Rate Limiters

The HP Networking implementation of the OpenFlow module offers per flow rate limiters. Any number of flows can be flexibly mapped to one of the rate limiters, irrespective of their source and destination ports.

Note:

The per-flow rate limiters are an HP proprietary extension to OpenFlow. This is not part of the OpenFlow Spec 1.0.0.

Per-flow rate limiters are used only if the hardware rate limiter for the OpenFlow instance is disabled. To disable the hardware rate limiter for an OpenFlow instance:

```
(config)# vlan 10 openflow hw-rate 0
```

The use of rate limiters requires a version of ovs-ofctl which includes the HP QoS extension. To create a rate limiter that has a limit of 512 kb/s (for example):

```
(config)# ovs-ofctl add-limiter tcp:10.11.12.1:975
     123 drop 512 kbps
```

To assign a flow to the above rate limiter:

```
(config)# ovs-ofctl add-flow tcp:10.11.12.1:975
     "priority=32769,idle_timeout=0,ip,
     nw_dst=10.0.0.3,nw_src=10.0.0.2,
     action=rate_limit:123,output:17"
```

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