Software-Defined Networking (SDN) Deployment Guide

Version 1.0

Notes, Cautions, and Warnings

NOTE: A NOTE indicates important information that helps you make better use of your computer.

CAUTION: A CAUTION indicates either potential damage to hardware or loss of data and tells you how to avoid the problem.

WARNING: A WARNING indicates a potential for property damage, personal injury, or death.

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Introduction

OpenFlow (OF) 1.0 [STD-1] is supported on the S4810, S4820T and Z9000 platform and MXL switches.

Overview

In a software-defined network (SDN), an external controller-cluster manages the network and the resources on each switch. OpenFlow is a protocol used for communication between the controller and the switch.

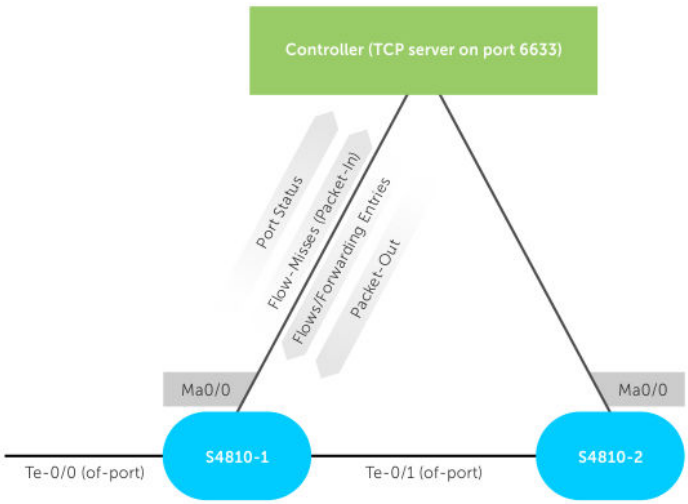

Figure 1. OpenFlow Topology — Overview

SDN offloads all switching and routing protocol state machines to the controller. A simplified and efficient software layer on the switch programs the forwarding tables.

Using OpenFlow, you can transmit the switch's ports and forwarding tables to the controller, allowing the controller to configure forwarding entries on the switch. OpenFlow also allows the controller to insert control packets through the switch and to redirect any missed flow packets from the switch to the controller.

The flows in OpenFlow allow the switch to match based on the following parameters:

- ingress port
- virtual local area network (VLAN) ID
- VLAN priority (vlan-pri)
- destination MAC address (DMAC)

- source MAC address (SMAC)
- EtherType
- session initiation protocol (SIP)
- dynamic IP (DIP)
- type of service (TOS)
- protocol
- transport source-port (transport sport)
- transport destination-port (transport dport)

The software forwards the match results out of one or more network ports, with the option to modify the packet headers. SDN currently supports OpenFlow version 1.0. For information about exceptions, refer to Exceptions.

OpenFlow 1.0 Support

OpenFlow (OF) 1.0 [STD-1] is supported on the S4810, S4820T, and Z9000 platform and MXL switches.

Unsupported OpenFlow Messages

The following OpenFlow messages are not supported. Some unsupported messages generate `OFPT_ERROR`, which is an error message sent to the controller.

Table 1. Unsupported OpenFlow Messages

Message	System Response
`OFPT_SET_CONFIG`	This message is ignored by the switch.
`OFPT_QUEUE_GET_CONFIG_REQUEST`	`OFPT_ERROR` generates in response.
`OFPT_PORT_MOD`	`OFPT_ERROR` generates in response.
Emergency Flows (`OFPFF_EMERG`)	`OFPT_ERROR` generates in response.
Queue Statistics (`OFPST_QUEUE`)	`OFPT_ERROR` generates in response.

For supported `flow-match` and `flow action` parameters for each flow type, refer to FlowTypes.

The following is a list of actions that are not supported for any flow types. All of the following commands generate an `OFPT_ERROR` message.

- `OFPAT_STRIP_VLAN`
- `OFPAT_SET_NW_SRC (set src-ip)`
- `OFPAT_SET_NW_DST (set dst-ip)`
- `OFPAT_SET_TP_SRC (set tcp/udp src-port)`
- `OFPAT_SET_TP_DST (set tcp/udp dst-port)`
- `OFPAT_ENQUEUE`
- `OFPAT_OUTPUT to OFPP_IN_PORT`
- `OFPAT_OUTPUT to OFPP_TABLE`
- `OFPAT_OUTPUT to OFPP_NORMAL`
- `OFPAT_OUTPUT to OFPP_LOCAL`

Limitations

- `OFPAT_OUTPUT to OFPP_FLOOD` and `OFPP_ALL` are supported on the S4810, S4820T, and MXL switches. These actions are not supported on the Z9000 platform.
- Multiple output ports are supported on S4810, S4820T, and MXL switches. Multiple output ports are not supported on the Z9000 platform.
- The set/modify actions must precede the output ports actions. If you specify multiple output ports, the switch cannot transmit different copies.

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Flow Types

Dell Networking switches support four types of flows:

- Access control list (ACL)
- L2
- L3
- Learning bridge (LB)

The following sections describe the mandatory match fields, optional match fields, mandatory actions, and optional actions for each flow type.

ACL Flows

Parameter Type	Parameters
Mandatory match fields	None; any of the match parameters can be wildcards.
Optional match fields	All 12 match fields defined in OpenFlow (OF) 1.0 are supported.
Mandatory actions	None.
Optional actions	• `set_vlan_id` • `set_vlan_pcp` • `set_dl_src` (set src-mac) • `set_dl_dst` (set dst-mac) • `set_nw_tos` • output to one or more switch ports

NOTE: For output action limitations, refer to OF 1.0 Support.

L3 Flows

Parameter Type	Parameters
Mandatory match fields	• You must specify `dl_dst` (dst-mac) as the switch's port mac. • You must specify `dl_type` (ether-type) as 0x800.

Parameter Type	Parameters
Optional match fields	• nw_dst (dst-ip) • All fields other than the ones listed in “Mandatory match fields” and “Optional match fields” must be wildcards.
Mandatory actions	• You must specify set_dl_src (set src-mac) as the port mac (local mac) for the swtich. • set_dl_dst (set dst-mac) • Single OFPAT_OUTPUT action to a switch port.
Optional actions	OFPAT_SET_VLAN is optional for OpenFlow (OF) ports and mandatory for OF virtual local area networks (VLANs).

L2 Flows

Parameter Type	Parameters
Mandatory match fields	• dl_vlan (input vlan id) • dl_dst (dst-mac)
Optional match fields	All fields other than dl_vlan and dl_dst must be wildcards.
Mandatory actions	Single OFPAT_OUTPUT action to a switch port.
Optional actions	None.

Learning Bridge (LB) Flows

Parameter Type	Parameters
Mandatory match fields	• dl_src (src-mac) • dl_dst (dst-mac) • LB flows are only installed in the L2 table if bidirectional traffic is present.
Optional match fields	All fields other than the ones listed in “Mandatory match fields” must be wildcards.
Mandatory actions	Single OFPAT_OUTPUT action to a switch port.
Optional actions	None.

Max Limits

This section defines the maximum number of permitted flow types. The number of available flow types varies depending on the type of flow.

- You can provision up to eight OF instances on each switch.

- The number of flows supported on each switch depends on the flow type.
- OF flow types can be combined — for example, the following flow combination is supported: 256 ACL flows, 48,000 L2 flows, 24,000 LB flows, and 6,000 L3 flows.

Flow Type	Max Limit
ACL	256 or 512 (depending on ACL content addressable memory [CAM] carving)
L2	48,000
LB	24,000
L3	6,000

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Configuring ACL CAM Carving on the S4810, S4820T, and MXL switch

Dell Networking switches can operate in Hybrid mode, which enables OpenFlow and legacy functionality on the same switch. By default, access control list content addressable memory (ACL CAM) space is not allocated for OpenFlow. To enable OpenFlow, reserve CAM space for OpenFlow using the following commands. For more information on CAM, refer to the *Content Addressable Memory (CAM)* chapter in the *FTOS Configuration Guide*.

NOTE: The commands to allocate CAM space for OpenFlow on the S4810, S4820T, and MXL switch differ from the commands used for the Z9000.

1. Enter a value for `cam-acl`.

   Select one of the following values for `cam-acl`:

   - 0 (default): No space is allocated for OpenFlow. Change this value to four or eight to enable OpenFlow.
   - 4: Allocates space for up to 242 flow entries (14 entries are reserved for internal purposes from the 256 available flows, leaving 242 entries for use by OpenFlow).
   - 8: Allocates space for up to 498 flow entries (14 entries are reserved for internal purposes from the 512 available flows, leaving 498 entries for use by OpenFlow).

   The following sample S4810 configuration reserves 512 entries for OpenFlow:

   ```
   FTOS(conf)#cam-acl l2acl 3 ipv4acl 2 ipv6acl 0 ipv4qos 2 l2qos 2 l2pt 0
   ipmacacl 0 vman-qos 0 ecfmacl 0 openflow 4 fcoeacl 0 iscsioptacl 0
   ```

2. Enter a value for `cam-acl-vlan`.

   Select one of the following values for `cam-acl-vlan`:

   - 0 (default): No space is allocated for OpenFlow. Change this value to 1 to enable OpenFlow.
   - 1: Enables OpenFlow functionality.

   The following sample configuration shows a value of 1 for `cam-acl-vlan`:

   ```
   FTOS(conf)#cam-acl-vlan vlanopenflow 1 vlaniscsi 1
   ```

   NOTE: Reboot the switch after changing the `cam-acl` and `cam-vlan-acl` values. If you do not reboot the switch, the configuration changes do not take effect.

   To upgrade any configuration changes that have changed the NVRAM content if you enable BMP 3.0, use the `reload conditional nvram-cfg-change` command to perform a reload on the chassis.

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Configuring ACL CAM Carving on Z9000

Dell Networking switches can operate in Hybrid mode, which enables OpenFlow and legacy functionality on the same switch. By default, access control list content addressable memory (ACL CAM) space is not allocated for OpenFlow. To enable OpenFlow, reserve CAM space for OpenFlow using the following commands. For more information on CAM, refer to the *Content Addressable Memory (CAM)* chapter in the *FTOS Configuration Guide*.

NOTE: The commands to allocate CAM space for OpenFlow on the Z9000 differ from the commands used for the S4810, S4820T, and MXL switch.

Enter a value for `cam-acl`.

Select one of the following values for `cam-acl`:

- 0 (default): No space is allocated for OpenFlow. Change this value to four or eight to enable OpenFlow.
- 4: Allocates space for up to 242 flow entries (14 entries are reserved for internal purposes from the 256 available flows, leaving 242 entries for use by OpenFlow).
- 8: Allocates space for up to 498 flow entries (14 entries are reserved for internal purposes from the 512 available flows, leaving 498 entries for use by OpenFlow).

The following sample Z9000 configuration reserves 512 entries for OpenFlow:

```
FTOS(conf)# cam-acl l2acl 2 ipv4acl 2 ipv6acl 0 ipv4qos 4 l2qos 1 l2pt 0
ipmacacl 0 vman-qos 0 ecfmacl 0 openflow 4
```

NOTE: For Z9000, the `cam-acl-vlan` value is set to 1 (enabled) by default; no additional configuration is required.

NOTE: Reboot the switch after changing the `cam-acl` values. If you do not reboot the switch, the configuration changes do not take effect.

To upgrade any configuration changes that have changed the NVRAM content, if you enable BMP 3.0, use the `reload conditional nvram-cfg-change` command to perform a reload on the chassis .

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Configuring OpenFlow Instances

This section describes how to enable and configure OpenFlow instances on a switch.

- You can use up to eight OpenFlow instances on a switch. The OpenFlow (OF) ID range is from 1 to 8.
- You must allocate CAM blocks for use by OpenFlow before configuring any OpenFlow instances. For more information, refer to Config_ACL_CAM_Carving for S4810, S4820T, and MXL switches or Config_ACL_CAM_Carving_Z9k for the Z9000 platform.
- Only transmission control protocol (TCP) connections are supported on Dell Networking switches. Transport layer security (TLS) connections are not supported.
- You can configure only one controller IP and one TCP port for each OF instance.
- The connection is established when you enable the OF instance using the `no shut` command.
- You cannot modify the OF instance while it is enabled. To make configuration changes, use the `shut` command on the OF instance, as shown below.

```
FTOS#show running-config openflow of-instance
!
openflow of-instance 1
 controller 1 10.11.205.184  tcp
 shutdown
FTOS#
```

- The `show openflow of-instance` command displays details on the instance, as shown below:

```
FTOS#show openflow of-instance 1

Instance         : 1
Admin State      : Down
Interface Type   : Port
DP Id            : 00:01:00:01:e8:8b:1a:30
Forwarding Tbls : acl
Flow map         :
LB assist        : disabled
EchoReq interval: 15 seconds
Connect interval: 15 seconds
Number of Flows : 0
Packets (acl)    : -
Bytes (acl)      : -
Controller 1     : TCP, 10.11.205.184/6633, not-connected
Controller 2     : -
 Port List       :
 Vlan List       :
 Vlan Mbr list   :
```

1. Create an OpenFlow instance.

   CONFIGURATION mode

   `openflow of-instance` *`of-id`*

2. Disable the OF instance.

   NOTE: All new OpenFlow instances are disabled by default. For existing OpenFlow instances, you must disable the OpenFlow instance before you can configure it.

3. OPENFLOW INSTANCE mode

   `shutdown`

4. Add a physical interface or VLAN to an OpenFlow instance.

   INTERFACE mode

   `of-instance` *`of-id`*

   NOTE: For more information, refer to OF_Interfaces

5. Specify the interface type for the OF instance.

   OPENFLOW INSTANCE mode

   `interface-type {any|port|vlan}`

   NOTE: Dell Networking does not recommend selecting `any` for the `interface-type` unless both of-ports and of-vlans are required in a single instance. If you select `any` for the `interface-type`, the number of available ACL flows is reduced by half (128 of 256 entries or 256 of 512 entries).

   NOTE: Dell Networking does not recommend configuring global spanning-tree protocol (STP) instances on ports using both legacy virtual local area networks (VLANs) and OF VLANs.

6. Specify the OF controller configuration used by OF to establish a connection.

   OPENFLOW INSTANCE mode

   `controller {`*`controller-id`*`}{`*`ip-address`*`}[port`*`port-number`*`]tcp`

7. (OPTIONAL) Configure the timed interval (in seconds) that the OF instance waits after attempting to establish a connection with the OF controller.

   OPENFLOW INSTANCE mode

   `connect retry-interval` *`interval`*

8. (OPTIONAL) Specify if flows installed by the controller should be interpreted by the switch for placement in L2 or L3 tables.

   OPENFLOW INSTANCE mode

   `flow-map {l2|l3} enable`

9. (OPTIONAL) Specify if learning bridge flows should be interpreted by the switch.

   OPENFLOW INSTANCE mode

   `learning-switch-assist enable`

10. (OPTIONAL) Advertise all forwarding tables (IFP, VLAN, L2, and L3) to the controller.

    OPENFLOW INSTANCE mode

    `multiple-fwd-table enable`

11. Enable the OF instance.

    OPENFLOW INSTANCE mode

    `no shutdown`

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OpenFlow Interfaces

This section describes how you can apply OpenFlow to specific interfaces.

- You can use the S4810, S4820T, Z9000 or MXL switch as a Hybrid switch, allowing both OpenFlow (OF) and legacy functionality simultaneously.
- By default, all ports are available for legacy functionality.
- To enable OpenFlow, associate a port or virtual local area network (VLAN) to an OF instance. You can only do this when the OF instance is disabled (in a Shut state).
- OpenFlow is supported with link aggregation groups (LAGs); for example, you can configure port channel interfaces as OF ports or as members of OF VLANs.

OF Ports

The following configuration example associates two ports (Te 0/7 and Te 0/31) to of-instance 1:

```
FTOS(conf)#interface tengigabitethernet 0/7
FTOS(conf-if-te-0/7)#of-instance 1
FTOS(conf-if-te-0/7)#interface tengigabitethernet 0/31
FTOS(conf-if-te-0/31)#of-instance 1
FTOS(conf-if-te-0/31)#
```

To see the list of ports associated with an OF instance, use the `show openflow of-instance` command. The number displayed in parentheses is the port ID sent to the controller (for example, Te 0/7 is sent to the controller as of-port 8, as shown below).

```
FTOS#show openflow of-instance 1

Instance          : 1
Admin State       : Up
Interface Type    : Port
DP Id             : 00:01:00:01:e8:8b:1a:30
Forwarding Tbls   : acl
Flow map          :
LB assist         : disabled
EchoReq interval  : 15 seconds
Connect interval  : 15 seconds
Number of Flows   : 1 (acl:1)
Packets (acl)     : 0
Bytes (acl)       : 0
Controller 1      : TCP, 10.11.205.184/6633, connected (equal)
Controller 2      : -
 Port List        :
                  Te 0/7 (8), Te 0/31 (32)
 Vlan List        :

 Vlan Mbr list    :
```

OF VLANs

Instead of assigning an entire port to an OF instance, you can assign a VLAN to an OF instance. Do this when you create the VLAN. Enter OF VLAN members in the same way as a legacy VLAN.

NOTE: You can only create OF VLANs when the associated instance is disabled (in a Shut state).

There is an `interface-type` parameter in each instance. By default, this parameter is set to `port`, indicating that the instance is used for OF ports. To use an instance in OF VLANs, change this parameter to `vlan`, as shown below:

```
FTOS(conf)#openflow of-instance 1
FTOS(conf-of-instance-1)#interface-type vlan
FTOS(conf-of-instance-1)#
```

To use both OF ports and OF VLANs, set the interface type to `any`.

NOTE: Dell Networking does not recommend using the interface type `any` unless both OF ports and OF VLANs are required in a single instance. If you use the `any` interface type, the number of ACL flows available to the controller is reduced by half (for example, to 128 of 256 available entries or to 256 of 512 available entries).

The following configuration example associates VLAN 100 (with tagged members Te 0/0 and Te 0/1) to of-instance 1:

```
FTOS(conf)#interface vlan 100 of-instance 1
FTOS(conf-if-vl-100)#tagged tengigabitethernet 0/0
FTOS(conf-if-vl-100)#tagged tengigabitethernet 0/1
FTOS(conf-if-vl-100)#no shutdown
FTOS(conf-if-vl-100)#
```

To display the OF VLANs and OF VLAN members associated with the OF instance, use the `show openflow of-instance` command , as shown below:

```
FTOS#show openflow of-instance

Instance         : 1
Admin State      : Up
Interface Type   : Vlan
DP Id            : 00:01:00:01:e8:8b:1a:30
Forwarding Tbls : acl
Flow map         :
LB assist        : disabled
EchoReq interval: 15 seconds
Connect interval: 15 seconds
Number of Flows : 0
Packets (acl)    : -
Bytes (acl)      : -
Controller 1     : TCP, 10.11.205.184/6633, connected (equal)
Controller 2     : -
 Port List       :

 Vlan List       :
                   Vl 100
 Vlan Mbr list   :
                   Te 0/0 (1), Te 0/1 (2)
```

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Flow Setup

This chapter describes the configuration options required to set up flows.

Sample Topology

In the following sample topology, two OF instances are shown. of-instance 1 has an interface type of `port` and demonstrates ACL and L3 flows. of-instance 2 has an interface type of `VLAN` and demonstrates ACL, L2, LB, and L3 flows. LB and L2 flows are supported on OF VLANs only.

Figure 2. SDN Sample Topology

To display the following information, use the `show running-config openflow of-instance 1` command :

NOTE: To display information using the `show running-config openflow of-instance 1` command, you must have an active connection to the OF controller.

```
FTOS# show running-config openflow of-instance 1
!
openflow of-instance 1
 controller 1 10.11.205.184  tcp
 flow-map l3 enable
 multiple-fwd-table enable
 no shutdown
FTOS# show openflow of-instance 1

Instance         : 1
Admin State      : Up
Interface Type   : Port
DP Id            : 00:01:00:01:e8:8b:1a:30
Forwarding Tbls  : acl,mac,route
Flow map         : l3
LB assist        : disabled
EchoReq interval: 15 seconds
Connect interval: 15 seconds
```

```
Number of Flows : 1
Packets (acl)   : -
Bytes (acl)     : -
Controller 1    : TCP, 10.11.205.184/6633, connected (equal)
Controller 2    : -
 Port List      :
                  Te 0/7 (8), Te 0/31 (32)
 Vlan List      :
 Vlan Mbr list  :
```

To display information for the second OF instance, use the `show running-config openflow of-instance 2` command:

```
FTOS# show running-config openflow of-instance 2
!
openflow of-instance 2
 controller 1 10.11.205.184  tcp
 flow-map l2 enable
 flow-map l3 enable
 interface-type vlan
 learning-switch-assist enable
 multiple-fwd-table enable
 no shutdown
FTOS#show openflow of-instance 2

Instance        : 2
Admin State     : Up
Interface Type  : Vlan
DP Id           : 00:02:00:01:e8:8b:1a:30
Forwarding Tbls : acl,mac,route
Flow map        : l2,l3
LB assist       : enabled
EchoReq interval: 15 seconds
Connect interval: 15 seconds
Number of Flows : 0
Packets (acl)   : -
Bytes (acl)     : -
Controller 1    : TCP, 10.11.205.184/6633, connected (equal)
Controller 2    : -
 Port List      :
 Vlan List      :
                  Vl 200
 Vlan Mbr list  :
                  Te 0/0 (1), Te 0/1 (2)
```

ACL Flows

By default, all flows are treated as ACL flows. No additional configuration is required to set up ACL flows. You can view per-flow and aggregate statistics for ACL flows using the `show openflow of-instance` and `show openflow flows of-instance` commands.

To clear these statistics, use the `clear openflow statistics of-instance` command. The following sample ACL flow was configured using a controller. It matches by `dmac`, `ether-type`, `ip-protocol`, and `tcp-dst-port`, then sets the VLAN ID to 111 and forwards the packet from Te 0/31.

```
FTOS#show openflow flows of-instance 1
Instance: 1, Table: acl, Flow: 1, Cookie: 0xa000003c435722
Priority: 32768, Internal Priority: 32768
Up Time: 0d 00:02:34, Hard Timeout: 0 seconds
Idle Timeout: 0 seconds, Internal Idle Timeout: 0 seconds
Packets: 1, Bytes: 64
Match Parameters:
```

```
  Valid Match: Etype,DMAC,IP proto,DPort
  In Port    : *                  EType     : ip
  SMAC       : *                  DMAC      : 00:11:11:11:11:11
  VLAN id    : *                  VLAN PCP  : *
  IP TOS     : *                  IP proto  : udp
  Src IP     : *                  Dest IP   : *
  Src Port   : *                  Dest Port : 8900
 Actions:
  Set VLAN id: 111
  Output: Te 0/31

FTOS#show openflow of-instance 1
Instance         : 1
Admin State      : Up
Interface Type   : Port
DP Id            : 00:01:00:01:e8:8b:1a:30
Forwarding Tbls : acl,mac,route
Flow map         : l3
LB assist        : disabled
EchoReq interval: 15 seconds
Connect interval: 15 seconds
Number of Flows : 1 (acl:1)
Packets (acl)    : 1
Bytes (acl)      : 64
Controller 1     : TCP, 10.11.205.184/6633, connected (equal)
Controller 2     : -
 Port List       :
                   Te 0/7 (8), Te 0/31 (32)
 Vlan List       :
 Vlan Mbr list   :
```

For complete ACL flow formats, refer to FlowTypes .

L3 Flows

To use L3 flows, enable the `multiple-fwd-table` and `flow-map l3` commands, as shown in the following example. If you do not enable either of these commands, L3 flows are added to the ACL table.

```
FTOS#show running-config openflow of-instance 1
!
openflow of-instance 1
 controller 1 10.11.205.184  tcp
 flow-map l3 enable
 multiple-fwd-table enable
 no shutdown
```

The entry for `dst-mac` in the match field and `set-src-mac` in the action set must use the switch's port MAC address. All ports on a Dell Networking switch are associated with the same MAC address, which you can view using the `show interface` command.

```
FTOS#show interfaces tengigabitethernet 0/0
TenGigabitEthernet 0/0 is up, line protocol is up
Hardware is DellForce10Eth, address is 00:01:e8:8b:1a:32
    Current address is 00:01:e8:8b:1a:32
...
```

You can configure L3 flows on OF ports as well as on OF VLANs. You must specify the `set-vlan-id` option in the action set for OF VLANs. As shown in the following example, the L3 flow in of-instance 1 transmits packets from OF port Te 0/31:

```
FTOS#show openflow flows of-instance 1
```

```
Instance: 1, Table: route, Flow: 2, Cookie: 0xfffffffffa17177b0
Priority: 32768, Internal Priority: 0
Up Time: 0d 00:00:13, Hard Timeout: 0 seconds
Idle Timeout: 0 seconds, Internal Idle Timeout: 0 seconds
Packets: -, Bytes: -
Match Parameters:
  Valid Match: Etype,DMAC,DIP
  In Port     : *                  EType      : ip
  SMAC        : *                  DMAC       : 00:01:e8:8b:1a:32
  VLAN id     : *                  VLAN PCP   : *
  IP TOS      : *                  IP proto   : *
  Src IP      : *                  Dest IP    : 1.1.1.0/24
  Src Port    : *                  Dest Port  : *
 Actions:
  Set SMAC: 00:01:e8:8b:1a:32
  Set DMAC: 00:00:00:00:00:11
  Output: Te 0/31
```

The following example shows the sample L3 flow in of-instance 2 transmitting packets from the OF VLAN port Te 0/1:

```
FTOS#show openflow flows of-instance 2

Instance: 2, Table: route, Flow: 3, Cookie: 0xfffffffffa4cb6a2e
Priority: 32768, Internal Priority: 0
Up Time: 0d 00:00:11, Hard Timeout: 0 seconds
Idle Timeout: 0 seconds, Internal Idle Timeout: 0 seconds
Packets: -, Bytes: -
Match Parameters:
  Valid Match: Etype,DMAC,DIP
  In Port     : *                  EType      : ip
  SMAC        : *                  DMAC       : 00:01:e8:8b:1a:32
  VLAN id     : *                  VLAN PCP   : *
  IP TOS      : *                  IP proto   : *
  Src IP      : *                  Dest IP    : 2.2.2.2/32
  Src Port    : *                  Dest Port  : *
 Actions:
  Set VLAN id: 200
  Set SMAC: 00:01:e8:8b:1a:32
  Set DMAC: 00:00:00:00:00:22
  Output: Te 0/1
```

For complete L3 flow formats, refer to FlowTypes .

L2 Flows

L2 flows are only supported on OF VLANs. In the following example, of-instance 2 is used to demonstrate an L2 flow. To use the L2 flow table, enable the `multiple-fwd-table` and `flow-map l2` commands, as shown in the following example. If you do not enable either command, L2 flows are added to the ACL table.

```
FTOS#show running-config openflow of-instance 2
!
openflow of-instance 2
 controller 1 10.11.205.184  tcp
 flow-map l2 enable
 flow-map l3 enable
 interface-type vlan
 learning-switch-assist enable
 multiple-fwd-table enable
 no shutdown
```

The following example demonstrates a sample flow in of-vlan 200:

```
FTOS#show openflow flows of-instance 2

Instance: 2, Table: mac, Flow: 4, Cookie: 0xfffffffffac2dbbf2
Priority: 32768, Internal Priority: 0
Up Time: 0d 00:00:09, Hard Timeout: 0 seconds
Idle Timeout: 0 seconds, Internal Idle Timeout: 0 seconds
Packets: -, Bytes: -
Match Parameters:
  Valid Match: DMAC,Vid
  In Port     : *                  EType      : *
  SMAC        : *                  DMAC       : 00:22:22:22:22:22
  VLAN id     : 200                VLAN PCP   : *
  IP TOS      : *                  IP proto   : *
  Src IP      : *                  Dest IP    : *
  Src Port    : *                  Dest Port  : *
 Actions:
  Output: Te 0/1
```

For complete L2 flow formats, refer to FlowTypes .

Learning Bridge (LB) Flows

Learning bridge flows are only supported on OF VLANs. In the following example, of-instance 2 represents an LB flow. To use the LB flow table, enable the `multiple-fwd-table` and `learning-switch-assist` commands, as shown in the following example. If you do not enable either command, LB flows are added to the ACL table.

```
FTOS#show running-config openflow of-instance 2
!
openflow of-instance 2
controller 1 10.11.205.184 tcp
 flow-map l2 enable
 flow-map l3 enable
 interface-type vlan
 learning-switch-assist enable
 multiple-fwd-table enable
no shutdown
```

The following example shows a sample flow in of-vlan 200:

```
FTOS#show openflow flows of-instance 2
Instance: 2, Table: lb, Flow: 5, Cookie: 0xfffffffffac2dbc22
Priority: 32768, Internal Priority: 0
Up Time: 0d 00:00:03, Hard Timeout: 0 seconds
Idle Timeout: 0 seconds, Internal Idle Timeout: 0 seconds
Packets: -, Bytes: -
Match Parameters:
  Valid Match: InPort,SMAC,DMAC,Vid
In Port     : Te 0/0             EType      : *
  SMAC        : 00:00:00:00:00:11  DMAC       : 00:00:00:00:00:33
VLAN id     : 200                VLAN PCP   : *
  IP TOS      : *                  IP proto   : *
  Src IP      : *                  Dest IP    : *
  Src Port    : *                  Dest Port  : *
 Actions:
  Output: Te 0/1
```

For complete LB flow formats, refer to FlowTypes .

Packet Trace

Enable OpenFlow protocol packet tracing by using the `debug openflow packets packet-type {packets} of-instance {of-id}` command. For more information, refer to debug openflow packets.

8

Exceptions

This section describes the constraints of OpenFlow.

- Dell Networking switches can operate as Hybrid switches (switches running OpenFlow and legacy functions simultaneously). You cannot enable Legacy functionality (switching and routing) on OF ports or OF virtual local area networks (VLANs), as these interfaces are controlled by an OpenFlow controller and are not available.
- Stacking of OpenFlow switches is not supported for the S4810, S4820T, or MXL switches. If you configure stacking but disabled it in preparation for future stacking, the stack unit number must be zero to enable OpenFlow on S4810, S4820T, or MXL switches.
- For OF ports and OF VLANs, the VLAN IDs used for OpenFlow must be unique; the VLAN IDs cannot be used for legacy functionality on the same switch.
- Dell Networking does not recommend using global spanning tree protocol (STP) instances on ports with both legacy VLANs and OF VLANs.
- Transport layer security (TLS) connections are not supported.
- Because controllers typically run their own version of link layer discovery protocol (LLDP), disable legacy LLDP on OF ports.
- To avoid session timeout issues if you change the system clock, you must disable and re-enable all existing OF instances.
- Controller high availability (HA) is not supported.
- Emergency flows are not supported.
- Packet buffering is not supported.
- Data center bridging (DCB) and Internet small computer system interface (iSCSI) are not supported on OpenFlow interfaces.
- The following packet types can only be copied to the controller and cannot be forwarded from a physical switch port:
  - STP BDPU
  - LLDP
  - GVRP
  - ARP Replies
  - 802.1x frames
  - untagged broadcast packets received on an OF port

ACL Flow Exceptions

- Flooding (action “output=all” or “output=flood”) is supported on S4810, S4820T, and MXL switches.
- By default, ACL flows override flows installed in the L2 or L3 tables.
- Address resolution protocol (ARP) opcode, sender IP, and target IP matching are not supported.

L3 Flow Exceptions

- Non-zero integers for the idle timeout are not supported and are ignored for L3 flows. L3 flows are not aged out.

- For L3 flows, flow priority is not applicable. Instead, the dst-ip network mask length is used to prioritize the flow, with longer mask lengths having priority over shorter mask lengths. For example, an L3 flow with a dst-ip network mask length of 32 has priority over a flow with a dst-ip network mask length of 31.
- Time-to-live (TTL) is decremented for traffic forwarded using L3 flows.

L2 Flow Exceptions

- If you specify a non-zero idle timeout value for an L2 flow and there is no activity or traffic, the flow is aged out according to the MAC address table aging time configured on the switch. If the idle timeout value is zero, the flow is not aged.
- Flow priority is ignored for L2 flows.
- L2 flows are supported on OF VLANs only.

Learning Bridge (LB) Flow Exceptions

- If you specify a non-zero idle timeout value for an LB flow and there is no activity or traffic, the flow is aged out according to the MAC address table aging time configured on the switch. If the idle timeout value is zero, the flow is not aged.
- Flow priority is ignored for LB flows.
- Dell Networking does not recommend station moves in an LB flow configuration.
- Parallel links or paths may not work in an LB flow configuration. Dell Networking recommends using port channels instead.
- LB flows are supported on OF VLANs only.

9

SDN Commands

The following commands are for software-defined networking (SDN) OpenFlow.

connect retry-interval

Configure the timed interval (in seconds) that the OpenFlow (OF) instance waits after requesting a connection with the OpenFlow controller.

Z9000 S4810 S4820T

Syntax	`connect retry-interval` *interval*	
Parameter	***interval***	Enter the number of seconds the OF instance waits after attempting to establish a connection with OF controller. The range is from 10 to 60.
Defaults	15 (seconds)	
Command Modes	OPENFLOW INSTANCE	
Command History	**Version 9.2(0.0)**	Introduced on the S4820T and MXL switch.
	Version 9.1(0.0)	Introduced on the Z9000 and S4810.
Usage Information	After the interval time lapses, the OpenFlow instance reattempts to establish a connection to the OpenFlow controller.	
Related Commands	openflow of-instance — Creates or modifies an OpenFlow instance.	

controller

Specify the OpenFlow controller configuration that the OpenFlow instance uses to establish a connection.

Z9000 S4810 S4820T

Syntax `controller {controller-id}{ip-address}[port port-number]tcp`

Parameter

controller-id	Enter the controller number (must be 1).
ip-address	Enter the IP address of the controller.
port *port-number*	Enter the keyword `port` followed by the port number to use for the connection. The range is from 1 to 65535.

Defaults Default port number for the TCP connection is 6633.

Command Modes OPENFLOW INSTANCE

Command History

Version 9.2(0.0)	Introduced on the S4820T and MXL switch.
Version 9.1(0.0)	Introduced on the Z9000 and S4810.

Usage Information The controller number must be entered as 1 to enable OpenFlow. Only TCP connection is supported.

Related Commands openflow of-instance — Creates or modifies an OpenFlow instance.

debug openflow packets

Enable debugging for OpenFlow packets.

Z9000 S4810 S4820T

Syntax `debug openflow packets packet-type {packets} of-instance {of-id}`

Parameter

{packet-type *packet-type*}	Enter the keywords `packet-type` followed by one of the following packet types:	
	`all`	Enable debugging for all packets.
	`barrier-reply`	Enable debugging for barrier-reply packets.
	`barrier-request`	Enable debugging for barrier-request packets.
	`echo-reply`	Enable debugging for echo-reply packets.
	`echo-request`	Enable debugging for echo-request packets.

error	Enable debugging for error packets.
features-reply	Enable debugging for features-reply packets.
features-request	Enable debugging for features-request packets.
flow-mod	Enable debugging for flow-mod packets.
flow-removed	Enable debugging for flow-removed packets.
get-config-reply	Enable debugging for get-config-reply packets.
get-config-request	Enable debugging for get-config-request packets.
hello	Enable debugging for hello packets.
packet-in	Enable debugging for packet-in packets.
packet-out	Enable debugging for packet-out packets.
port-mod	Enable debugging for port-mod packets.
port-status	Enable debugging for port-status packets.
queue-get-config-reply	Enable debugging for queue-get-config-reply packets.
queue-get-config-request	Enable debugging for queue-get-config-request packets.
set-config	Enable debugging for set-config packets.
stats-reply	Enable debugging for stats-reply packets.
stats-request	Enable debugging for stats-request packets.
vendor	Enable debugging for vendor packets.

of-instance {*of-id*} Enter the keywords `of-instance` followed by the OF instance ID.

Defaults None

Command Modes EXEC

Command History

Version 9.2(0.0)	Introduced on the S4820T and MXL Switch.
Version 9.1(0.0)	Introduced on the Z9000 and S4810.

Usage Information If you need to enable debugging for all packets, use the `debug openflow packets packet-type all` command.

Related Commands reload conditional nvram-cfg-change — Reloads the chassis to upgrade any configuration changes to the NVRAM content.

flow-map

Specify if flows installed by the controller should be interpreted by the switch for placement in L2 or L3 tables.

Z9000 S4810 S4820T

Syntax	`flow-map {l2|l3} enable`	
Parameter	**l2**	Enter l2 to interpret Layer 2 flows.
	l3	Enter l3 to interpret Layer 3 flows.
Defaults	None (not enabled)	
Command Modes	OPENFLOW INSTANCE	
Command History	**Version 9.2(0.0)**	Introduced on the S4820T and MXL Switch.
	Version 9.1(0.0)	Introduced on the Z9000 and S4810.
Usage Information	L2 flow-mapping is not supported on OpenFlow instances with an interface-type of `port`.	
Related Commands	openflow of-instance — Creates or modifies an OpenFlow instance.	

interface-type

Specify the type of interface (port, VLAN, or any) for the OpenFlow instance.

Z9000 S4810 S4820T

Syntax	`interface-type {any|port|vlan}`	
Defaults	`port`	
Parameter	**any**	Enter the keyword `any` to enable configuration of physical interfaces, LAGs, and VLANs on the selected OF instance.
	port	Default. Enter the keyword `port` to enable configuration of LAGs or physical interfaces on the selected OF instance.
	vlan	Enter the keyword `vlan` to enable configuration of VLANs on the selected OF instance.
		NOTE: You must associate the OF instance with the VLAN when you create the VLAN.
Command Modes	OPENFLOW INSTANCE	

Command History	**Version 9.2(0.0)**	Introduced on the S4820T and MXL Switch.
	Version 9.1(0.0)	Introduced on the Z9000 and S4810.

Example (VLAN interface type)

```
FTOS(conf)#openflow of-instance 1
FTOS(conf-of-instance-1)#interface-type vlan
FTOS(conf-of-instance-1)#
```

Usage Information

Dell Networking does not recommend selecting `any` for the `interface-type` unless both of-ports and of-vlans are required in a single instance. If you select `any` is selected for the `interface-type`, the number of available ACL flows is reduced by half (128 of 256 entries or 256 of 512 entries).

Disable legacy LLDP on of-ports to avoid conflicts with the controller's version of LLDP.

Dell Networking does not recommend configuring global STP instances on ports using both legacy VLANs and OF VLANs.

Related Commands

openflow of-instance — Creates or modifies an OpenFlow instance.

learning-switch-assist

Specify if learning bridge flows should be interpreted by the switch.

Z9000 S4810 S4820Th

Syntax

```
learning-switch-assist enable
```

Defaults

Disabled

Command Modes

OPENFLOW INSTANCE

Command History	**Version 9.2(0.0)**	Introduced on the S4820T and MXL Switch.
	Version 9.1(0.0)	Introduced on the Z9000 and S4810.

Usage Information

To allow the switch to interpret flows and update L2 tables to reduce the number of flows installed for VLANs, use this command for OpenFlow instances with an interface-type of either `vlan` or `any`.

Related Commands

openflow of-instance — Creates or modifies an OpenFlow instance.

interface-type — Selects the OpenFlow instance interface type (`port`, `VLAN`, or `any`).

multiple-fwd-table enable

Advertise all forwarding tables (IFP, VLAN, L2, and L3) to the controller.

Z9000 S4810 S4820T

Syntax

```
multiple-fwd-table enable
```

Defaults	Disabled
Command Modes	OPENFLOW INSTANCE
Command History	**Version 9.2(0.0)** Introduced on the S4820T and MXL Switch. **Version 9.1(0.0)** Introduced on the Z9000 and S4810.
Usage Information	This is a vendor-specific CLI.
Related Commands	openflow of-instance — Creates or modifies an OpenFlow instance.

of-instance (Interface)

Add a physical interface or LAG to an OpenFlow instance.

Z9000 S4810 S4820T

Syntax	`of-instance` *of-id*
Parameter	***of-id*** Enter the OpenFlow instance ID. The range is from 1 to 8.
Command Modes	INTERFACE MODE
Command History	**Version 9.2(0.0)** Introduced on the S4820T and MXL Switch. **Version 9.1(0.0)** Introduced on the Z9000 and S4810.

Example

In the following example, the ports Te 0/7 and Te 0/31 are associated with of-instance 1:

```
FTOS(conf)#interface tengigabitethernet 0/7
FTOS(conf-if-te-0/7)#of-instance 1
FTOS(conf-if-te-0/7)#interface tengigabitethernet 0/31
FTOS(conf-if-te-0/31)#of-instance 1
FTOS(conf-if-te-0/31)#
```

Usage Information

To enable OpenFlow, associate a port or a VLAN to an OF instance. Associate ports and VLANs when you create the OF instance and it is in a Shut state (`shutdown`).

LAGs or port-channel interfaces are supported as of-ports or of-vlan members on OpenFlow.

By default, all ports are available for legacy functionality.

The following features are not supported on physical interfaces associated with an OpenFlow instance:

- Dot1x
- Ethernet
- GVRP
- IPv4
- IPv6

- MAC
- MTU
- Port-channel protocols
- Spanning-tree protocols
- Switchport

The following features are not supported on LAGs associated with an OpenFlow instance:

- Ethernet
- GVRP
- IPv4
- IPv6
- MAC
- MTU
- Spanning-tree protocols
- Switchport

Related Commands openflow of-instance — Creates or modifies an OpenFlow instance.

openflow of-instance

Create an OF instance or modify an existing OF instance.

Z9000 S4810 S4820T

Syntax `openflow of-instance` *of-id*

Parameters

of-id	Enter the number of the OF instance. The range is from 1 to 8.

If you are creating a new OF instance, enter the number you want to assign to the OF instance.

If you are modifying an existing OF instance, enter the number of the instance you want to change.

NOTE: Disable the OF instance before making any configuration changes.

Defaults none

Command Modes CONFIGURATION

Command History

Version 9.2(0.0)	Introduced on the S4820T and MXL Switch.
Version 9.1(0.0)	Introduced on the Z9000 and S4810.

Usage Information

- Stacking for S4810, controller High Availability (HA), and virtual link trunking (VLT) are not supported on OF instances.
- To enable OpenFlow on the S4810, the stack unit number must be zero.
- You can create up to eight OF instances.

- To establish a connection with the controller, enable the OF instance using the `no shutdown` command.
- To modify the OF instance, disable the OF instance first using the `shutdown` command.
- You can configure one controller IP and one TCP port for each OF instance.
- The number of supported flows depends on the flow type. The following table provides the number of supported flows for each flow type:

Flow Type	Maximum Number of Available Flows
ACL	256 or 512 (depending on ACL CAM carving)
L2	48,000
LB	24,000
L3	6,000

- To avoid session timeout issues if you change the time or date on the system clock, you must disable and re-enable all existing OpenFlow instances.

Related Commands

shutdown — Enables or disables the OpenFlow instance.

show openflow — Displays general information about OpenFlow instances.

controller — Specifies the OpenFlow controller configuration that the OpenFlow instance uses to establish a connection.

show openflow

Display general information about OpenFlow instances.

Z9000 S4810 S4820T

Syntax

```
show openflow [of-instance[of-id]]
```

Parameter

of-instance *of-id* (OPTIONAL)

Enter the keywords `of-instance` to display information such as administrative state, interface-type, and operational state for all OpenFlow instances.

(OPTIONAL) Enter the keywords `of-instance` followed by the OF instance ID to display details for the specified OF instance. The range is from 1 to 8.

Defaults

None

Command Modes

EXEC

Command History

Version 9.2(0.0)	Introduced on the S4820T and MXL Switch.
Version 9.1(0.0)	Introduced on the Z9000 and S4810.

Example

```
FTOS#show openflow of-instance 1
Instance         : 1
Admin State      : Down
Interface Type   : Port
```

```
DP Id           : 00:01:00:01:e8:8b:1a:30
Forwarding Tbls : acl
Flow map        :
LB assist       : disabled
EchoReq interval: 15 seconds
Connect interval: 15 seconds
Number of Flows : 0
Packets (acl)   : -
Bytes (acl)     : -
Controller 1    : TCP, 10.11.205.184/6633, not-connected
Controller 2    : -
 Port List      :
 Vlan List      :
 Vlan Mbr list  :
```

Usage Information To display general information such as version, capabilities, and supported actions, use the `show openflow` command.

Related Commands openflow of-instance — Creates or modifies an OpenFlow instance.

show openflow flows

Display detailed information about OpenFlow instances.

Z9000 S4810 S4820T

Syntax `show openflow flows[of-instance{`*`of-id`*`}][table{`*`acl`*`|`*`lb`*`|`*`mac`*`|`*`route`*`|`*`vlan`*`}flow-id{`*`flow-id`*`}]`

Parameter

of-instance *of-id* Enter the keywords `of-instance` followed by the OF instance ID to display details of all flows installed for the specified OF instance. The range is from 1 to 8.

table *acl* / *lb* / *mac* / *route* / *vlan* flow-id *flow-id* Enter the keyword `table` followed by the table type and the keywords `flow-id` followed by the flow ID to display details for the specified flow:

acl	Display ACL table information.
lb	Display learning bridge table information.
mac	Display MAC table information.
route	Display routing table information.
vlan	Display VLAN table information.

Defaults None

Command Modes EXEC

Command History

Version 9.2(0.0)	Introduced on the S4820T and MXL Switch.
Version 9.1(0.0)	Introduced on the Z9000 and S4810.

Related Commands	show openflow — Displays general information about OpenFlow instances.

shutdown (OpenFlow Instance)

Enable or disable the OpenFlow instance.

Z9000 S4810 S4820T

Syntax	`[no] shutdown`
Defaults	Disabled (`shutdown`)
Command Modes	OPENFLOW INSTANCE
Command History	**Version 9.2(0.0)** Introduced on the S4820T and MXL Switch. **Version 9.1(0.0)** Introduced on the S4810 and Z9000.
Usage Information	To enable the OpenFlow instance, use the `no shutdown` command. When you use the `no shutdown` command, the OpenFlow instance sends a request to the OpenFlow controller to establish a connection. To disable an OpenFlow instance, use the `shutdown` command. Use the `shutdown` command before making any configuration changes to the OpenFlow instance. All OpenFlow instances are disabled by default.
Related Commands	openflow of-instance — Creates or modifies an OpenFlow instance. controller — Configures the controller used by OpenFlow.