Configure OpenFlow Agent

OpenFlow is a specification developed by the Open Networking Foundation (ONF). It defines a flow-based forwarding model for Ethernet switches (Layers 2–4) and provides a standardized protocol interface for programmatic control.

OpenFlow enables a centralized controller to manage the forwarding behavior of network switches via a secure channel. Through this interface, the controller can

- discover switch capabilities,
- add or remove flow entries, and
- request flow statistics

Note OpenFlow does not handle local device configuration. This remains outside the scope of the protocol.

At its core, OpenFlow acts as a forwarding instruction set, allowing applications to program routing and switching behavior directly. It supports flexible packet handling, including

- arbitrary matching on packet header fields,
- custom actions such as header rewriting, and
- any-to-any routing and switching logic

Traditional routers and switches combine packet forwarding and routing decisions within the same device. These decisions are typically governed by built-in protocols and control plane logic, with limited user configuration. In contrast, OpenFlow separates control from forwarding, enabling more dynamic and programmable network behavior.

Key features

These are some of the key features of the OpenFlow Agent:

- Flow-Based Forwarding: Implements a model that allows forwarding decisions based on flows rather than individual packets.
- Standardized API: Defines a protocol that enables:
    - Learning switch capabilities

- Adding and removing flow control entries
- Requesting flow statistics

- Controller Integration: Allows a controller to securely manage the forwarding behavior of a switch through a secure channel.

For details regarding OpenFlow, see the OpenFlow chapter in the *System Management Configuration Guide for Cisco ASR 9000 Series Routers*.

Prerequisites

These are the prerequisites required to configure OpenFlow agent on the platforms supporting IOS-XR.

- Release 5.1.x software that has the OpenFlow functionality.
- The Enhanced Ethernet line card for the Cisco ASR 9000 Series Router is required for the OpenFlow agent feature.
- Any controller with version 1.1 or 1.3 is required, for example, POX, ODL.
- The asr9k-k9sec Package Installation Envelope (PIE) must be present. The asr9k-mpls PIE is required for support on MPLS core (such as, PWHE).

Limitations and guidelines for OpenFlow agent

These are some of the limitations you must be aware before configuring OpenFlow agent.

- Same interface cannot be added to more than one logical OpenFlow switch.
- No support for the output as an action for layer3 OpenFlow logical switch, such as pipeline131 and 132.
- Only layer 3 interface support the NetFlow sampling statistics.

How does OpenFlow Agent work

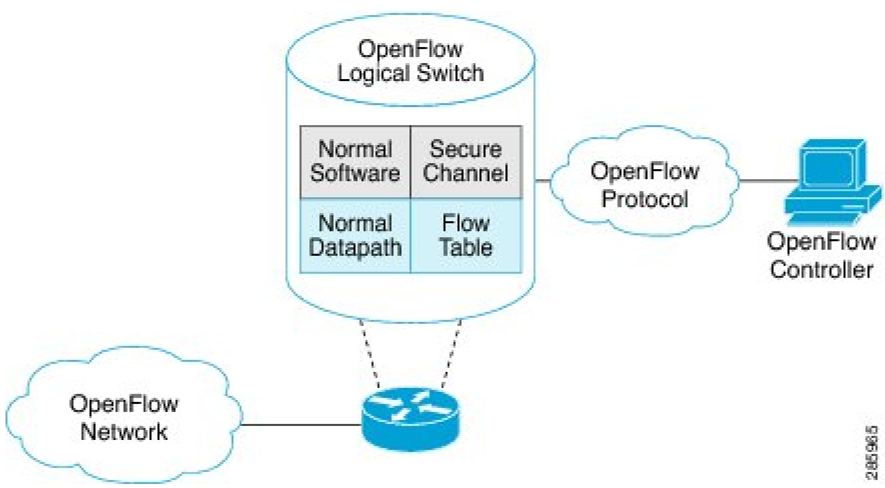
The OpenFlow protocol is based on the Ethernet switch model. It uses an internal flow table and a standardized interface to manage traffic flows by adding or removing flow entries. OpenFlow defines the communication channel between the OpenFlow Agent on the switch and the OpenFlow controller on an external server. All network management functions are either integrated into the controller or performed through it.

A physical switch can be segmented into multiple logical switches. This segmentation is configured using the CLI, where each logical switch is associated with a specific controller connection and a set of enabled interfaces. The OpenFlow Agent software manages these logical switches and facilitates communication with the controller.

Note The OpenFlow Agent resides on the switch and is responsible for managing flow entries and interfacing with the controller.

The following figure illustrates the Cisco OpenFlow network architecture:

Figure 1: OpenFlow network architecture



Key Elements in the Cisco OpenFlow Architecture Diagram

1. OpenFlow Controller (External Server)
   - Resides outside the switch.
   - Manages flow entries and network behavior.
   - Communicates with the OpenFlow Agent via a secure channel.

2. OpenFlow Agent (On the Switch)
   - Embedded in the switch OS.
   - Interfaces with the controller to receive flow instructions.
   - Manages flow tables and applies actions to packets.

3. Logical Switches
    - A single physical switch is divided into multiple logical switches.
    - Each logical switch is configured via CLI and associated with a specific controller.
    - Interfaces are assigned to logical switches for traffic segmentation.
4. Flow Tables
    - Contain match-action rules.
    - Define how packets are processed (e.g., forward, drop, modify headers).
5. Secure Channel
    - TLS or TCP-based communication between the controller and the agent.
    - Ensures secure and reliable control traffic.
6. Data Plane vs. Control Plane
    - The data plane handles packet forwarding based on flow table rules.
    - The control plane (controller) makes high-level routing decisions.

This architecture enables centralized control and programmable network behavior, which is a core principle of Software Defined Networking (SDN).

Note Openflow for the Cisco ASR 9000 Series router functions in the Integrated Hybrid mode. In this mode, both Openflow and normal switching and routing (for layer 3) operations such as L2 ethernet switching, L3 routing, etc are supported. Packets processed as the Openflow forwarding path can be processed as a normal forwarding path.

OpenFlow table types

An OpenFlow flow table is a structured collection of flow entries, where each entry defines specific match criteria and associated actions to be performed on matching packets. The capabilities of a flow table are determined by the types of match fields and actions it supports, which may vary depending on the switch implementation.

Flow tables operate exclusively in the ingress direction, meaning they are applied only to incoming traffic. This behavior is analogous to how a policy-map is applied in traditional networking. As such, OpenFlow matches and actions are evaluated and executed solely on packets as they enter the switch.

In OpenFlow, a pipeline refers to a sequence of one or more flow tables arranged in a specific order. Each packet entering the switch is processed through this ordered set of tables according to defined pipeline rules.

On the ASR 9000 (ASR9K) platform, the OpenFlow pipeline is limited to a **single flow table**. This means that all packet matching and action execution must occur within that single table, without the ability to chain multiple tables as in more complex OpenFlow implementations.

Table 1: OpenFlow Table Types

Table Type	Pipeline	Supported Interfaces	Description
L2	129	Bridge-domain, Gigabit ethernet, Bundle, Bundle-subinterfaces, PWHE-subinterfaces	• Supports L2 header matches. • Supports L2 actions. • Can be applied to the ingress L2 interfaces.
L2_L3	130	Bridge-domain, Gigabit ethernet, Bundle, Bundle-subinterfaces, PWHE-subinterfaces	• Supports L2 and L3 (IPv4/IPv6) header matches. • Supports L2 actions. • Can be applied to the ingress L2 interfaces.
L3_V4	131	VRF and global interfaces, BVI (ipv4 only), Bridge-domain, Gigabit ethernet, Bundle, Bundle-subinterfaces	• Supports L3 (IPv4) header matches. • Supports L3 (IPv4) actions. • Can be applied to the ingress L3 interfaces.
L3_DS	132	VRF and global interfaces, BVI, Bridge-domain, Gigabit ethernet, Bundle, Bundle-subinterfaces	• Supports L2 and L3 (IPv4/IPv6) header matches. • Supports L3 (IPv4/IPv6) actions. • Can be applied to the ingress L3 interfaces.

Packet-In and Packet-Out Feature

The **Packet-In and Packet-Out** feature enables communication between the OpenFlow Agent (logical switch) and the OpenFlow Controller. This mechanism allows the agent to forward specific packets to the controller for processing or decision-making.

To achieve this, the flow entry is programmed with a special output action that uses the `OFP_CONTROLLER` port. When a packet matches such a flow, it is sent directly to the controller.

Additionally, this feature supports the standard **OpenFlow output-to-port** action. This action instructs the OpenFlow Agent to forward all packets matching a given flow to a designated physical or logical port on the switch.

On-Demand Analytics with OpenFlow and NetFlow

Applications can be provided with on-demand analytics by using the OpenFlow protocol with NetFlow. NetFlow provides statistics on packets flowing through the router, and is the standard for acquiring IP operational data from IP networks.

The following NetFlow maps must be configured:

- Flow Exporter Map—Specifies the destination IP address of the NetFlow collector where the NetFlow Version 9 packets are sent.
- Flow Monitor Map—Specifies the profile of the NetFlow producer, including the timeout values of active and inactive timers, size of the NetfFow cache and the exporter to be used.
- Sampler Map—Specifies how often Network Processor (NPU) needs to sample incoming and outgoing packets and create flow-packets to punt to the Line Card (LC) Central Processing Unit (CPU).

The following parameters must be specified on the OpenFlow Agent logical switch:

- Interface associated with the OpenFlow Agent logical switch that is enabled for NetFlow.
- Flow Monitor Map
- Sampler Map
- Controller IP address

OpenFlow can be integrated with **NetFlow** to provide applications with on-demand traffic analytics. NetFlow is a widely adopted protocol for collecting IP traffic statistics, offering detailed insights into packets traversing the router.

Enable NetFlow based analytics

To enable NetFlow-based analytics, the following NetFlow maps must be configured:

- Flow Exporter Map: Defines the destination IP address of the NetFlow collector where NetFlow Version 9 packets are exported.
- Flow Monitor Map: Specifies the characteristics of the NetFlow producer, including
  - active and inactive timeout values,
  - NetFlow cache size, and
  - associated Flow Exporter Map
- Sampler Map: Determines the sampling rate for the Network Processor (NPU), indicating how frequently packets (incoming and outgoing) are sampled and forwarded to the Line Card (LC) CPU for flow creation.

OpenFlow Agent configuration requirements

The following parameters must be specified on the OpenFlow Agent logical switch to enable NetFlow integration.

- The **interface** associated with the OpenFlow Agent logical switch that is enabled for NetFlow
- The configured **Flow Monitor Map**

- The configured **Sampler Map**
- The **Controller IP address**

OpenFlow Agent (OFA) on Cisco routers and switches

OpenFlow Software-Defined Networking (SDN) applications rely on network elements that support the standard OpenFlow protocol and implement the OpenFlow switch model. On Cisco platforms, the **OpenFlow Agent (OFA)** operates as a local process that enables this functionality by providing the following capabilities:

Key Features of the OpenFlow Agent

- OpenFlow Protocol Stack: Implements the standard OpenFlow protocol for communication with SDN controllers.
- OpenFlow Switch Model: Abstracted from Cisco's diverse hardware and software platforms.
- Version and Feature Negotiation: Supports dynamic negotiation of OpenFlow versions and capabilities with controllers.
- Local State and Statistics Aggregation: Collects and maintains flow and interface statistics locally.
- Native CLI and Troubleshooting Tools: Offers dedicated command-line interface support for configuration and diagnostics.
- High Availability: Designed for resilient operation in high-availability environments.

Functional components

The OpenFlow Agent supports the configuration of **multiple controllers** per logical switch. It can establish connections with up to **eight controllers** simultaneously, providing them access to the logical switch's flow tables and interfaces. The agent receives flow entries from the controllers and reports flow and interface statistics back to them.

For **Layer 3 match conditions**, Cisco extends the OpenFlow 1.0 and 1.3 protocols with a proprietary **set-nexthop** action to enable routing functionality.

OpenFlow Agent on Cisco ASR 9000 series routers

On the Cisco ASR 9000 platform, the OpenFlow Agent supports **multiple logical switch instances**. Each logical switch can manage

- a set of physical or logical interfaces,
- a Layer 2 bridge domain, or
- a Virtual Routing and Forwarding (VRF) instance

Each logical switch can establish

- a single OpenFlow connection to one controller, or
- multiple connections to different controllers for redundancy

Connections to controllers use either **plain TCP** or **TLS** for secure communication.

Controller connection behavior

When a logical switch initiates a connection to a configured controller, the OpenFlow version is negotiated based on the supported version bitmap on both the agent and the controller.

If a logical switch starts for the first time or loses connectivity with all controllers, it enters one of the following modes based on configuration:

- Fail-Secure Mode *(default)*: Continues forwarding based on a predefined default rule.
- Fail-Standalone Mode: Operates independently without controller input. This mode is enabled or disabled via CLI using the `fail-standalone` option.

OpenFlow matches

Matches are supported on ingress port and various packet headers depending upon the packet type. Flows can have priorities. Hence, the highest priority flow entry that matches the packet gets selected.

Following table shows the list of matches supported for various table types on Cisco ASR 9000 series routers

OpenFlow Matches		**OpenFlow Switch Types Supported on ASR9K**			
		Applied to L2 Bridge domain		**Applied to L3 or L3 VRF interface**	
OXM Flow match field type for OpenFlow basic class	**Description**	**L2 only**	**L2_L3**	**L3_V4**	**L3_DS**
OFPXMT_OFB_IN_PORT	Switch input port	Yes	Yes	Yes	Yes
OFPXMT_OFB_IN_PHY_PORT	Switch physical port	No	No	No	No
OFPXMT_OFB_METADATA	Metadata passed between tables	No	No	No	No
OFPXMT_OFB_ETH_DST	Ethernet destination address	Yes	Yes	No	Yes
OFPXMT_OFB_ETH_SRC	Ethernet source address	Yes	Yes	No	Yes
OFPXMT_OFB_ETH_TYPE	Ethernet frame type	Yes	Yes	No	Yes
OFPXMT_OFB_VLAN_VID	VLAN ID	Yes	Yes	No	Yes
OFPXMT_OFB_VLAN_PCP	VLAN priority	Yes	Yes	No	Yes
OFPXMT_OFB_IP_DSCP	IP DSCP (6 bits in ToS field)	No	Yes	Yes	Yes

OpenFlow Matches		OpenFlow Switch Types Supported on ASR9K			
		Applied to L2 Bridge domain		Applied to L3 or L3 VRF interface	
OFPXMT_OFB_IP_ECN	IP ECN (2 bits in ToS field)	No	No	No	No
OFPXMT_OFB_IP_PROTO	IP protocol	No	Yes	Yes	Yes
OFPXMT_OFB_IPV4_SRC	IPv4 source address	No	Yes	Yes	Yes
OFPXMT_OFB_IPV4_DST	IPv4 destination address	No	Yes	Yes	Yes
OFPXMT_OFB_TCP_SRC	TCP source port	No	Yes	Yes	Yes
OFPXMT_OFB_TCP_DST	TCP destination port	No	Yes	Yes	Yes
OFPXMT_OFB_UDP_SRC	UDP source port	No	Yes	Yes	Yes
OFPXMT_OFB_UDP_DST	UDP destination port	No	Yes	Yes	Yes
OFPXMT_OFB_SCTP_SRC	SCTP source port	No	Yes	Yes	Yes
OFPXMT_OFB_SCTP_DST	SCTP destination port	No	No	No	No
OFPXMT_OFB_ICMPV4_TYPE	ICMP type	No	No	No	No
OFPXMT_OFB_ICMPV4_CODE	ICMP code	No	No	No	No
OFPXMT_OFB_ARP_OP	ARP opcode	No	No	No	No
OFPXMT_OFB_ARP_SPA	ARP source IPv4 address	No	No	No	No
OFPXMT_OFB_ARP_TPA	ARP target IPv4 address	No	No	No	No
OFPXMT_OFB_ARP_SHA	ARP source hardware address	No	No	No	No
OFPXMT_OFB_ARP_THA	ARP target hardware address	No	No	No	No
OFPXMT_OFB_IPV6_SRC	IPv6 source address	No	Yes	No	Yes

OpenFlow Matches		OpenFlow Switch Types Supported on ASR9K			
		Applied to L2 Bridge domain		Applied to L3 or L3 VRF interface	
OFPXMT_OFB_IPV6_DST	IPv6 destination address	No	Yes	No	Yes
OFPXMT_OFB_IPV6_FLABEL	IPv6 Flow Label	No	No	No	No
OFPXMT_OFB_ICMPV6_TYPE	ICMPv6 type	No	No	No	No
OFPXMT_OFB_ICMPV6_CODE	ICMPv6 code	No	No	No	No
OFPXMT_OFB_IPV6_ND_TARGET	Target address for ND	No	No	No	No
OFPXMT_OFB_IPV6_ND_SLL	Source link-layer for ND	No	No	No	No
OFPXMT_OFB_IPV6_ND_TLL	Target link-layer for ND	No	No	No	No
OFPXMT_OFB_MPLS_LABEL	MPLS label	No	No	No	No
OFPXMT_OFB_MPLS_TC	MPLS TC	No	No	No	No
OFPXMT_OFP_MPLS_BOS	MPLS BoS bit	No	No	No	No
OFPXMT_OFB_PBB_ISID	PBB I-SID	No	No	No	No
OFPXMT_OFB_TUNNEL_ID	Logical Port Metadata	No	No	No	No
OFPXMT_OFB_IPV6_EXTHDR	IPv6 Extension Header pseudo-field	No	No	No	No

OpenFlow actions

Packet forwarding and packet modification types of actions are supported. The lists of actions are always immediately applied to the packet.

Note

- Only “Apply-actions” instruction (OFPIT_APPLY_ACTIONS) of OpenFlow 1.3 is supported.
- Pipeline processing instructions that allow packets to be sent to subsequent tables for further processing are not supported in this release.
- Group tables and Meter tables are not supported.

Following table shows the list of action types supported for various table types on Cisco ASR 9000 series routers

OpenFlow Actions		**OpenFlow Switch Types Supported on ASR9K**			
		Applied to L2 Bridge domain		**Applied to L3 or L3 VRF interface**	
OXM Flow action field type for OpenFlow basic class	**Description**	**L2 only**	**L2_L3**	**L3_V4**	**L3_DS**
OFPAT_OUTPUT	Output to switch port.	Yes	Yes	No	No
OFPAT_COPY_TTL_OUT	Copy TTL "outwards"	No	No	No	No
OFPAT_COPY_TTL_IN	Copy TTL "inwards"	No	No	No	No
OFPAT_SET_MPLS_TTL	MPLS TTL	No	No	No	No
OFPAT_DEC_MPLS_TTL	Decrement MPLS TTL	No	No	No	No
OFPAT_PUSH_VLAN	Push a new VLAN tag	Yes	Yes	No	No
OFPAT_POP_VLAN	Pop the outer VLAN tag	Yes	Yes	No	No
OFPAT_PUSH_MPLS	Push a new MPLS tag	No	No	No	No
OFPAT_POP_MPLS	Pop the outer MPLS tag	No	No	No	No
OFPAT_SET_QUEUE	Set queue id when outputting to a port	No	No	No	No
OFPAT_GROUP	Apply group	No	No	No	No
OFPAT_SET_NW_TTL	IP TTL	No	No	No	No
OFPAT_DEC_NW_TTL	Decrement IP TTL	No	No	No	No
OFPAT_SET_FIELD	Set a header field using OXM TLV format	Yes	Yes	Yes	Yes
OFPAT_PUSH_PBB	Push a new PBB service tag (I-TAG)	No	No	No	No

OpenFlow Actions		OpenFlow Switch Types Supported on ASR9K			
		Applied to L2 Bridge domain		Applied to L3 or L3 VRF interface	
OFPAT_POP_PBB	Pop the outer PBB service tag	No	No	No	No

Cisco extension actions

The set ipv4 or set ipv6 nexthop actions are used to redirect an ipv4 or ipv6 packet to the specified nexthop address, instead of using the destination address in the packet. This provides ABF (ACL Based Forwarding) kind of functionality using OpenFlow. However, VRF support and nexthop tracking as supported by CLI based ABF feature is not supported in this release.

The set fcid (Forward Class ID) action can be used to support PBTS (Policy Based Tunnel Selection) functionality using OpenFlow.

Following table shows the list of actions added by Cisco to support some extra features on Cisco ASR 9000 series routers.

Cisco proprietary actions		OpenFlow Switch Types Supported on ASR9K			
		Applied to L2 Bridge domain		Applied to L3 or L3 VRF interface	
OXM Flow match field type for OpenFlow basic class	**Description**	**L2 only**	**L2_L3**	**L3_V4**	**L3_DS**
Set Ipv4 Nexthop	Set ipv4 nexthop address	No	No	Yes	Yes
Set Ipv6 Nexthop	Set ipv6 nexthop address	No	No	No	Yes
Set Forward Class ID	Set forward class ID	No	No	Yes	Yes

Set Field Actions

This table lists the set field actions supported by the Cisco ASR 9000 series router:

OpenFlow Matches		OpenFlow Switch Types Supported on ASR9K			
		Applied to L2 Bridge domain		Applied to L3 or L3 VRF interface	
OXM Flow match field type for OpenFlow basic class	**Description**	**L2 only**	**L2_L3**	**L3_V4**	**L3_DS**
OFPXMT_OFB_ETH_DST	Ethernet destination address	Yes	Yes	No	No

OpenFlow Matches		OpenFlow Switch Types Supported on ASR9K			
		Applied to L2 Bridge domain		Applied to L3 or L3 VRF interface	
OFPXMT_OFB_ETH_SRC	Ethernet source address	Yes	Yes	No	No
OFPXMT_OFB_ETH_TYPE	Ethernet frame type	No	No	No	No
OFPXMT_OFB_VLAN_VID	VLAN ID	Yes	Yes	No	No
OFPXMT_OFB_VLAN_PCP	VLAN priority	Yes	Yes	No	No
OFPXMT_OFB_IP_DSCP	IP DSCP (6 bits in ToS field)	No	No	Yes	Yes
OFPXMT_OFB_IP_ECN	IP ECN (2 bits in ToS field)	No	No	No	No
OFPXMT_OFB_IP_PROTO	IP protocol	No	No	No	No
OFPXMT_OFB_IPV4_SRC	IPv4 source address	No	No	Yes	Yes
OFPXMT_OFB_IPV4_DST	IPv4 destination address	No	No	Yes	Yes
OFPXMT_OFB_TCP_SRC	TCP source port	No	No	Yes	Yes
OFPXMT_OFB_TCP_DST	TCP destination port	No	No	Yes	Yes
OFPXMT_OFB_UDP_SRC	UDP source port	No	No	Yes	Yes
OFPXMT_OFB_UDP_DST	UDP destination port	No	No	Yes	Yes
OFPXMT_OFB_SCTP_SRC	SCTP source port	No	No	No	No
OFPXMT_OFB_SCTP_DST	SCTP destination port	No	No	No	No
OFPXMT_OFB_ICMPV4_TYPE	ICMP type	No	No	No	No
OFPXMT_OFB_ICMPV4_CODE	ICMP code	No	No	No	No
OFPXMT_OFB_ARP_OP	ARP opcode	No	No	No	No

OpenFlow Matches		OpenFlow Switch Types Supported on ASR9K			
		Applied to L2 Bridge domain		Applied to L3 or L3 VRF interface	
OFPXMT_OFB_ARP_SPA	ARP source IPv4 address	No	No	No	No
OFPXMT_OFB_ARP_TPA	ARP target IPv4 address	No	No	No	No
OFPXMT_OFB_ARP_SHA	ARP source hardware address	No	No	No	No
OFPXMT_OFB_ARP_THA	ARP target hardware address	No	No	No	No
OFPXMT_OFB_IPV6_SRC	IPv6 source address	No	No	No	No
OFPXMT_OFB_IPV6_DST	IPv6 destination address	No	No	No	No
OFPXMT_OFB_IPV6_FLABEL	IPv6 Flow Label	No	No	No	No
OFPXMT_OFB_ICMPV6_TYPE	ICMPv6 type	No	No	No	No
OFPXMT_OFB_ICMPV6_CODE	ICMPv6 code	No	No	No	No
OFPXMT_OFB_IPV6_ND_TARGET	Target address for ND	No	No	No	No
OFPXMT_OFB_IPV6_ND_SLL	Source link-layer for ND	No	No	No	No
OFPXMT_OFB_IPV6_ND_TLL	Target link-layer for ND	No	No	No	No
OFPXMT_OFB_MPLS_LABEL	MPLS label	No	No	No	No
OFPXMT_OFB_MPLS_TC	MPLS TC	No	No	No	No
OFPXMT_OFP_MPLS_BOS	MPLS BoS bit	No	No	No	No
OFPXMT_OFB_PBB_ISID	PBB I-SID	No	No	No	No
OFPXMT_OFB_TUNNEL_ID	Logical Port Metadata	No	No	No	No
OFPXMT_OFB_IPV6_EXTHDR	IPv6 Extension Header pseudo-field	No	No	No	No

Configure OneP for OpenFlow

Purpose of this task is to configure OneP (One Platform Kit) for OpenFlow.

Before you begin

- To configure OneP (One Platform Kit) for OpenFlow, it's important to note that OnePK support was discontinued starting with Cisco IOS XR Release 5.3.4. Therefore, OneP is no longer used or supported for OpenFlow configuration.
- Instead, you can configure OpenFlow directly through the **OpenFlow Agent (OFA)** using native CLI commands. This includes setting up logical switches, controller connections, flow tables, and optionally integrating with NetFlow for analytics.

Procedure

Run the onep command to enter the OneP configuration submode. This is where you define the parameters related to the One Platform Kit, which provides APIs for external applications to interact with the router.

Example:

```
Router# configure
Router(config)# onep
Router(config-onep)# datapath transport vpathudp sender-id 1001
Router(config-onep)# commit
```

Configure a Layer 2 logical switch for the OpenFlow Agent

The purpose of this task is to enable Software-Defined Networking (SDN) control over Layer 2 (Ethernet) traffic flows.

Procedure

Run the following command to enter the logical switch configuration mode. For L2-only switch, the pipeline number is 129.

Example:

```
Router# configure
Router(config)# openflow
Router(config-openflow)#  switch 1 pipeline 129
Router(config-openflow-switch)# tls trust-point local tp1 remote tp2
Router (config-openflow) # bridge-group SDN-1 bridge-domain of2
Router(config-openflow-switch)# controller ipv4 5.0.1.1 port 6633 security tls
Router(logical-switch)# commit
```

Configure Layer 2_Layer 3 logical switch for the OpenFlow Agent

The purpose of this task is to enable centralized control and dynamic routing of both Layer 2 (switching) and Layer 3 (routing) traffic by allowing the OpenFlow controller to manage a unified logical switch.

Procedure

Step 1 Run the following command to configure Layer 2_Layer 3 logical switch for the OpenFlow Agent

Example:

```
Router# configure
Router(config)# openflow
Router(config-openflow)#  switch 1 pipeline 129
Router(config-openflow-switch)# tls trust-point local tp1 remote tp2
Router (config-openflow) # bridge-group SDN-1 bridge-domain of2
Router(config-openflow-switch)# controller ipv4 5.0.1.1 port 6633 security tls
Router(logical-switch)# commit
```

Step 2 Repeat to configure another logical switch for the OpenFlow Agent.

Configure a Layer 3_VRF logical switch

The purpose of this task is to configure a Layer 3 VRF logical switch to enable the OpenFlow Agent to centrally manage routing and traffic segmentation across virtual routing instances.

Procedure

Step 1 Run the following command to configure a Layer 3_VRF logical switch

Example:

```
Router# configure
Router(config)# openflow
Router(config-openflow)#  switch 1 pipeline 131
Router(config)# vrf IPv4
Router(config-openflow-switch)# tls trust-point local tp1 remote tp2
Router(config-openflow-switch)# controller ipv4 5.0.1.1 port 6633 security tls
Router(logical-switch)# commit
```

Step 2 Repeat to configure another logical switch.

Configure a Layer 3_dual-stack logical switch for the OpenFlow Agent

The purpose of this task is to configure a Layer 3 dual-stack logical switch to enable the OpenFlow agent to centrally manage both IPv4 and IPv6 routing within a unified virtual network environment.

Procedure

Step 1 Run the following commands to configure a Layer 3_dual-stack logical switch

Example:

```
Router# configure
Router(config)# openflow
Router(config-openflow)#  switch 1 pipeline 132
Router(config-openflow)#  interface Bundle-Ether2.1
Router(config-openflow-switch)# tls trust-point local tp1 remote tp2
Router (config-openflow) # bridge-group SDN-1 bridge-domain of2
Router(config-openflow-switch)# controller ipv4 5.0.1.1 port 6633 security tls
Router(logical-switch)# commit
```

Step 2 Repeat these steps to configure another logical switch for the OpenFlow Agent.

Enable Transport Layer Security (TSL)

The purpose of this task is to enable Transport Layer Security (TLS) to ensure secure, encrypted communication between network components, protecting data integrity and confidentiality.

Procedure

Run the following commands to enable TLS

Example:

```
Router# configure
Router(config)# openflow switch 100
Router(config-openflow-switch)# tls trust-point local tp1 remote tp2
Router(config-openflow-switch)# commit
```

Configure NetFlow for the OpenFlow Agent

The purpose of this task is to configure NetFlow for the OpenFlow Agent to enable detailed traffic monitoring and flow analysis for enhanced network visibility and performance management.

Procedure

Run the following commands to configure NetFlow for the OpenFlow Agent

Example:

```
Router# configure
Router(config)# flow exporter-map fem
Router(config-fem)# destination 10.0.1.2
Router(config-fem)# version v9
Router(config-fem-ver)# commit
Router(config-fem-ver)# exit
Router(config)# flow monitor-map mmap
Router(config-fmm)# record ipv4
Router(config-fmm)# exporter fmap
Router(config-fmm)# cache entries 4096
Router(config-fmm)# cache timeout active 10
Router(config-fmm)# commit
Router(config-fmm)# exit
Router(config)# sampler-map
Router(config-sm)# random 1 out-of 65535
Router(config-sm)# commit
Router(config-sm)# exit
```

Configuration Examples: Openflow

The purpose of the task is to view the configuration examples of OpenFlow.

Procedure

Step 1 Attaching a bridge domain to an Openflow Switch: Examples

Example:

```
Attaching a L2-only Openflow switch
openflow
switch 1 pipeline 129
  tls trust-point local tp1 remote tp1
  bridge-group SDN-2 bridge-domain OF-2
  controller ipv4 5.0.1.200 port 6653 security tls\


Attaching a L2_L3 Openflow switch
openflow
```

```
switch 1 pipeline 130
  tls trust-point local tp1 remote tp1
  bridge-group SDN-2 bridge-domain OF-2
  controller ipv4 5.0.1.200 port 6653 security tls
```

L3_V4 switch can be attached either to a VRF or directly to layer 3 interfaces under global VRF. In case of VRF, all the interfaces in that VRF become part of the OpenFlow switch.

```
openflow
switch l1 pipeline 131
  vrf IPv4
  controller ipv4 5.0.1.200 port 6653 security none
 !
```

L3_DS switch can be attached either to a VRF or directly to layer 3 interfaces under global VRF.

```
openflow
switch l2 pipeline 132
  vrf IPv4
  controller ipv4 5.0.1.200 port 6653 security none
 !
```

Step 2 OpenFlow Agent with NetFlow Collection and Analytics Configuration: Example

Example:

The following example describes the NetFlow exporter map configuration for the OpenFlow logical switch.

```
Device> enable
Device# configure terminal
Device(config)# flow exporter-map fem
Device(config-fem)# destination 10.0.1.2
Device(config-fem)# version v9
Device(config-fem-ver)# commit
Device(config-fem-ver)# exit
```

The following example describes the NetFlow monitor map configuration for the OpenFlow logical switch.

```
Device(config)# flow monitor-map mmap
Device(config-fmm)# record ipv4
Device(config-fmm)# exporter fmap
Device(config-fmm)# cache entries 4096
Device(config-fmm)# commit
Device(config-fmm)# exit
```

The following example describes the NetFlow sampler map configuration for the OpenFlow logical switch.

```
Device(config)# sampler-map
Device(config-sm)# random 1 out-of 65535
Device(config-sm)# commit
Device(config-sm)# exit
```

The following example describes how the OpenFlow Agent logical switch is configured so that the NetFlow collection and analytics are associated with it.

```
Device(config)# openflow switch 100 netflow
Device(logical-switch)# flow monitor mmap sampler smap
Device(logical-switch)# interface GigabitEthernet0/1/0/6
Router(logical-switch)# controller 10.0.1.2 port 6633
Device(logical-switch)# commit
Device(logical-switch)# end
```

The following example describes **show** command output for an OpenFlow Agent logical switch that is configured with NetFlow collection and analytics.

```
Device# show openflow switch 100
Fri Jan 25 14:29:21.078 UTC
```

```
Logical Switch Context
         Id:                     100
         Switch type:            Netflow
         Layer:                  NONE
         Signal version:         Openflow 1.0
         Data plane:             secure
         Fallback:               normal
         Config state:           no-shutdown
         Working state:          enabled
         TLS version:            NONE
         TLS private key:        none:none
         TLS private key file:   NONE
         TLS certificate file:   NONE
         Controller:             10.0.1.2:6633, last alive ping: 2013-01-25 14:29:20
         Netflow Monitor:        mmap
         Netflow Sampler:        smap
         Loopback i/f:           <none>
         Loopback addr:          <none>
         Interfaces:
                GigabitEthernet0/1/0/6

Device# show openflow switch 100 flows
Fri Jan 25 14:29:24.787 UTC

Logical Openflow Switch [100]:
NXST_FLOW reply (xid=0x0):
cookie=0x0, duration=204.729s, table=0, n_packets=0, n_bytes=0, priority=500 actions=netflow

Switch flow count: 1

Device# show openflow switch 100 controllers
Fri Jan 25 14:29:28.660 UTC

Logical Openflow Switch [100]:
        Controller [tcp:10.0.1.2:6633]
           role                 :  Other
           connected            :  Yes
           state                :  ACTIVE
           sec_since_connect    :  487
```

Step 3 **Usecase for Layer2**

- The Scenario: Enterprise Data Center needs to perform data backup to multiple other backup sites based on the Traffic flow. The Main DC is in Vlan 100 and Backup sites are at VLAN 1000,1001,1002. These Sites are interconnected through L2VPN.
- The Solution: Openflow, we can match any Layer 2 header field (in this example we have taken priority bits) and steer the traffic to go on any L2 interconnect and also rewrite the VLANs appropriately.

Step 4 **Usecase for Layer3**

- The Scenario: Three different flows from 3 different sites connected to PE1 are trying to send 350 mbps of traffic each to PE2. The bandwidth of the shortest link, Path-2 (between PE1 and PE2) is only 1 Gigabit. Hence Path-2 gets congested as soon as the third site begins to send traffic.
- The Solution: Openflow controller can be used to install rules on PE1:
  - Match on Flow 1 (destined to Video server) and redirect traffic to Path-2
  - Match on Flow 2 (destined to Web server) and redirect traffic to Path-1

    - Match on Flow 3 (destined to File transfer server) and redirect traffic to Path-3

- The Inference: Effectively utilizing the network bandwidth by redirecting destination specific traffic using OpenFlow rules.