Black Book

íxía

Edition 10

SDN/OpenFlow

Your feedback is welcome

Our goal in the preparation of this Black Book was to create high-value, high-quality content. Your feedback is an important ingredient that will help guide our future books.

If you have any comments regarding how we can improve the quality of this book, or suggestions for topics to be included in future Black Books, please contact us at <u>ProductMgmtBooklets@ixiacom.com</u>.

Your feedback is greatly appreciated!

Copyright © 2014 Ixia. All rights reserved.

This publication may not be copied, in whole or in part, without Ixia's consent.

RESTRICTED RIGHTS LEGEND: Use, duplication, or disclosure by the U.S. Government is subject to the restrictions set forth in subparagraph (c)(1)(ii) of the Rights in Technical Data and Computer Software clause at DFARS 252.227-7013 and FAR 52.227-19.

Ixia, the Ixia logo, and all Ixia brand names and product names in this document are either trademarks or registered trademarks of Ixia in the United States and/or other countries. All other trademarks belong to their respective owners. The information herein is furnished for informational use only, is subject to change by Ixia without notice, and should not be construed as a commitment by Ixia. Ixia assumes no responsibility or liability for any errors or inaccuracies contained in this publication.

Contents

How to Read this Book	vii
Dear Reader	viii
Introduction – Software Defined Networking	1
OpenFlow	2
OpenFlow Basic	3
Test Case: OpenFlow Switch Setup and Functional Test	7
Test Case: OpenFlow Switch Forwarding Test	21
Test Case: Switch Flow Failover Performance Test	43
Test case: OpenFlow Controller Scalability Test	63
Test case: Packet_out Rate Calculation	75
Test Case: Bandwidth Rate Limiting and QoS validation	85
Contact Ixia	103

How to Read this Book

The book is structured as several standalone sections that discuss test methodologies by type. Every section starts by introducing the reader to relevant information from a technology and testing perspective.

Each test case has the following organization structure:

Overview	Provides background information specific to the test case.
Objective	Describes the goal of the test.
Setup	An illustration of the test configuration highlighting the test ports, simulated elements and other details.
Step-by-Step Instructions	Detailed configuration procedures using Ixia test equipment and applications.
Test Variables	A summary of the key test parameters that affect the test's performance and scale. These can be modified to construct other tests.
Results Analysis	Provides the background useful for test result analysis, explaining the metrics and providing examples of expected results.
Troubleshooting and Diagnostics	Provides guidance on how to troubleshoot common issues.
Conclusions	Summarizes the result of the test.

Typographic Conventions

In this document, the following conventions are used to indicate items that are selected or typed by you:

- **Bold** items are those that you select or click on. It is also used to indicate text found on the current GUI screen.
- *Italicized* items are those that you type.

Dear Reader

Ixia's Black Books include a number of IP and wireless test methodologies that will help you become familiar with new technologies and the key testing issues associated with them.

The Black Books can be considered primers on technology and testing. They include test methodologies that can be used to verify device and system functionality and performance. The methodologies are universally applicable to any test equipment. Step-by-step instructions using Ixia's test platform and applications are used to demonstrate the test methodology.

This tenth edition of the black books includes twenty two volumes covering key technologies and test methodologies:

Volume 1 – Higher Speed Ethernet	Volume 12 – IPv6 Transition Technologies
Volume 2 – QoS Validation	Volume 13 – Video over IP
Volume 3 – Advanced MPLS	Volume 14 – Network Security
Volume 4 – LTE Evolved Packet Core	Volume 15 – MPLS-TP
Volume 5 – Application Delivery	Volume 16 – Ultra Low Latency (ULL) Testing
Volume 6 – Voice over IP	Volume 17 – Impairments
Volume 7 – Converged Data Center	Volume 18 – LTE Access
Volume 8 – Test Automation	Volume 19 – 802.11ac Wi-Fi Benchmarking
Volume 9 – Converged Network Adapters	Volume 20 – SDN/OpenFlow
Volume 10 – Carrier Ethernet	Volume 21 – Network Convergence Testing
Volume 11 – Ethernet Synchronization	Volume 22 – Testing Contact Centers

A soft copy of each of the chapters of the books and the associated test configurations are available on Ixia's Black Book website at http://www.ixiacom.com/blackbook. Registration is required to access this section of the Web site.

At Ixia, we know that the networking industry is constantly moving; we aim to be your technology partner through these ebbs and flows. We hope this Black Book series provides valuable insight into the evolution of our industry as it applies to test and measurement. Keep testing hard.

Errol Ginsberg, Acting CEO

SDN/OpenFlow

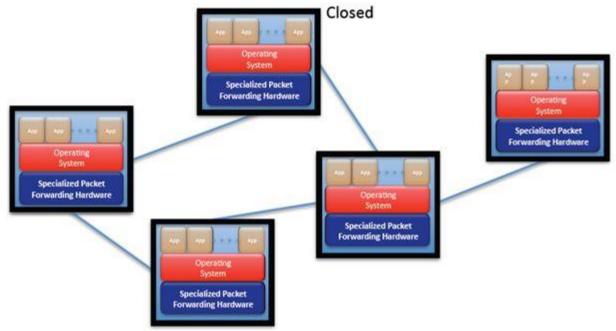
SDN/OpenFlow Test Methodologies

The tests in this booklet describe detailed methodologies to verify the functionalities and performance of SDN implementations including OpenFlow.

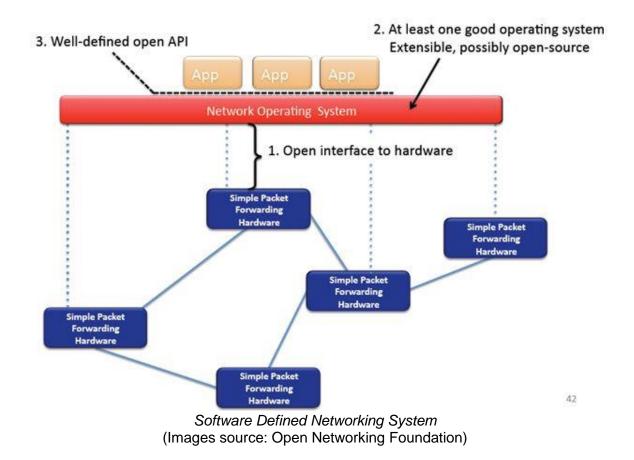
Introduction – Software Defined Networking

Most modern day network architectures rely on a traditional and conventional hierarchical organization, dependent on a tree-like structure of Ethernet switches and routers. Focusing solely on client-server computing, the network architectures fail to meet the needs of today's computing trends. With the changes in traffic patterns for increased accessibility and connectivity, the rising prominence of both private and public cloud services, and the immense parallel server processing necessary for mega datasets, it is imperative that the demand for higher network capacity is fulfilled.

By using software defined networking (SDN), it becomes possible to address these needs using a more dynamic and flexible networking architecture. SDN moves away from traditional architecture and to a revolutionary service delivery platform that can easily and readily address the changes in industry. With SDN, the control plane is accessed and modified using open protocols through software clients. By allowing third parties increased access to the control plane via software, SDN provides enterprises and carriers unparalleled programmability and network flexibility with rapid experimentation and optimization to address business needs.



Current Networking Systems



OpenFlow

OpenFlow is one such communication protocol that enables SDN. OpenFlow, the first standard interface communications protocol designed specifically for SDN, decouples the control- and data-planes so that software can determine the network packets passing through a network thereby customizing the needs of applications and its users. With the centralization of the control plane, it is possible to introduce and experiment with new capabilities in isolated slices of the network without affecting the rest of the network. This major change in network architecture offers its users a way to introduce new applications without the reliance upon individual device configuration and vendor releases.

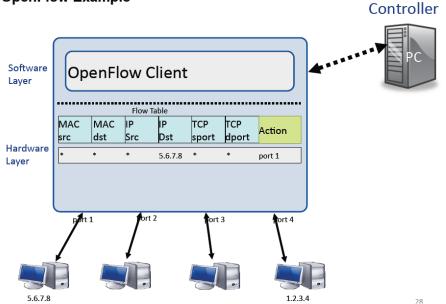
SDN via OpenFlow revolutionizes and expands the capabilities of networking architecture, providing key benefits for the ever-changing market. With rapid innovation and experimentation possible through software control, OpenFlow delivers the flexibility necessary to combat current and future network problems. Additionally, not only is there an increased choice regarding new applications but there is also an increased choice regarding vendor markets. The switch from a hardware-based to a software-based networking architecture creates open multivendor markets as the network operator can select different control- and data-plane vendors. The division of the planes increases network reliability and security, creating the potential to lower both CAPEX and OPEX costs while decreasing the complexity of networking hardware and network management.

OpenFlow Basic

OpenFlow defines two main device types; a controller and a switch. The OpenFlow controller talks to each OpenFlow switch over an IP connection (known as OF Channel) and has the ability to program the forwarding table of the switch with flow-table entries.

OpenFlow Controller							
DpenFlow Protocol (SSL/TCP)							
Control Path	OpenFlow						
Data Path (Hardware)							

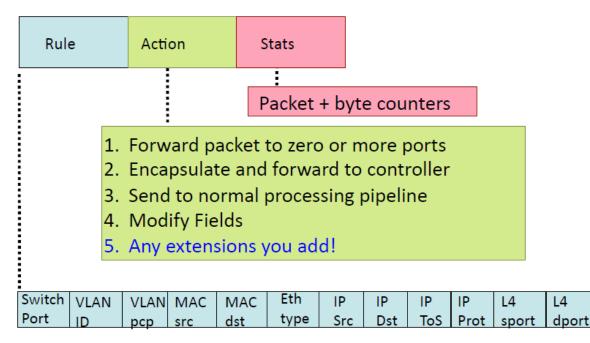
These Flow Table entries are called Flows. A Flow has set of match fields and related actions. A match fields define the packet match criteria for the switch. Match fields are various protocol fields such as L2 MAC address, L3 IP address, VLAN address, etc. For each set of Match, there is a corresponding Action associated with it. The action defines what the switch supposed to do when packets matches the Match criteria. An Action could set certain protocol fields such as VLAN address and/or forward the packet to a port. A port could be a physical port or it could be virtual port number to identify an operation such as flood.



OpenFlow Example

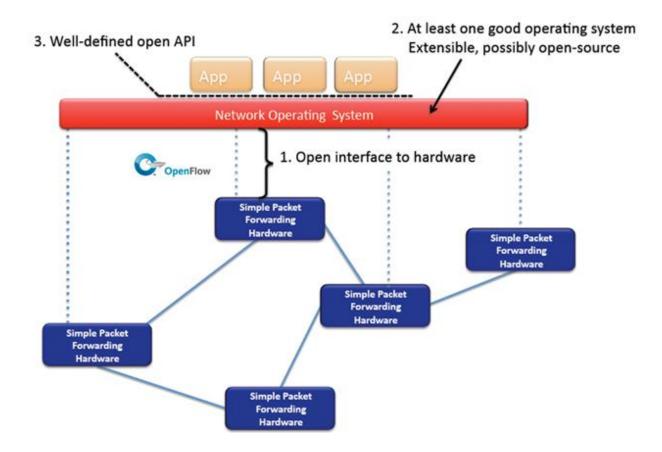
When a packet enters a switch, the switch performs match criteria on the packet by looking up its Flow Table. When a packet matches a Flow table entry, switch performs a corresponding match associated with that flow entry. Please note that not all the match fields need to be

defined. A wildcard is used to match for all the values for a certain match field. Along with match and action, a flow entry also has stats counter. The counters indicated the packet count for each flows.



+ mask what fields to match

The SDN applications run on top of the OpenFlow controller using a well-defined API, known as the north-bound API. Each controller vendor provides their own set of APIs. Applications can range from layer 2 or layer 3 learning networks to static provisioned networks and can be as simple or complicated as the requirements demand. New applications are being developed every day to address challenges in the data center, service provider WAN, enterprise, and other networks.



Test Case: OpenFlow Switch Setup and Functional Test

Overview

One of the most important aspects of OpenFlow protocol is to create OF Channel. OF Channel establishes connection between the controller and switch using TCP or TLS. After the TCP session is established, controller and switch exchanges an OFPT_Hello message. The version field in the message is set to the highest OpenFlow protocol version supported by the sender. After receiving the message, the recipient calculates the OpenFlow protocol version to be used. The lowest version that is sent and received successfully is used as the OpenFlow protocol version.

After version negotiation, the controller sends Features Request message and switch sends Features Reply message to advertise their capabilities. Then Echo Request and Echo Reply messages are exchanged to keep the OF Channel session alive between the controller and the switch.

Ladder diagram

The following diagram illustrates the message exchange between the switch and the controller.

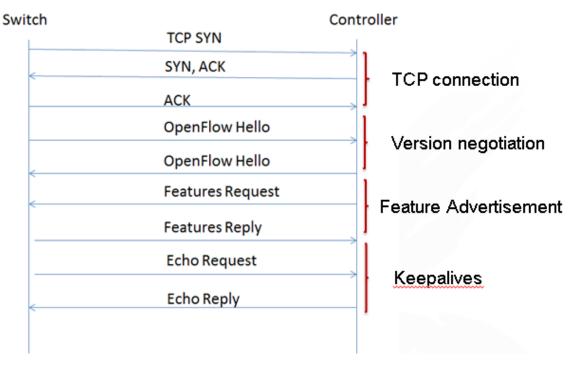


Figure 1: Message Exchange between Switch and Controller

Objective

The OpenFlow Switch Setup and Functional test verifies the functionality of OpenFlow switches. The test provides basic guidelines on how to configure OpenFlow controller, establish OF Channel, and retrieve switch capabilities using learned information. The test also trigger stat request using on demand message function and verifies that switch sends reply with requested information. At the end of the test, statistics are reviewed.

Setup

The following figure illustrates the test setup.

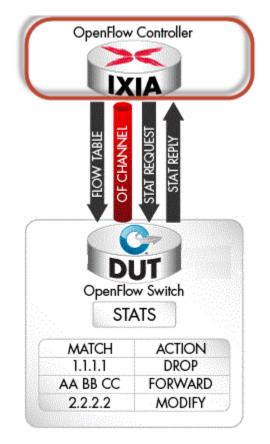


Figure 2: Test Setup – OpenFlow Switch Setup and Functional Test, test setup

Step-by-Step Instructions

The following steps describe the procedure for performing the test.

1. Reserve one Ixia port

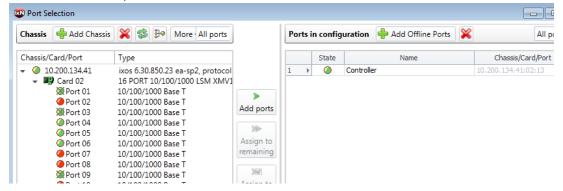


Figure 3: Port Selection window

2. Enable OpenFlow by selecting the **OpenFlow** check box in the **RoutingSwitching** tab in the **Protocols** window.

🔐 Overview		Protocols	t Carrier	Ethernet	Acc	ess Authentica	tion C	ata Center Bridgir	ng Wi	reless	
Chassis		Port Description	Port Owner	Link	ARP	PING for IPv4	BFD	BGP/BGP+	EIGRP	ISIS L2/L3	OpenFlow
Protocols Protocol Interfaces OpenFlow Static	1	Controller - 10/100/1000 Base	bNetwor	0							

Figure 4: Routing/Switching tab, Protocols window

 Configure the emulated controller IP address and Gateway address from the Connected Interface tab on the Protocol Interfaces window. Use the IP address of the OpenFlow switch if you have only one switch. For Of Channel, ensure that ARP is resolved.

	• ≽ 📿 • ⊚ 💭 • 🛄 🚺 mation Results / Reports		otocols Tools			IxNetwork [te	st_case_2.ixncfg]
Protocols • Protocol Interfaces Actions •	Send ARP Send NS Group ID Fing	fresh Add	🐈 Add Interface 🐈 Add Multiple Interfac 💥 Remove Interface		ld IPv4 move IPv4	Add IPv6	Add DHCP TLV
	Actions	Build				Edit	
Coverview Coverview	Connected Interfaces	Unconnected Interfaces Send Single ARP per	1 1	overed Neighbor ink Up 🔽 S			CPv4 Discovered Information Filter By Unresolved Interfa
Chassis	Port Des	. LINK	Interface Description		IPv4 Addre 10.0.x.x - Rese	erved IP) Wic	th Gateway
Protocol Interface		100/1000 Base 🔗	Connected - Protocolint	<u> </u>	10.1.1.2		24 10.1.1.1

Figure 5: Protocol Interfaces window

- 4. Define the port role by selecting the role from the **Port Role** list on the **Ports** tab on the **OpenFlow** window. You can select any of the following port roles:
 - a. Control: Ixia port will only act as a Controller.
 - b. Traffic: Ixia port will be used as traffic endpoints.
 - c. Control & In-Band Traffic: Ixia port will act as emulated controller as well as traffic endpoints (that is, in-band signaling).

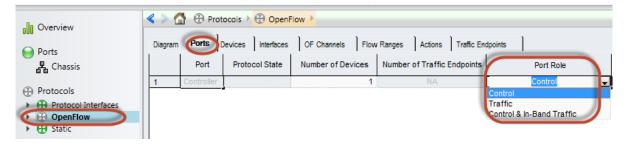


Figure 6: Ports tab, OpenFlow window

5. Configure the **Number of Interfaces** by going to the **Devices** tab on the **OpenFlow** window. The number of interfaces should be equal to the number of emulated NICs of a controller.

Protocols OpenFlow OpenFlow	Traffic roup ID	🖶 Add Device 💥 Remove Device(s)	Grid Operations •	
Actions	Grid			
 Overview Ports Chassis Protocols Protocol Interfaces OpenFlow Static 		cols CopenFlow C	nannels Flow Ranges Actions Traffic Endpoi Device Role Version Number of I Controller 1.0.0	



6. Go to the **Interface** tab of the **OpenFlow** window and assign the **Protocol Interfaces** that you created on the **Protocol Interface** window. This interface is used for the control-plane (OF Channel). Configure **Number of Channels** as *1*.

Overview	< > 🔂 🕀 Protocols > 🔁 OpenFlow >
OUU OVELVIEW	Diagram Ports Devices Interfaces OF Channels Flow Ranges Actio
🖌 😝 Ports	Diagram Pons Devices and deces OF Channels Flow Ranges Acto
🖧 Chassis	To change number of Interfaces, select 'Devices' tab, and enter number in 'Numbe
Protocols	Enable Protocol Interface Number of OF Channels
Protocol Interfaces Protocol Interfaces Protocol Interfaces	1 Connected - ProtocolInterface - 100:01 -
Gopennow Static	Connected - Protocolinterface - 100:01 - 4

Figure 8: Interfaces tab, OpenFlow window

Following are some of the important parameters available on the **Interface** tab of the **OpenFlow** window:

- Periodic Echo: Used to keep OF Channel session alive
- Mode of Connection: Used to indicate whether Ixia port initiates TCP connection. The available options are **Passive** and **Active**. **Passive** is selected by default and it indicates that the Ixia port will not initiate the TCP connection. Active indicates that the Ixia port will be used to initiate the TCP connection.
- **TCP Port**: Indicates the port is used to setup OF Channel. The default is 6633.

• Delete all Flow at Startup: Used to ensure that the switch does not have any pre-installed flow in its table. If this check box is selected, Ixia emulated controller will send Flow Delete message with all 12 Tuples set as wildcard (*) after the OF Channel is up. And the test starts with no pre-installed flows.

Devices	Interfaces	OF Channel	s Flow Ranges A	ctions										
To cha	nge number of In	terfaces, s	elect 'Devices' tab, ar	nd enter number in	'Number o	f Interfaces	' field							
	Device Description	Enable	Protocol Interface	Number of OF Channels	Periodic Echo	Echo Interval	Enable Echo Timeout	Timeout Option	Multiplier / Timeout Value	Type of Connection	Mode of Connection	Accept Unconfigured	TCP Port	Delete all Flows at Startup
1	Device-1 - Con	ঘ	Connected - Prot	1	ন	10	Г	Timeout	5,000	TCP	Passive	ঘ	6,633	ম

Figure 9: Interface tab, OpenFlow window parameters

7. Go to the OF Channels tab on the Controller window and enable OF Channel by selecting the Enable check box. Also, enter the DUT IP address in the Remote IP field. The IP address that you enter in the Remote IP field is the IP address of the OpenFlow switch.

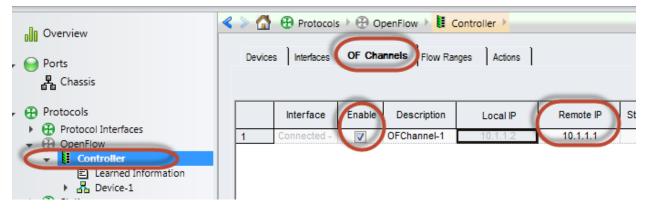


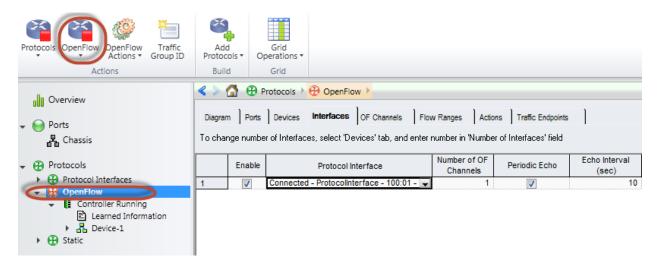
Figure 10: OF Channels tab, Controller window

8. Enable control capture by selecting the **Control Enable** check box on the **Captures** window. Also, start capture using the **Capture** control on the ribbon.

💷 📄 🗁 🖬 - 🤅	🗿 • 🖂 • 🍉 🖉 • (o 💭 🕶 🚺	- - -		Analyz	zer Tools	
File Home	Automation	Results / Rep	ports Vie	ws Debug	g Packet	Capture	
Capture File		ternal tt Viewer re	Grid Operations • Ports Grid	Merge Capture + Merge			
la oi	·	< > 🚮	★ Captures	•			0
🔐 Overview			ort ate	Port Name		Port Captures	Data - Control - Enable Enable
Chassis		1 > (Controller	1			
	v oller earned Information	Summary	Data Contro	ol All			
⇒⊄ Traffic		Captures	for port(s): C	ontroller			
			Capture Nar			Started	
Impairments		▶ ऄ	Controller -				12 17:10:25
🕁 QuickTests		2 24	Cond olier -	Condition		10/23/20	12 17:10:23
Captures	\supset						

Figure 11: Captures window

9. Start OpenFlow protocol from the **Protocols** control on the ribbon.





Results Analysis

The test results are available on the **OpenFlow Controller Aggregated Statistics** tab.

St	tat Name	Port Name	OF Channel Configured	OF Channel Configured Up	OF Channel Learned Up	OF Channel Flap Count	Hellos Tx	Hellos Rx	Echo Requests Tx	Echo Replies Rx	Echo Requests Rx	Echo Replies Tx	Feature Requests Tx	Feature Replies Rx
1 10	0.200.134.41/Card02/Port16	Controller	1	1	0	0	1	1	214	214	0	0) 1	1

Figure 13: OpenFlow Controller Aggregated Statistics tab

This Statistics tab shows detailed information on OpenFlow connection status, message exchange, error condition, and packet_ins.

OF Channel Configured	Displays number configured OF Channel
OF Channel Configured UP	This statistics displays status of the configured OF Channel
OF Channel Learned UP	By default Ixia emulated controller accepts OF Channel connection from a switch even if it is not configured. This statistics shows the un- configured OF Channel.
	Note: The Configure OF Channels option under Learned Information allows configuring the learned OF Channel.
OF Channel flap count	This statistics shows the number of times the TCP session is reset.
Hello Tx/Rx	This statistics displays hello message exchange.
Echo request Tx/Rx	This statistics displays echo message for the liveliness between the switch and controller.

You can verify the following statistics to analyze the OF Channel connection:

If the **OpenFlow Controller Aggregated Statistics** tab is not available, you need to enable it from the **Select Views** window.

To enable the **OpenFlow Controller Aggregated** Statistics tab, click **Select Views** and select **OpenFlow Controller Aggregated Statistics** check box as shown in the following figure.

tom View
,t

Figure 14: Select Views window

Go to **Capture Analyzer** and click on **Ladder Diagram** to verify message exchange between the controller and the switch.

Flow Summ	nary Ladder Dia	igram	1 ▷
Flow Sun 6 messag 2 endpoin this flow.	e(s) and	10.1.1.1:55260 OFP Endpoint	10.1.1.2:6633 OFP Endpoint
1	17:02:51.9	56371 📮 Hello (SM) (8B)
2	17:02:51.9	56541 🗧	Hello (SM) (8B)
3	17:02:52.1	61472	Features Request (CSM) (8B)
4	17:02:52.1	62609 Ģ-Features	Reply (CSM) (272B)
5	17:03:01.9	66368 🔶 🗕	Echo Request (SM) (8B)
6	17:03:01.9	67 27 5 🛱 📥 Echo Rep	ly (SM) (8B)

Figure 15: Capture Analyzer, Ladder Diagram tab

To verify the switch capabilities, supported action or any error condition, go to **Learned Information** window. The Learned Information window contains several tabs as shown in the figure below.. Click **Refresh** button on the ribbon to update this information. The **OF Channel Learned Info** tab, contains multiple panes. Left pane displays OF Channel information including **TCP port**, **Data Path ID**, **Reply State** and any error message received from the switch. When you select a row (OF Channel), the right pane displays all OpenFlow enabled ports information on that switch.

😽 stetson2.ixiacom.com - Remote	Desktop Connection							- 6
🕮 🗋 🍋 🛄 • 🚳 • 🖂 - 📐	2 • ●	IxNetwo	k [default_kbhamre1.ixncfg]					_ @ Σ
File Home Automatic								a Abou
	affic Refrection of Processes of Continuing Protocols - Build							
Overview	< > 🚰 🤁 Protocols > 🤁 OpenFlow > 🞚 Controller Running >	Learned Information						
rate a Scenario	Learned Info Records : OF Channel: 1, Topology: 0, Flow Stat : 0, Flow Aggr. Stat : 0, Port Stat Vendor Stat : 0, Desc. Stat : 0, Table Stat : 0, Queue Config : 0, Queue	:: 0 Stat : 0						
- Orts	OF Channel Learned Info Flow Stat Flow Aggregated Stat Port Stat Vi		Queue Config Queue Stat Topology	eamed Info				
Protocols Protocol Interfaces	Refresh Learned Info for:	V						
- 💮 OpenFlow	Select the rows to send trigger/stat requests							
Controller Running	Data Path ID Data Path ID (Hex	Local Port Number	Remote Port Number	Reply State		Data Path ID	Data Path ID (Hex)	Port Number 🔺
→ db Device-1	1 1,108,102,824,500 0x00000102001342	34 6,633	55,221	Feature Reply Received	1	1,108,102,824,500	0x0000010200134234	1
Static					2	1,108,102,824,500	0x0000010200134234	2
					3	1,108,102,824,500	0x0000010200134234	3
⇒ Traffic					4	1,108,102,824,500	0x0000010200134234	4
(D) Transien under					5	1,108,102,824,500	0x0000010200134234	5
Impairments					6	1,108,102,824,500	0x0000010200134234	6
4 QuickTests					7	1,108,102,824,500	0x0000010200134234	7
De Quick resus					8	1,108,102,824,500	0x0000010200134234	8
Captures					9	1,108,102,824,500	0x0000010200134234	9
					10	1,108,102,824,500	0x0000010200134234	10
		1			11	1,108,102,824,500	0x0000010200134234	11 -
	Learned OF Channel				K			<u> </u>
	Learned UF Channel /				Ports /			

Figure 16: OF Channel Learned Info tab, Learned Info window

The Ports Stat view displays the details of each OpenFlow ports of the connected switch.

Various OpenFlow message can be sent from controller using On Demand Message button on the ribbon. Select the OF Channel and then click On Demand Message button. On the OpenFlow Learned Info Trigger Settings window, select the Port Stat check box (Multiple stats request can be sent) and click OK.

₩ C >>> ->> + +>>> >>>>>>>>>>>>>>>>>>>>>>		otocols Tools Configuration		IxNetwork [c
	Traffic Dup ID Actions	Add Protocols - Build		
Overview Chassis Protocols Protocol Interfaces OpenFlow Charsel Controller Running Controller Running Everned Infor Potocol Potocol Potocol Interfaces	< > The Protocols / Copeninow in		nfo Trigger Settings regated Stat Port Stat OFPP_NONE 5,000	Vendor Stat Vendor

Figure 17: OpenFlow Learned Info Trigger Settings window

This feature allows you to monitor the switch status without logging on to the switch. In this example, you can view OpenFlow switch ports information like Tx and Rx packet counts, dropped packet, CRC, Frame alignment, Collision and Overrun errors. The Latency field shows the response time of the switch for the particular stat request.

OF Cha	ed Info Records : en nel : 1, Topology : 0 Stat : 0, Desc. Stat :	l, Flow Stat : 0, Flov 0, Table Stat : 0, Q	# Aggr. Stat : 0, Port lueue Config : 0, Qui	Stat : 54 eue Stat : 0											
	el Learned Info Flow o 'OF Channel' tab to		ated Stat	Vendor Stat Description 8	Stat Table Stat	Queue Config	Queue Stat	Fopology Learned Info							
	Local IP	Remote IP	Data Path ID	Data Path ID (Hex)	Latency (usec)	Error Type	Error code	Reply State	Port No	Received Packets	Transmitted Packets	Received Bytes	Transmitted Bytes	Packets Dropped by RX	Packets Dropped-
1	10.200.134.233	10.200.134.234	1,108,102,824,50	0x0000010200134234	5857	NA	NA	Reply Received	1	817	3,013	174,190	537,626	794	0
	10.200.134.233	10.200.134.234	1,108,102,824,50	0x0000010200134234	5857	NA	NA	Reply Received	2	309,777	1,049	39,726,223	283,585	40,000	0
3	10.200.134.233	10.200.134.234	1,108,102,824,50	0x0000010200134234	5857	NA	NA	Reply Received	3	810	272,771	173,901	35,067,007	809	0
1	10.200.134.233	10.200.134.234	1,108,102,824,50	0x0000010200134234	5857	NA	NA	Reply Received	4	0	0	0	0	0	0
5	10.200.134.233	10.200.134.234	1,108,102,824,50	0x0000010200134234	5857	NA	NA	Reply Received	5	0	0	0	0	0	0
3	10.200.134.233	10.200.134.234	1,108,102,824,50	0x0000010200134234	5857	NA	NA	Reply Received	6	0	0	0	0	0	0
	10.200.134.233	10.200.134.234	1,108,102,824,50	0x0000010200134234	5857	NA	NA	Reply Received	7	0	0	0	0	0	0
1	10.200.134.233	10.200.134.234	1,108,102,824,50	0x0000010200134234	5857	NA	NA	Reply Received	8	0	0	0	0	0	0
	10.200.134.233	10.200.134.234	1,108,102,824,50	0x0000010200134234	5857	NA	NA	Reply Received	9	0	0	0	0	0	0
0	10.200.134.233	10.200.134.234	1,108,102,824,50	0x0000010200134234	5857	NA	NA	Reply Received	10	0	0	0	0	0	0
1	10.200.134.233	10.200.134.234	1,108,102,824,50	0x0000010200134234	5857	NA	NA	Reply Received	11	0	0	0	0	0	0
2	10.200.134.233	10.200.134.234	1,108,102,824,50	0x0000010200134234	5857	NA	NA	Reply Received	12	0	0	0	0	0	0
	10.200.134.233	10.200.134.234	1,108,102,824,50	0x0000010200134234	5857	NA	NA	Reply Received	13	0	0	0	0	0	0
3					5857	NA	NA	Reply Received	14	0	0	0	0	0	

Figure 18: Port Stats tab showing OpenFlow switch ports information

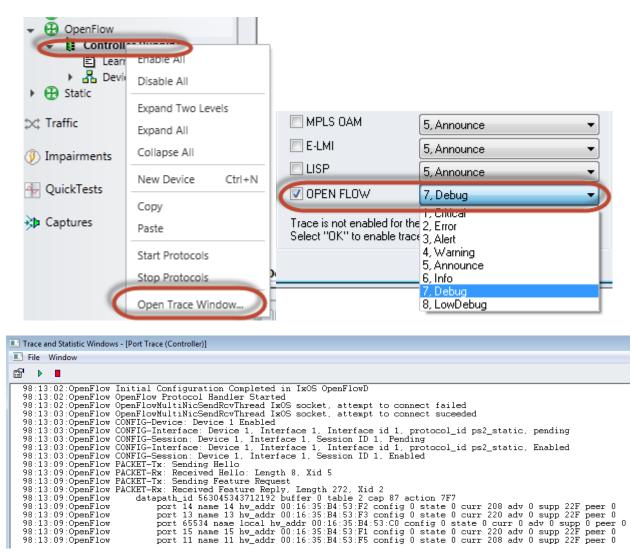
Troubleshooting

Use following steps to troubleshoot any OF Channel issues:

- Enure **ARP** is resolved under **Protocol Interface**. Also try to PING emulated controller IP (Ixia) from OpenFlow switch.
- You can enable protocol trace from the trace window.

To open the trace window, right-click on **Controller Interface** and then click **Open Trace Window**.

On the trace window select the **OPEN FLOW** check box and then select the debug level from the list and click **OK**.



IxNetwork Analyzer can decode OpenFlow messages. Use **Control**-plane capture to see **bi-directional** communication in real-time (Note - It requires Analyzer Chassis component license). Using this trace, you can determine whether bi-directional communication is happening properly as per ladder diagram shown earlier.

				🗁 Networ	k Packets (38 items)				
acket No [~]	Time	Packet Length 🦉	Packet Summary	Source MAC	Dest MAC	Source IP	Dest IP	Protoc	col 🖂
ا000 🕹	15:13:53.863239	78 bytes	50097 > 6633 Win=65535 Len=0 MSS=1460 WS=1 TSV=8812	00:16:35:B4:53:C0	00:00:42:1B:0D:28	10.1.1.1	10.1.1.2	TCP	
alia di seconda di sec	15:13:53.863415	74 bytes	6633 > 50097 Win=5792 Len=0 MSS=1460 TSV=358447990 T	00:00:42:1B:0D:28	00:16:35:B4:53:C0	10.1.1.2	10.1.1.1	TCP	
alia de la constante de la const	15:13:53.864111	66 bytes	50097 > 6633 Win=33304 Len=0 TSV=881207360 TSER=3584	00:16:35:B4:53:C0	00:00:42:1B:0D:28	10.1.1.1	10.1.1.2	TCP	
0004 کے	15:13:53.864167	74 bytes	Hello (SM) (8B)	00:16:35:B4:53:C0	00:00:42:1B:0D:28	10.1.1.1	10.1.1.2	OFP	
0005 🕹	15:13:53.864180	66 bytes	6633 > 50097 Win=1446 Len=0 TSV=358447991 TSER=88120	00:00:42:1B:0D:28	00:16:35:B4:53:C0	10.1.1.2	10.1.1.1	TCP	
0006 占	15:13:53.864326	74 bytes	Hello (SM) (8B)	00:00:42:1B:0D:28	00:16:35:B4:53:C0	10.1.1.2	10.1.1.1	OFP	
alia de la composición de la c	15:13:54.055542	66 bytes	50097 > 6633 Win=33300 Len=0 TSV=881207560 TSER=3584	00:16:35:B4:53:C0	00:00:42:1B:0D:28	10.1.1.1	10.1.1.2	TCP	
8000 🕹	15:13:54.055558	74 bytes	Features Request (CSM) (8B)	00:00:42:1B:0D:28	00:16:35:B4:53:C0	10.1.1.2	10.1.1.1	OFP	
٥٥٥٩ 占	15:13:54.056713	338 bytes	Features Reply (CSM) (272B)	00:16:35:B4:53:C0	00:00:42:1B:0D:28	10.1.1.1	10.1.1.2	OFP	
alia de la composición de la c	15:13:54.096683	66 bytes	6633 > 50097 Win=1608 Len=0 TSV=358448224 TSER=88120	00:00:42:1B:0D:28	00:16:35:B4:53:C0	10.1.1.2	10.1.1.1	TCP	
alia di	15:14:03.861394	74 bytes	Echo Request (SM) (8B)	00:16:35:B4:53:C0	00:00:42:1B:0D:28	10.1.1.1	10.1.1.2	OFP	
o012 🕹	15:14:03.861441	66 bytes	6633 > 50097 Win=1608 Len=0 TSV=358457990 TSER=88121	00:00:42:1B:0D:28	00:16:35:B4:53:C0	10.1.1.2	10.1.1.1	TCP	
占 0013	15:14:03.861561	74 bytes	Echo Reply (SM) (8B)	00:00:42:1B:0D:28	00:16:35:B4:53:C0	10.1.1.2	10.1.1.1	OFP	
alia di	15:14:04.052444	66 bytes	50097 > 6633 Win=33292 Len=0 TSV=881217560 TSER=3584	00:16:35:B4:53:C0	00:00:42:1B:0D:28	10.1.1.1	10.1.1.2	TCP	
0015 🕹	15:14:04.052456	74 bytes	Echo Request (SM) (8B)	00:00:42:1B:0D:28	00:16:35:B4:53:C0	10.1.1.2	10.1.1.1	OFP	
0016 🕹	15:14:04.053327	74 bytes	Echo Reply (SM) (8B)	00:16:35:B4:53:C0	00:00:42:1B:0D:28	10.1.1.1	10.1.1.2	OFP	
								TCP	
low Sumr	15:14:04.092616	66 bytes	6633 > 50097 Win=1608 Len=0 TSV=358458223 TSER=88121	OFP Fea • Sou	tures Request (CSM) (8B) Irce port: 6633 (6633)	10.1.1.2	10.1.1.1	 00000000 	00 16 3
Flow Sumr Flow Sum 20 messa 2 endpoir	nary Ladder Diagr nmary ge(s) and t(s) in			OFP Fea Sou Des Hea Flag	tures Request (CSM) (8B) irce port: 6633 (6633) tination port: 50097 (50097) idder length: 32 bytes js: 0x0018 (PSH, ACK)		10.1.1.1		00 16 3 00 3C 7 01 01 1 05 Å6 0
Flow Sumr Flow Sum 20 messa 2 endpoir	nary Ladder Diagr	am 10.1.1.1:50097 OFP Endpoint	d Þ	OFP Fea Sou Det Hea Flag	tures Request (CSM) (8B) tures port: 6833 (6633) tination port: 50097 (50097) der length: 32 bytes po: 0x018 (FSH, ACK) 0		10.1.1.1	* 00000000 0000010 00000020 00000030	00 16 3 00 3C 7 01 01 1 05 A6 0
Flow Sumr Flow Sun 20 messa 2 endpoir this flow.	nmary ge(s) and t(s) in More	am 10.1.1.1:50097 OFP Endpoint 1558	10.1.1.2./6633 OFP Endpoint	OFP Fea Sou Det Het Flag o	tures Request (CSM) (8B) trore port 6833 (6833) titnation port: 50097 (50097) der length: 32 bytes so: 0x018 (FSH, ACK)		10.1.1.1	* 00000000 0000010 00000020 00000030	00 16 3 00 3C 7 01 01 1 05 A6 0
Flow Sumr Flow Sun 20 messa 2 endpoir this flow. 3	nary Ladder Diagr nmary ge(s) and t(s) in @ More 15:13:54.055	am 10.1.1.1:50097 OFP Endpoint 558 5713	د به	OFP Fea Sot Des Hes • Flag •	Lures Request (CSM) (8B) tures Request (CSM) (863) initiation prd: 50097 (50097) ider length: 32 bytes iso 0x018 (PRH, ACK) 0		10.1.1.1	* 00000000 0000010 00000020 00000030	00 16 3 00 3C 7 01 01 1 05 A6 02 9 08 0
Flow Sum Flow Sum 20 messa 2 endpoir this flow. 3 4	nary Ladder Diagr nmary ge(s) and tt(s) in @ More 15:13:54.055 15:13:54.056 15:13:54.056	Tam 10.1.1.1:50097 OFP Endpoint 5558 5713 5713 5713 5713 5713 5713 5713 5713 5713 5713 5713 5713 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 5714 57	4 ► 10.1.1.2.6633 OFP Endpoint Features Request (CSM) (89) → ures Reply (CSM) (2728) →	OFP Fea Sot Oete Hea Fla	tures Request (CSM) (8B) trore port 6833 (6833) titnation port: 50097 (50097) der length: 32 bytes is: 0x0018 (PSH,ACK) 0		10.1.1.1	* 00000000 0000010 00000020 00000030	00 16 3 00 3C 7 01 01 1 05 A6 0
Flow Sur 20 messa 2 endpoir this flow. 3 4 5	nary Ladder Diagr nmary gg(s) and t(s) in gg(s) 15:13:54.055 15:13:54.056 15:13:54.0361 15:14:03.861	am 10.1.1.1150097 OFP Endpoint 1558		OFP Fea Sou Bete Hete Flag	tures Request (CSM) (8B) tures Request (CSM) (8B3) tintation prf: 50097 (50097) der length: 32 bytes so 0x018 (PSH, ACK) 0		10.1.1.1	* 00000000 0000010 00000020 00000030	00 16 3 00 3C 7 01 01 1 05 A6 0
Flow Sumr Flow Sui 20 messe 2 endpoin this flow. 3 4 5 6	Imary Ladder Diagr ge(s) and ge(s) and (i) More 15:13:54.055 15:13:54.055 15:13:54.056 15:14:03.861 15:14:03.861	10.1.1.1150097 OFP Endpoint 3558 C Feat 394 C Echt 551 C Echt 551 C Echt		OFP Fea Sou Sou Heu Fia Sou	tures Request (CSM) (8B) trace part (633) (6633) tination part 50097 (50097) der length: 32 bytes ps: 0x0018 (FSH, ACK) 0	ced (CWR): Not set	10.1.1.1	* 00000000 0000010 00000020 00000030	00 16 3 00 3C 7 01 01 1 05 A6 0
Flow Sum Flow Sum 20 messe 2 endpoin this flow. 3 4 5 6 7	Image Ladder Diagr nmary ge(s) and ge(s) and t(s) in More 15:13:54.055 15:13:54.055 15:14:03.861 15:14:03.861 15:14:03.861	am 10.1.1.150097 OFP Endpoint 3394 — Echt 561 — — 3227 — Echt	Image: Constraint of the second sec	OFP Fea Sot OFP Fea Sot OFP Het Fia O Sot	tures Request (CSM) (8B) tures Request (CSM) (8B3) tintation prf: 50097 (50097) der length: 32 bytes so 0x018 (PSH, ACK) 0	ced (CWR): Not set	10.1.1.1	* 00000000 0000010 00000020 00000030	00 16 3 00 3C 7 01 01 1 05 A6 0
Flow Sum Flow Sum 20 messe 2 endpoin this flow. 3 4 5 6 7 8	Image Image <th< td=""><td>am 10.1.1.150097 OFP Endpoint 1558 551 552 554 554 554 554 554 554 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 55</td><td></td><td>OFP Fea South Det Het Flat OFP Fue OFU Vue Vue Oth Oth Oth</td><td>Lures Request (CSM) (8B) tures Request (CSM) (863) tintation port: 50097 (50097) ider length: 32 bytes type: 50098 (PSH ACK) 0</td><td>ced (CWR): Not set</td><td>10.1.1.1</td><td>* 00000000 0000010 00000020 00000030</td><td>00 16 3 00 3C 7 01 01 1 05 A6 0</td></th<>	am 10.1.1.150097 OFP Endpoint 1558 551 552 554 554 554 554 554 554 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 555 55		OFP Fea South Det Het Flat OFP Fue OFU Vue Vue Oth Oth Oth	Lures Request (CSM) (8B) tures Request (CSM) (863) tintation port: 50097 (50097) ider length: 32 bytes type: 50098 (PSH ACK) 0	ced (CWR): Not set	10.1.1.1	* 00000000 0000010 00000020 00000030	00 16 3 00 3C 7 01 01 1 05 A6 0
Flow Sumr Flow Sumr 20 messe 20 endpoint this flow. 3 4 5 6 7 8 9 10 11	nary Ladder Diagr nmary ge(s) and ge(s) and ge(s) and (a) More 15:13:54.055 15:13:54.056 15:14:03.861 15:14:03.861 15:14:04.053 15:14:04.053 15:14:04.053 15:14:13.859	am 10.1.1.1150097 OPP Endpoint 1558 551 551 551 551 551 551 55	Io. 1: 1: 2: 6633 OFP Endpoint Features Request (CSM) (88) Echo Reply (SM) (88) Echo Reply (SM) (88) Echo Reply (SM) (88) Echo Request (SM) (88)	OFP Fea South Det Flag ·	tures Request (CSM) (8B) tures Request (CSM) (8B3) tintation port: 50097 (50097) der length: 32 bytes so 0x018 (PSH, ACK) 0	e 0x6737)	10.1.1.1	* 00000000 0000010 00000020 00000030	00 16 3 00 3C 7 01 01 1 05 A6 0
Flow Sum Flow Sum 20 messe 2 endpoin this flow. 3 4 5 6 7 8 9 9 10	Image Ladder Diagr mmary ge(s) and (if) in (if) More 15:13:54.055 15:13:54.055 15:13:154.056 15:14:03.861 15:14:03.861 15:14:03.861 15:14:03.861 15:14:03.861 15:14:103.851 15:14:13.859 15:14:13.859 15:14:13.859	am 10.1.1.1:5097 OFP Endpoint 3558 Effect 354 Echt 354 Echt 355 Echt 354 Echt 355 Echt	ID.11.2.6633 OFP Endpoint Features Request (CSM) (8B) Echo Reply (SM) (8B) Echo Request (SM) (8B) Echo Reply (SM) (8B)	OPP Fea South Det Het OF Chu Opt Chu Opt	Interest (CSM) (8B) tures Request (CSM) (863) initiation prd: 50097 (50097) ider length: 32 bytes iso X00018 (PRH, ACK) 0	e 0x6737)	10.1.1.1	* 00000000 0000010 00000020 00000030	00 16 3 00 3C 7 01 01 1 05 A6 0
Flow Sumr Flow Sumr 20 messe 20 endpoint this flow. 3 4 5 6 7 8 9 10 11	Image Ladder Diagr Immary ge(s) and ge(s) and ge(s) and 15:13:54.055 15:13:54.055 15:13:14:03.861 15:14:104.052 15:14:104.052 15:14:104.053 15:14:14:13.859 15:14:14:13.859	am 10.1.1.150097 OFP Endpoint 1558 1558 1558 1558 1558 1561 1561 1561 1560 1561 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 1560 156	IO.1.1.2:16633 OFP Endpoint Features Request (CSM) (8B) Echo Reply (SM) (8B) Echo Request (SM) (8B)	OFP Fea South Det Flag ·	tures Request (CSM) (8B) tures Request (CSM) (8B3) tintation port: 50097 (50097) ide length: 32 bytes jso 0x018 (FSH, ACK) 0	e 0x6737)	10.1.1.1	* 00000000 0000010 00000020 00000030	00 16 3 00 3C 7 01 01 1 05 A6 0
Flow Sum Flow Sum 20 messe 2 endpoint this flow. 3 4 5 6 7 8 9 10 11 12	Isider Diagram nmary Ladder Diagram qe(s) and (s) in 15:13:54.055 15:14:03.861 15:14:03.861 15:14:03.861 15:14:04.033 15:14:14:03.861 15:14:14:03 15:14:14:04.033 15:14:14:14:051 15:14:14:14:051	am 10.1.1.1150097 OPP Endpoint 1558 551 551 551 551 551 551 55	ID 1.1.1.2.6633 OFP Endpoint 0.1.1.2.6633 Interstand 0.1.1.2.6633 OFP Endpoint 0.1.1.2.6633 ures Reply (CSM) (2225) 0.1.1.2.6633 Echo Reply (SM) (88) 0.1.1.2.6633	OFP Fea Soto Det Het OF Fla O	tures Request (CSM) (8B) tures Request (CSM) (8B3) tintation port: 50097 (50097) ide length: 32 bytes jso 0x018 (FSH, ACK) 0	e 0x6737)	10.1.1.1	* 00000000 0000010 00000020 00000030	00 16 3 00 3C 7 01 01 1 05 A6 0
Flow Sumr 20 messa 2 endpoint this flow. 3 4 5 6 7 8 9 9 10 11 12 13	Image Ladder Diagr mmary ge(s) and (if) in	am 10.1.1.15097 OFP Endpoint 3558 4556 4556 4556 4556 4556 4556 4556 4556 4556 4556 4556 4556 4556 4556 4556 4556 4556 4566 457 457 457 457 457 457 457 457	ID.1.1.2.6633 OF Endpoint Features Request (CSM) (6B) ures Reply (SM) (6B) Echo Reply (SM) (6B) Echo Request (SM) (6B) Echo Reply (SM) (6B)	OFP Fea Solution OFP Fea Solution OperFile Op	tures Request (CSM) (8B) troe port 6633 (6633) tination port: 50097 (50097) der length: 32 bytes so 20018 (F8H, ACK) 0 = Congestion Window Redu 0	e 0x6737)	10.1.1.1	* 00000000 0000010 00000020 00000030	00 16 3 00 3C 7 01 01 1 05 A6 0

Conclusions

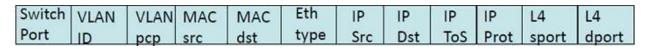
By validating the statistics and control-plane message exchanges using the features above, we have verified that the DUT can successfully establish OF Channel, keep the session alive and respond to Stats Request from the controller.

Test Case: OpenFlow Switch Forwarding Test

Overview

Through OpenFlow you can program data path by building the flow table in OpenFlow switch. In the flow table there are two components: Match and One or more Actions.

OpenFlow 1.0 specification covers 12 tuple matches as shown below.

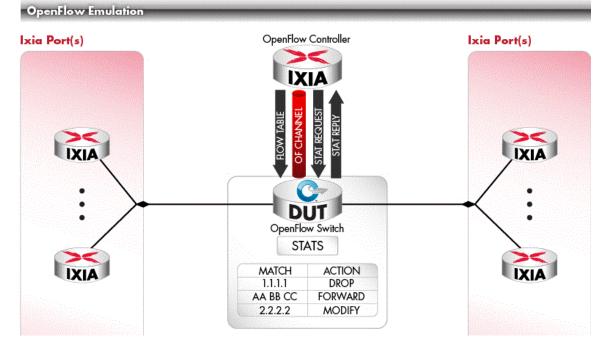


After the match, certain actions can be performed, such as forward packet to zero or more ports, modify the field, drop the packet or if no match found forward it to controller.

Objective

The objective of this test is to verify the ability of the OpenFlow switch to forward L2 traffic. The DUT should be able to look up the Flow Table when L2 traffic is received and forward the traffic based on specified actions. In this test, initially controller will push down L2 flows with certain Match and Action parameters. Then using traffic wizard, matching traffic will be created and sent. Using the traffic statistics; switch forwarding performance will be verified.

Setup



The following figure illustrates the test setup:

Figure 19: OpenFlow Switch Forwarding Test, test setup

Step-by-Step Instructions

The following steps describe the procedure for performing the test.

1. Reserve 3 Ixia ports (1 for controller and 2 port traffic endpoints)

Chassis 🕂 🕂 Add Chas	sis 💥 😂 🌮 More 🗸 All ports		Po	rts i	n confi	guration
Chassis/Card/Port	Туре				State	
 I0.200.134.41 	ixos 6.30.0.421 eb, protocol 7.00.0.		1	Þ	0	Controlle
🚽 🂵 Card 02	16 PORT 10/100/1000 LSM XMV16		2		0	Host-1
🎑 Port 01	10/100/1000 Base T		3		0	Host-2
🎽 Port 02	10/100/1000 Base T	-				
🎑 Port 03	10/100/1000 Base T	Add ports				
Ort 04	10/100/1000 Base T	>>>>				
Ort 05	10/100/1000 Base T	Assian to				
Ort 06	10/100/1000 Base T	remaining				
Port 07	10/100/1000 Base T					
Port 08	10/100/1000 Base T	307				
🂓 Port 09	10/100/1000 Base T	Assian to				
Port 10	10/100/1000 Base T	selected				
Ort 11	10/100/1000 Base T					
Ort 12	10/100/1000 Base T	<i></i>				
🂓 Port 13	10/100/1000 Base T	Unassign				
VPort 14	10/100/1000 Base T	selected				
VPort 15	10/100/1000 Base T					
V Port 16	10/100/1000 Base T					

Figure 20: Port Selection window

2. Enable OpenFlow on all the ports by selecting the **OpenFlow** check box on the **Protocols** window.

Overview	Routing	g/Switching	MPLS	Multicast	Carrier Eth	ernet	Access	Authentication	Data Cent	ter Bridging 🛛 W	ireless		
Scenario		Po	irt Descri	iption	Port Owner	Link	ARP	PING for IPv4	BFD	BGP/BGP+	EIGRP	ISIS L2/L3	OpenFlov
orts	1	Controller	- 10/100)/1000 Base	IxNetwor	0	ম	Г	Г	Г	Г	Г	N
hassis	2	Host-1 - 1	0/100/10	000 Base T	IxNetwor	0	R					Γ	R
	3	Host-2 - 1	0/100/10	000 Base T	IxNetwor	0			Γ		Γ	Γ	
ocols													
otocoi interfaces													
enFlow													
Controller													
Host-1													
lost-2													

Figure 21: RoutingSwitching tab, Protocols window

3. Configure the emulated controller IP address and **Gateway** address from the **Connected Interface** tab on the **Protocol Interfaces** window. Use the IP address of the OpenFlow switch if you have only one switch. For Of Channel, ensure that ARP is resolved. You do not have to configure anything on host port.

File Home Automatic	ion Results / Reports Vi	ews (Configuration					
🗠 👘 🕅	Send ARP	25	👍 Add Interface	4	Add IPv4	👍 Add IP	V6	Add DHCP TLV
-00-	Send ARP Send NS Fraffic Dup ID Ping	Add Protocols -	Add Multiple Interfa		Remove IPv4	Remov		Remove DHCP TLV
Action	ns	Build					Edit	
Overview	< ≽ 🚮 🤁 Protocols > 🤂 I	Protocol Interf	aces 🕨					
x₀ Scenario ✓ ● Ports	ARP on Link Up 🔽 Send	Port	rGateway 🔽 NS on L		_		_	
Lassis	Port Description	ר Link	Interface Description	Enable	(10.0.x.x - Res	erved IP)	Width	Gateway
→ ⊕ Protocols	1 Controller - 10/100/100	00 Base 🙆	Connected - ProtocolInt	_ ▼	10.200.134	.233	24	10.200.134.234
Protocol Interfaces	2 Host-1 - 10/100/1000 I		[Empty]					
• (A) OpenFlow	3 Host-2 - 10/100/1000 I	Base T 🥝	[Empty]					
Controller HI Host-1 HI Host-2 For Static								

Figure 22: Connected Interfaces tab, Protocol Interface window

- 4. Define the port role by selecting the role from the **Port Role** list on the **Ports** tab on the **OpenFlow** window. You can select any of the following port roles:
 - a. **Control**: for Controller port
 - b. **Traffic**: for host ports

	<	🖌 🔂 Pro	itocols 🕨 💮 Ope	nFlow >		
Overview	Diag	gram Ports	Devices Interface	s OF Channels	Flow Ranges Actions Traffic End	points
■ Scenario		Port	Protocol State	Number of Devices	Number of Traffic Endpoints	Port Role
Ports	1	Controller		1	NA	Control
Lassis	2	Host-1		NA	1	Traffic
	3	Host-2		NA	1	Traffic /
🔁 Protocols				S		
Protocol Interfaces						
🗸 🚯 OpenFlow 🧼						
Controller						
Host-1						
Host-2						

5. Configure the **Number of Interfaces** as *1*, by going to the **Devices** tab on the **OpenFlow** window. The number of interfaces should be equal to the number of emulated NICs of a controller.

Protocols OpenFlow OpenFlow Actions Group ID	Add Protocols •	Hadd Device	Grid Operations •	
Actions	Build	Edit	Grid	
Overview Ports Protocols Protocol Interfaces OpenFlow Static		ices Interfaces OF CP	nannels Flow Ranges Actions Traffic Endpoi Device Role Version Number of I Controller 1.0.0	



6. Go to the **Interface** tab of the **OpenFlow** window and assign the **Protocol Interfaces** that you created on the **Protocol Interface** window. This interface is used for the control-plane (OF Channel). Configure **Number of Channels** as *1*.

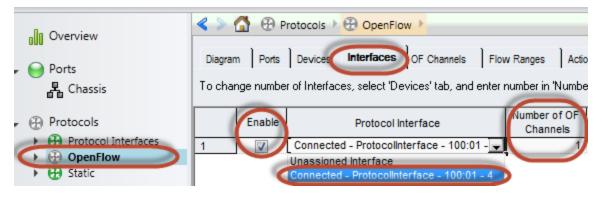


Figure 24: Interfaces tab, OpenFlow window

7. Go to **OF Channels** tab and enter DUT IP address in **Remote IP** field. Change flow range count to 2.

0 Overview	< > {	🎦 💮 Proto	cols > 💮	OpenFlow 🕨 🕌	Controller >					
■ Cenario	Devices	Interfaces	OF Channe	Flow Range	es Actions					
▼ ⊖ Ports La Chassis		Interface	Enable	Description	Local IP	Remote IP	Use Datapath	Datapath ID	Datapath ID	Startup Number of Flow Ranges
👻 🤁 Protocols							D	Datapatri D	(In Hex)	Feature
Protocol Interfaces	1	Connected -		OFChannel-1	10.200.134.233	10.200.134.234			U	
OpenFlow Controller ELearned Informatio B Device-1 Host-1 Host-2										

Figure 25: OF Channel tab, OpenFlow window

8. In the Flow Range tab, create 5 flows on each range. Enter Source/Destination MAC and VLAN-ID. For remaining all field use wild card value (*). This means, Switch will make forwarding decision based on matching Src/Dst MAC address and VLAN-ID. Configure correct In Port field with the switch port number that is connected to Ixia host port generating traffic.

	F Channel	Enable	Description	Home	Configure Range		Dootandaon	Type		IPv4 Source (addr/mask)		Protocol		Transport Source/ICMP Type	
OF	Channel-1		FlowRange- FlowRange-	5			00 00 00 00 22 01	*	1 6		*	*	*	*	*

Figure 26: FlowRanges tab, OpenFlow window

9. Use **Configure Range** button (...) to increment MAC and VLAN.

	🎦 🤁 Protoc	:ols 🕨 🔁	OpenFlow →	Control	ler Running 🕨		Co	onfigure Flow Enti	ry Range				
							Ran	ige configuration —					
Devices	Interfaces	OF Chann	els Flow Rai	iges Actio	ns			Fields	In Port	Ethernet Source	Ethernet De	estination	VLAN ID
	05.01			Number of			1	Start Value	2	00.00.00.00.11.01	00 00 00 0	10 22 04	1
	OF Channel	Enable	Description	Flows	Configure Range	In Port	2	Step Value	0	00 00 00 00 00 01	00 00 00 0	00 00 01	1
C	OFChannel-1	v	FlowRange-	5		2	3	Repeat Count	1	1	1		1
!		V	FlowRange-	5		2	4	Wrap Count	65535	1000000	10000	000	4095
			_				5	Increment Typ	Increment	Increment	Increm	nent	Incremer
			D	utton			•						
			D	utton)			al Count 5	_	Update]
			D	utton)			al Count 5	Ethernet So		stination V	/LAN ID	<u>)</u>
			D	utton)			In Port		burce Ethernet Des		/LAN ID	<u>)</u>
			D	utton)			In Port	Ethernet So	ource Ethernet De: 01 00:00:00:00:22	2:01 1	/LAN ID	<u>)</u>
			D	utton)		Tol	In Port	Ethernet Sc 00:00:00:00:11	Ethernet Des 01 00:00:00:00:22 02 00:00:00:00:22	2:01 1 2:02 2	/LAN ID	<u> </u>
Match ,	{ Config } Al	u /	D	utton	,		Tol	2 (1) 2 (1) 2 (1) 2 (1)	Ethernet So 00:00:00:00:11 00:00:00:00:00:11	Ethernet Des 001 00:00:00:00:22 002 00:00:00:00:22 003 00:00:00:00:22	2:01 1 2:02 2 2:03 3	/LAN ID	1

10. Now create Number of Action from Config tab.

vice	s Interfaces OF Channel	OF Channels Flow Ra	Actions Actions Idle Timeout (sec)	Hard Timeout (sec)	Priority	Send Flow Removed	Check Overlap	Emergency Flow	Do not Add on Channel Up	Number of Actions
	OFChannel-1	Loose	0	0	0	Г	Г	Г	Г	1
		Loose	0	0	0	Γ	Γ	Γ	Ē	1

11. Go to **Actions** tab and select **Action Type** as *OutPut* and **Output Port Type** as *Custom/Manual*. Enter the **Output Port** value of the switch where the traffic will be forwarded to.

	Flow Ranges	Action Type	Output Port Type	Output Por
FlowF	Range-1 - OFChannel-1 - Connec	Output	Custom/Manual	3
FlowF	ange-2 - OFChannel-1 - Connec	Output	Custom/Manual	3

Figure 27: Actions tab

12. Use the **OpenFlow** control on the ribbon to start OpenFlow protocol and make sure OF Channel comes up. The value of the **OF Channel Configured UP** field indicates that the OF Channel is up.

File Home	Automation F	Results / Reports	Views	Configur	ation	
Protocol OpenFlow	Flow Traffic ons + Group ID	Add Protocols -	Start OpenFlo	N Gri Operat		
Actions		Build	Selected	Gri		
Overview	< >	🕨 🚮 🤁 Protoc	iols 🕨 🤂 Oper	Flow 🕨 🚺 C	Controller Running 🕨	
000	De	evices Interfaces	OF Channels	Flow Ranges	Actions	
■ Cenario	To	change number o	f Interfaces, sele	ect 'Devices' ta	ab, and enter number in 'N	lumber of Interfaces' field
👻 😝 Ports						
Chassis		Device De			Protocol Interface	Number of OF Channels
👻 🔁 Protocols	1	Device-1 - C	ontroller	Conne	cted - ProtocolInterfa	1
Protocol Interfa OpenFlow	aces					
Controller	r Running					
Host-1						
Static						
😂 Traffic		Select Views.	Global	Protocol Statis	tics OpenFlow Co	ntroller Aggregated Statistics
		Stat Name		Port Name	OF Channel Configured	I OF Channel Configured Up OF Cha
Impairments			/Card02/Port14			
🕂 QuickTests		-	/Card02/Port15			
Captures		3 10.200.134.41	/Card02/Port16	Controller		

Figure 28: Controller Running, showing OF Channel Configured Up

To verify the switch capabilities, supported action or any error condition, go to **Learned Information** window. Several tabs are available as shown in the following figure. Click **Refresh** button on the ribbon to update the information.

Go to **OF Channel learned Info** tab, It has two panes. Left pane displays OF Channel information including **TCP Port**, **Data Path ID**, **Reply State** and any error message received from the Switch. When you select a row (OF Channel), the right pane displays all OpenFlow enabled ports information on that switch.

	Actions		Build									
Overview	< ≽ 🚮 😛 Protocols I) 🔂 OpenFlow	Controller Ru	nning > 🖻 Learned Info	ormation							
1 Overview	□ armed Info Becords :											
Scenario	OF Channel : 1, Topolog		Elow é a ar Stat : I	0. Post Stat : 0								
	Vendor Stat : 0, Desc. S	Stat: 0, Table Stat	: 0, Queue Config :	0, Queue Stat : 0								
Ports												
Chassis	OF Channel Learned Info	Flow Stat Flow A	lggregated Stat Por	t Stat Vendor Stat Desc	ription Stat Tai	ble Stat Queue	Config Queue Stat Top	logy Learned Info				
	□ Refresh Learned Info fo	or:										
Protocols												
Protocol Interfaces	Device All	 Interface 		¥								
OpenFlow	Device All Select the rows to send tri	_		<u>×</u>								
OpenFlow		_		Data Path ID (Hex)	Local Port Number	Remote Port Number	Reply State	Mex Buffer Size		Local IP	Remote IP	Data Path ID
OpenFlow I Controller Running Learned Informs	Select the rows to send tri	igger/stat requests Remote IP	Data Path ID	Data Path ID (Hex)		Number	Reply State	Max Buffer Size	1	Local IP 10.200.134.233	Remote IP 10.200.134.234	
OpenFlow Controller Running	Select the rows to send tri	igger/stat requests Remote IP	Data Path ID		Number	Number			1			Deta Path ID 1,108,102,824,500 1,108,102,824,500
OpenFlow Controller Running Learned Inform: db Devicer1	Select the rows to send tri	igger/stat requests Remote IP	Data Path ID		Number	Number			1	10.200.134.233 10.200.134.233 10.200.134.233	10.200.134.234 10.200.134.234 10.200.134.234	1,108,102,824,500 1,108,102,824,500 1,108,102,824,500
OpenFlow Controller Running Controller Running Controller Running Controller Running Controller Running Learned Informs Gh Devicer1 Host1	Select the rows to send tri	igger/stat requests Remote IP	Data Path ID		Number	Number			1 2 3 4	10.200.134.233 10.200.134.233 10.200.134.233 10.200.134.233	10.200.134.234 10.200.134.234 10.200.134.234 10.200.134.234	1,108,102,824,500 1,108,102,824,500 1,108,102,824,500 1,108,102,824,500 1,108,102,824,500
OpenFlow Controller Running Controller Running Controller Running Controller Running Gib Denter1 Lift Host1 Lift Host2 Lift Host3	Select the rows to send tri	igger/stat requests Remote IP	Data Path ID		Number	Number			1 2 3 4 5	10.200.134.233 10.200.134.233 10.200.134.233 10.200.134.233 10.200.134.233 10.200.134.233	10.200.134.234 10.200.134.234 10.200.134.234 10.200.134.234 10.200.134.234 10.200.134.234	1,108,102,824,500 1,108,102,824,500 1,108,102,824,500 1,108,102,824,500 1,108,102,824,500 1,108,102,824,500
OpenFlow Controller Running Controller Running dis Dence1 Most1 Host2 Host3 Static	Select the rows to send tri	igger/stat requests Remote IP	Data Path ID		Number	Number			1 2 3 4 5 6	10.200.134.233 10.200.134.233 10.200.134.233 10.200.134.233 10.200.134.233 10.200.134.233	10.200.134.234 10.200.134.234 10.200.134.234 10.200.134.234 10.200.134.234 10.200.134.234	1,108,102,824,500 1,108,102,824,500 1,108,102,824,500 1,108,102,824,500 1,108,102,824,500 1,108,102,824,500 1,108,102,824,500
OpenFlow Controller Running Controller Running dis Dence1 Most1 Host2 Host3 Static	Select the rows to send tri	igger/stat requests Remote IP	Data Path ID		Number	Number			1 2 3 4 5 6 7	10.200.134.233 10.200.134.233 10.200.134.233 10.200.134.233 10.200.134.233 10.200.134.233 10.200.134.233 10.200.134.233	10.200.134.234 10.200.134.234 10.200.134.234 10.200.134.234 10.200.134.234 10.200.134.234 10.200.134.234	1,108,102,824,500 1,108,102,824,500 1,108,102,824,500 1,108,102,824,500 1,108,102,824,500 1,108,102,824,500 1,108,102,824,500
OpenFlow Controller Running Categories Controller Running Categories Categor	Select the rows to send tri	igger/stat requests Remote IP	Data Path ID		Number	Number			1 2 3 4 5 6 7 8	10.200.134.233 10.200.134.233 10.200.134.233 10.200.134.233 10.200.134.233 10.200.134.233	10.200.134.234 10.200.134.234 10.200.134.234 10.200.134.234 10.200.134.234 10.200.134.234	1,108,102,824,500 1,108,102,824,500 1,108,102,824,500 1,108,102,824,500 1,108,102,824,500 1,108,102,824,500 1,108,102,824,500

Figure 29: Learned Information window

13. From **OF Channel Learned Info** tab use **On Demand Messages** button to request switch to send flow table information.

File Home Auto	omation Results / Reports Views Co	onfiguration
Protocols OpenFlow OpenFlow	Traffic Groups Actions	Add Protocols - Build
Overview		Open Flow Learned Info Trigger Settings
ex <mark>e</mark> Scenario	Learned Info Records : OF Channel : 1, Topology : 0, Flow Stat : Vendor Stat : 0, Desc. Stat : 0, Table Stat	Flow Stat Flow Aggregated Stat Port Stat Vendor Stat Vendor Message Descr
✓	OF Channel Learned Info Flow Stat Flow J	Table ID All Tables 🔽 255
	Refresh Learned Info for:	Out Port OFPP_NONE 65,535
Protocols Protocol Interfaces		Response Timeout 5.000
OpenFlow Controller Pupp	Select the rows to send trigger/stat requests	Match Criteria
C 🗈 Learned II		In Port X
Host-1	1 1,108,102,824,500	Ethemet Type
Host-2		
🕨 🤂 Static		Ethernet Source *
👻 😂 Traffic		Ethernet Destination
► 🔀 L2-3 Traffic Items		VLAN ID X VLAN Priority
☆ L2-3 Flow Groups	Learned OF Channel	
Impairments		IP DSCP × IP Protocol ×
4 QuickTests	Select Views Global Protoco	IPv4 Source/Mask
Captures	Stat Name Port N	Destination/Mask
3P Captures	▶ 1 10.200.134.41/Card02/Port14 Host-	Transport * Transport * Source/ICMP Type
	2 10.200.134.41/Card02/Port15 Host-	
	3 10.200.134.41/Card02/Port16 Contr	OK Cancel Help

Figure 30: OpenFlow Learned Info Trigger Settings window

To verify flow table information, go to **Flow Stat** tab. On this tab, make sure that switch has correct flow entries to match the fields defined earlier in the flow range, input port and wild card entry for non-matching field.

OF C				r. Stat : 0, Port Stat : 5 Config : 0, Queue Stat :							
F Cha	nnel Learned Info (low Stat	Flow Aggregated Sta	t PortStat VendorS	Stat Descri	ption Stat	Table Stat	ueue Config	Queue Stat	Topology Learned Inf	0
Switch	n to 10F Channel' ta	ab to send	d trigger			_					
	Reply State	In Port	Ethernet Source	Ethernet Destination	Ethernet Type	VLAN ID	VLAN Priority	IPv4 Source	IP∨4 Destination	IP Protocol	IP DSC
1	Reply Receive	2	00:00:00:00:11:0a	00:00:00:00:22:0a	*	10	*	*	*	*	*
2	Reply Receive	2	00:00:00:00:11:09	00:00:00:00:22:09	*	9	*	*	*	*	*
3	Reply Receive	2	00:00:00:00:11:08	00:00:00:00:22:08	*	8	*	*	*	*	*
4	Reply Receive	2	00:00:00:00:11:07	00:00:00:00:22:07	*	7	*	*	*	*	*
5	Reply Receive	2	00:00:00:00:11:06	00:00:00:00:22:06	*	6	*	*	*	*	*
6	Reply Receive	2	00:00:00:00:11:05	00:00:00:00:22:05	*	5	*	*	*	*	*
7	Reply Receive	2	00:00:00:00:11:04	00:00:00:00:22:04	*	4	*	*	*	*	*
3	Reply Receive	2	00:00:00:00:11:03	00:00:00:00:22:03	*	3	*	*	*	*	*
9	Reply Receive	2	00:00:00:00:11:02	00:00:00:00:22:02	*	2	*	*	*	*	*
10	Reply Receive	2	00:00:00:00:11:01	00:00:00:00:22:01	*	4	*	*	*	*	*

Figure 31: Flow Stat tab, Learned Information window

14. Create Traffic endpoints on host ports using **Generate Traffic Endpoint** wizard. This option will be available from **Flow Ranges** tab.

Protocols OpenFlow OpenFlow Group Actions		Add Protocols - Build	Ge	nerate Traffi	Click th	is									
u∭ Overview ¤x <mark>∰</mark> Scenario	< > Diagrar		otocols) Devices	Open H		6	Jes Act	ions Traff	ic Endpoints						
	1	OF Channel OFChann	ন	Description Primary Secondary	Number of Flows 1	Configure Range 	In Port	Ethernet Source	Ethernet Destination *	Ethernet Type 0800 0800	VLAN ID *	VLAN Priority	IPv4 Source (addr/mask) 1.1.1.1/24 1.1.1.1/24	IPv4 Destination (addr/mask) 2.2.2.2/24 2.2.2.2/24	IP Protocol
	2												1.1.1.124		

Figure 32: Flow Ranges tab

- 15. The following steps will help you use the **OpenFlow Traffic Converter Wizard** to create the corresponding traffic end points for the Flow Range values on Ixia ports.
 - a. Select host ports where Traffic Endpoints will be created and click next.

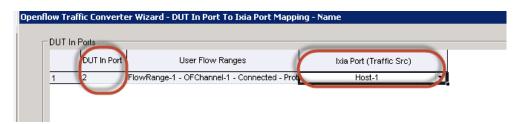
	Enable	rd Configuration Port Description
-		Controller - 10/100/1000 Base T
2		Host-1 - 10/100/1000 Base T
}		Host-2 - 10/100/1000 Base T

Figure 33: OpenFlow Traffic Converter Wizard

b. Enable Flow Ranges to be included for traffic endpoints

	Flow Range	Include Ir Traffic
1	FlowRange-1 - OFChannel-1 - Connected - ProtocolInterface - 100:03 - 1 - Device	N
2	FlowRange-2 - OFChannel-1 - Connected - ProtocolInterface - 100:03 - 1 - Device	<u> </u>

c. Map the Traffic source port, Host-1 in following figure with **DUT In port**. This will enable IxNetwork to map the traffic ports to switch ports.



d. Map Traffic destination port, Host-2 in following figure with **DUT Out port**. This will enable IxNetwork to map the traffic ports to switch ports.

Openflow Traffic Converte	er Wizard - DUT Out Port To Ixia Port M	1apping - Name
DUT Out Ports		
DUT Out Por	User Flow Ranges	Ixia Port (Traffic Dst)
1 3	- FlowRange-1 - OFChannel-1 - Connected	Host-2

e. Leave everything default on next two windows.

	Deut.	hinner a		ARP via	Interfa	Magazites	0.1
	Port	Name	Range Size	Interface	ce	MAC Address	Gateway MAC
1	Host-1	Traffic - 1 FlowRange-1 - OF	5	Γ	NA	00 00 00 00 11 01	00 00 00 00 22 01
2		Traffic - 2 FlowRange-2 - OF	5	Г	NA	00 00 00 00 11 06	00 00 00 00 22 06

f. Select **Generate and Overwrite Existing Configuration** option to remove previously generated traffic endpoint. Click Finish to complete the wizard configuration.

Ope	nflow Traffic Converter Wizard - Name
	C Generate and Append to Existing Configuration
	Generate and Overwrite Existing Configuration

g. Go to each host port and make sure the wizard has generated correct traffic endpoint.

Kanario	_	am Ports	Devices Interfaces OF	Channels Flow I	Ranges Actio				
		Port	Name	Range Properties	Range Size	ARP via Interface	Interface	MAC Address	Gateway MAC
e Ports	1	Host-1	Traffic - 1 FlowRange-1		5	Г	NA	00 00 00 00 11 01	00 00 00 00 22 01
Chassis	2		Traffic - 2 FlowRange-2		5	Γ	NA	00 00 00 00 11 06	00 00 00 00 22 06
	3	Host-2	Traffic - 1 FlowRange-1		5	Γ	NA	00 00 00 00 22 01	00 00 00 00 11 01
Protocols	4		Traffic - 2 FlowRange-2		5	Γ	NA	00 00 00 00 22 06	00 00 00 00 11 06
Protocol Interfaces OpenFlow Controller Running Host-1 Host-2									

- 16. Go to Traffic Wizard to create traffic flow between Host-1 and Host-2
 - a. Select **Traffic** from the tree and click on **Add L2-3 Traffic** button in the ribbon. It opens the **Advance Traffic Wizard**.

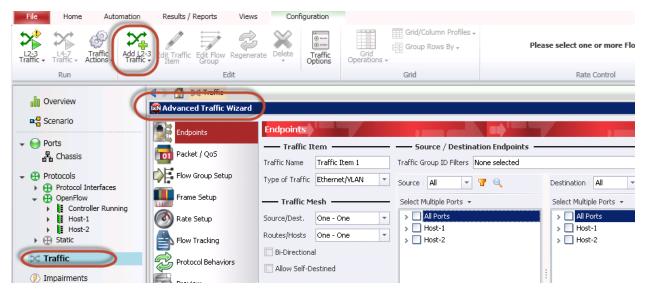


Figure 34: Advanced Traffic Wizard

b. Select **Type of Traffic** as **Ethernet/VLAN** and use **OpenFlow** encapsulation filter for **Source** and **Destination** endpoints.

💀 Advanced Traffic Wizard			
Endpoints	Endpoints		LXN
Packet / QoS	Traffic Item Traffic Name Traffic Item 1	Source / Destination Endpoints - Traffic Group ID Filters None selected	·
Frame Setup	Type of Traffic Ethernet/VLAN	Source All Select Minon-MPLS	Destination OpenF 🤉 🐨 🔍 况 Select Multiple Ports 👻
Rate Setup	Source/Dest. One - One 🔻	> AL2VPN	All Ports Host-1
Flow Tracking	Routes/Hosts One - One Bi-Directional	> + HMPLS 6PE	> Host-2
Protocol Behaviors	Allow Self-Destined	6VPE BGP-VPLS	:
Preview		MAC-In-MAC Data Center MVPN-P2MP	
Validate		MPLS-TP LISP TRILL FabricPath	
		OpenFlow	

c. Select source and destination endpoint and click Next.

🔊 Advanced Traffic Wiz	ard			_ 🗆 >
Endpoints	Endpoints			N
Packet / QoS	Traffic Item			
· · ·	Traffic Name Traffic Item 1	Traffic Group ID Filters None selected		-
Flow Group Setup	Type of Traffic Ethernet/VLAN 💌	Source All 🔻 🝸 🔍	Destination 🛛 🔽 🔽	
Frame Setup	Traffic Mesh	Select Multiple Ports 👻	Select Multiple Ports 👻	
🚳 Rate Setup	Source/Dest. One - One 💌	All Ports		
Flow Tracking	Routes/Hosts One - One 💌	V Open-Flow	Host-2	
Rrotocol Behaviors	Bi-Directional	 Mac Ranges 00:00:00:00:11:01 Cnt: 5 	Open-Flow Mac Ranges	
	Allow Self-Destined	 ✓ 00:00:00:11:01 Cit: 5 ✓ 00:00:00:00:11:06 Cit: 5 		5
Preview		> Host-2	00:00:00:22:06 Cnt: 5	5
Validate				
		🕞 🕫 💥 — Endpoint Sets ———		
1		Encapsulation Source Endpoints	Destination Endpoints Traffic Groups	
U	Number of hosts per Route 1	✓ Name: EndpointSet-1		
		1 > Ethernet II.VLAN 2 Endpoints	2 Endpoints None selected	
	Merge Destination Ranges	✓ Name: EndpointSet-2		
	Uncheck this option to test overlapping VPN addresses	2 <new> <new></new></new>	<new> None selected</new>	
	Max # of VPN Label Stack 2	Brev Ne	xt Einish Cancel H	Help

Figure 35: Advanced Traffic Wizard, Source and Destination Endpoints

d. Leave default values for Packet/QoS, Flow Group setup and Frame Setup page.

Advanced Traffic Wizard					
Endpoints	Rate Setup				
	 All Encapsulations Per Encapsulation 				
Packet / QoS	Tx Port Encapsulation Transmission Ta		Target Rate Dis		
Flow Group Setup	Name: EndpointSet-1				
	1 Host-1 Ethernet II.Custom Continuous 100			enly split port rate among the	
Frame Setup					
Rate Setup					
	All Encapsulations - Same settings will be applied to all (1) a	encapsulation(s)			
Flow Tracking		 Flow Group Transm	 iission Mode		
Rrotocol Behaviors	C Tabula and	Continuous	[
	Interleaved	-	Stop After	1 iterations	
Preview	Sequential	🔘 Fixed Packet Count	Start Delay	0 bytes 🔻	
Validate	The Interleaved Transmit mode will interleave the packets from each Flow Group when sending Traffic	O Fixed Iteration Count	Minimum Gap	12 bytes	
	packets from each flow Group when sending frame	O Fixed Duration			
		🔘 Burst (Auto)			
		🚫 Burst (Custom)			
		How it will look on the wire:	1 2 3 1 2	3 1 2 3 1 2 3	
	C Line rate 10.00 %	Ports:			
	Packet rate 1000.00 per second	Apply rate on all ports			
	C Layer2 Bit Rate 1000.00 bps -	Split rate evenly among Flow Groups:] ports		
		Apply port rate to all Florence	ow Groups		
		Split port rate evenly a			
			Prev	Next Eini	iish

e. Set the desired traffic load on **Rate Setup** page and click **Next**.

f. On Flow Tracking page, enable Source/Dest Value Pair tracking option. Click Next.

Advanced Traffic Wizard	
Endpoints	Flow Tracking
Packet / QoS	Traffic Item
Flow Group Setup	Source/Dest Endpoint Pair
How Group Setup	Source/Dest Value Pair Offset from Root
Frame Setup	Source/Dest Port Pair Offset 0 bits
	Source Endpoint
Rate Setup	Dest Endpoint
	Values Values Values
Flow Tracking	Traffic Group ID
	MPLS Flow Descriptor 2 <type add="" to="" value=""></type>
Protocol Behaviors	Frame Size
Preview	Flow Group
	Ethernet II : Destination MAC Address Ethernet II : Source MAC Address
Validate	Ethernet II : Ethernet-Type
	Ethernet II : PFC Queue
	Egress Tracking
	Eachiel Jahren Bie Maargumenenke
	Numbers of Riss 8 Minimum step size: 0.0
	Ethernet:Outer Encapsulation Ethernet
	Offset Outer VLAN Priority (▼ 1 0.00 1.0
	<u>3 1.42 2.0</u> 4 2.00 2.6
	5 2.82 4.0
X	
	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
	Prev Next

g. Skip '**Protocol Behaviors** window and go to **Preview** window to view how the traffic flow will look like and click **Finish** button to end traffic wizard.

Endpoints	Pre	view							Ix
Packet / QoS		- Flow	Groups/Packets		🧿 Current Tra	affic Item 🔘	All Traffic Items	View Flow G	iroups/Pack
Flow Group Se	tup	Y Po	Flow Group			Traf	fic Item	Click	
Frame Setup	1	▶ Tra	iffic Item 1-EndpointSet-1 - Flo	w Group 0001	Traffic Item 1			butto	
Rate Setup									
Flow Tracking									
Protocol Beha	viors								
Preview		10 Packet:	s for flow group: Traffic Item 1	I-EndpointSet-1 - Flow	 Group 0001				
Validate	Pack	et#	Destination MAC Address	Source MAC Address	Ethernet-Type	PFC Queue	VLAN Priority	VLAN-ID	
		1	00:00:00:00:22:01	00:00:00:00:11:01	8100	0	1	1	
		2	00:00:00:00:22:02	00:00:00:00:11:02	8100	0	1	2	
		3	00:00:00:00:22:03	00:00:00:00:11:03	8100	0	1	3	
		4	00:00:00:00:22:04	00:00:00:00:11:04	8100	0	1	4	
		5	00:00:00:00:22:05	00:00:00:00:11:05	8100	0	1	5	
		6	00:00:00:00:22:06	00:00:00:00:11:06	8100	0	1	6	
	199	7	00:00:00:00:22:07	00:00:00:00:11:07	8100	0	1	7	
	0	8	00:00:00:00:22:08	00:00:00:00:11:08	8100	0	1	8	
		9	00:00:00:00:22:09	00:00:00:00:11:09	8100	0	1	9	
	7 =	10	00:00:00:00:22:0a	00:00:00:00:11:0a	8100	0	1	10	
	X		1 4 1 1 1						

17. Click L2-3 Traffic button to push the traffic on port and start traffic.

File Home Automation	Results / Reports	Views Config	guration				
L2.3 L4-7 Traffic - Actions -	2-3 Edit Traffic Edit Flow R	egenerate Delete	© === ⊚ === Options O	Grid/Column Pr		0%	Host-1
Run	Edit	:		Grid		Rate Control (1	out of 1 Fl
Overview	Flow Groups Topology	CL2-3 Traffic Items					- 0
¤< <mark>ª</mark> Scenario	Transmit State	Suspend	Tx Port	Rx Ports		ow Group Name	Configu
Ports Protocols		raffic Item Name: T Host-1	raffic Item 1	TX Mode: Interleaved, Src/Dst Host-2;)neToOne, Route Mes tem 1-EndpointSet	
	Please wait Apply Traffic:	Configuring Traffic Sta	atistics Settings. 78%				
► 💮 Static	Configuring St	atistics Views: Traffic	item view profile	e			
X Traffic Traffic Items X Traffic Items X Traffic Item 1 X L2-3 Flow Groups					Ca	incel	
Impairments	Select Views]					
QuickTests							
Captures							

Results Analysis

• On **Traffic Item Statistics** verify that traffic is flowing through the switch without packet loss.

	(a) Select V	Views	Flow Detective	e Data Plar	e Port Statistic	s User Defir	ned Statistics	Traffic Iten	Statistics	
Traffic Item 1 270,176 270,176 0 0.000 1,000.000 1,000.000 23,775,488 88,000.000 88,000.000	Traffic Item	Tx Frames	Rx Frames	Frames Delta	Loss %	Tx Frame Rate	Rx Frame Rate	Rx Bytes	Tx Rate (Bps)	Rx Rate (Bps)
	Traffic Item 1	270,176	270,176	0	0.000	1,000.000	1,000.000	23,775,488	88,000.000	88,000.000
	name ream r	270,170	270,170	0	0.000	1,000.000	1,000.000	23,773,400	00,000.000	00,000.

Figure 36: Traffic Item Statistics view

• Select the **Traffic Item** and Right click on it. Select drill down per **Source/Destination Value Pair** tracking option. This drill down view will display traffic statistics per individual source and destination MAC address.

Select Views Flow Det	ective Da	ta Plane Port S	tatistics U	ser Defined S	statistics T	raffic Item Statistics
Back 🔻 👦 Traffic Item	Source/Dest	Value Pair				
Source/Dest Value Pair	Tx Frames	Rx Frames	Frames Delta	Loss %	Tx Frame Rate	Rx Frame Rate R
00:00:00:00:11:01-00:00:00:00:22:01	16,989	16,989	0	0.000	100.000	100.000
00:00:00:00:11:02-00:00:00:00:22:02	16,989	16,989	0	0.000	100.000	100.000
00:00:00:00:11:03-00:00:00:00:22:03	16,988	16,988	0	0.000	100.000	100.000
00:00:00:00:11:04-00:00:00:00:22:04	16,988	16,988	0	0.000	100.000	100.000
00:00:00:00:11:05-00:00:00:00:22:05	16,988	16,988	0	0.000	100.000	100.000
00:00:00:00:11:06-00:00:00:00:22:06	16,988	16,988	0	0.000	100.000	100.000
00:00:00:00:11:07-00:00:00:00:22:07	16,988	16,988	0	0.000	100.000	100.000
00:00:00:00:11:08-00:00:00:00:22:08	16,988	16,988	0	0.000	100.000	100.000
00:00:00:00:11:09-00:00:00:00:22:09	16,988	16,988	0	0.000	100.000	100.000
00:00:00:00:11:0a-00:00:00:00:22:0a	16,988	16,988	0	0.000	100.000	100.000

• Make policy change on controller and push it to the switch and verify that switch changes packet forwarding decision according to the rule set by the controller.

Leave traffic and OpenFlow protocol in *Running* state. Go to **OpenFlow Controller Flow Range** and clear the second flow range.

	Overview Scenario	< > C	🕈 🕀 Protoco s Interfaces		DpenFlow >									
- -			OF Channel	Enable	Description	Number of Flows	Configure Range	In Port	Ethernet Source	Ethernet Destination	Ethernet Type			IPv4 Source (addr/mask)
-	Lassis	1	OFChannel-1	2	FlowRange-	5		2	00 00 00 00 11 01	00 00 00 00 22 01	*	1	*	*
		2			FlowRange-	5		2	00 00 00 00 11 06	00 00 00 00 22 06	*	6	*	*
- 🕀	Protocols													
•	Protocol Interfaces													
-	OpenFlow													
	 Controller Running 													
	Learned Informatio													
	Bevice-1													

Ensure following MAC address and VLAN stops receiving traffic. Go to traffic statistics to verify this functionality.

Devices	Interfaces	OF Chann	neis Pio	w Ranges A	ctions					
	OF Channel	Enable	Descri	ption Number Flows	I Configure	e Range In	Port	Ethernet Source	Ethernet Destination	Ethern Type
	OFChannel-1	☑	FlowRa	nge-	5		2	00 00 00 00 11 01	00 00 00 00 22 01	*
			FlowRa	nge-	<u>.</u>		2	00 00 00 00 11 06	00 00 00 00 22 06	*
			Conf	igure Flow Er	ntry Range	2				
			Range	configuration ⁻						
				Fie	lds	In Port		Ethernet Source	Ethernet Destin	ation
			1	Start Value		2		00 00 00 00 11 06	00 00 00 00 22	2 06
			2	Step Value		0		00 00 00 00 00 00 01	00 00 00 00 00	0 01
			3	Repeat Coun	t	1		1	1	
			4	Wrap Count		65535		1000000	1000000	
	Select Views		5	Increment Ty	pe	Incremen	nt	Increment	Increment	
1 10 2 10	<mark>at Name</mark>).200.134.41/C).200.134.41/C).200.134.41/C	ard	Total (Count 5		Update	8	1		
				In Port	Etherr	et Source		Ethernet Destination	VLAN ID	
			1	2	00:00:00:0	00:11:06	00	0:00:00:00:22:06	6	
			2	2	00:00:00:0	00:11:07	00):00:00:00:22:07	7	
			3	2	00:00:00:0	00:11:08	00):00:00:00:22:08	8	
			4	2	00:00:00:0	00:11:09	00):00:00:00:22:09	9	
				2	00:00:00:0	10:11:0a	00):00:00:00:22:0a	10	

🌾 Back 🔻 💮 Traffic Item	Source/Dest	Value Pair				
Source/Dest Value Pair	Tx Frames	Rx Frames	Frames Delta	Loss %	Tx Frame Rate	Rx Frame Rate
00:00:00:00:11:01-00:00:00:00:22:01	110,789	110,789	0	0.000	100.000	100.000
00:00:00:00:11:02-00:00:00:00:22:02	110,789	110,789	0	0.000	100.000	100.000
00:00:00:00:11:03-00:00:00:00:22:03	110,788	110,788	0	0.000	100.000	100.000
00:00:00:00:11:04-00:00:00:00:22:04	110,788	110,788	0	0.000	100.000	100.000
00:00:00:00:11:05-00:00:00:00:22:05	110,788	110,788	0	0.000	100.000	100.000
00:00:00:00:11:06-00:00:00:00:22:06	110,788	46,839	63,949	57.722	100.000	0.000
00:00:00:00:11:07-00:00:00:00:22:07	110,788	46,840	63,948	57.721	100.000	0.000
00:00:00:00:11:08-00:00:00:00:22:08	110,788	46,840	63,948	57,721	100.000	0.000
00:00:00:00:11:09-00:00:00:00:22:09	110,788	46,840	63,948	57.721	100.000	0.000
00:00:00:00:11:0a-00:00:00:00:22:0a	110,788	46,840	63,948	57.721	100.000	0.000

• Select the flow range again and see if switch starts forwarding traffic for that MAC/VLAN again.

Overview	< > 🕻	Protocols 🕀) 🤁 OpenFlow	Controller R	unning 🕨		
scenario	Devices	Interfaces	OF Channels	Ranges Actions	1		
→ ⊖ Ports		OF Channel	Enable Descripti	on Number of Flows	nfigure Range In P	ort Ethernet Source	Ethernet Destination
🖧 Chassis	1	OFChannel-1	FlowRang		2		
		ined Statist		: Item Statistics	s Data Pla	ne Port Statistics	Flow Detect
	Jser Def	ined Statist Source/Dest		: Item Statistics	s Data Pla	ne Port Statistics	Flow Detect
	<u>c Item</u>			Titem Statistics	Data Plan		Flow Detect
🞼 Back 🔻 👧 Traffic	<u>c Item</u>	Source/Dest	<u>: Value Pair</u> Rx Frames		Loss %	T× Frame Rate	
Back Traffic Source/Dest Value Pair	<u>c Item</u> 	<u>Source/Dest</u> Tx Frames	<u>Xalue Pair</u> Rx Frames 147,189	Frames Delta	Loss %	Tx Frame Rate 100.000	Rx Frame Rate 100.000

147,188

147.188

50,770

50,771

50,771

50,771

50,771

0

96,418

96,417

96,417

96,417

96,417

0

0.000

0.000

65.507

65.506

65.506

65.506

65,506

100.000

100.000

100.000

100.000

100.000

100.000

100.000

100.000

100.000

100.000

100.000

100.000

100.000

100.000

Conclusions

This test case can be used to verify:

00:00:00:00:11:04-00:00:00:00:22:04

00:00:00:00:11:05-00:00:00:00:22:05

0:00:00:00:11:06-00:00:00:00:22:06

00:00:00:00:11:07-00:00:00:00:22:07

00:00:00:00:11:08-00:00:00:00:22:08

00:00:00:00:11:09-00:00:00:00:22:09

0:00:00:00:11:0a-00:00:00:00:22:0a

- Switch installs correct flow entries in its flow table as pushed by the controller.
- It makes packet forwarding decision as per the rule set by the controller.
- It complies to one or more action set by the controller.

147,188

147,188

147,188

147,188

147,188

147,188

147.188

Test Variables

The following variables can be used to verify the behavior of an OpenFlow Switch.

1. L3 Forwarding Test

Set the matching criteria on L3 header field such as Source IP, Destination IP and DSCP value

2. Use multiple Actions

Apply multiple actions for each Flow range. Use one of the following actions along with Output and verify that switch correctly performs multiple actions on the packets.

Set VLAN ID	Add or Change VLAN ID for matching flow
Strip VLAN Header	Strip the VLAN header from the matching flow
Set Ethernet Src/Dst.	Change source/destination MAC for matching flow
Set IP DSCP	Change DSCP value for matching flow
Set IPv4 Src/Dst.	Change IP address for matching flow
Set Transport Src/Dst.	Change TCP/UDP port

Test Case: Switch Flow Failover Performance Test

Overview

Networking infrastructure has become key component for any business. Today's networks carries Voice, Data and Video traffic over the same network infrastructure. Even the few seconds outage can cause huge impact on the business. Therefore networks are designed with redundant links to minimize the downtime and increase the reliability. The key challenge for any networking device is to be able to detect the failure and forward traffic to redundant path without affecting application traffic performance.

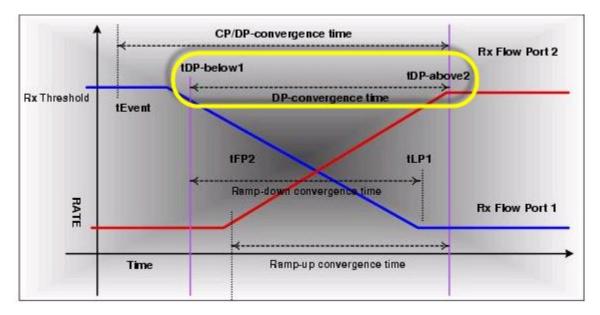
Objective

The objective of this test case is to verify Switch performance to handle convergence in the network and ability to converge the traffic to secondary path without affecting traffic forwarding performance. For this test, Ixia's unique TrueView convergence test methodology will be used to measure the data-plane to data-plane convergence time of the switch.

TrueView convergence test provides the following measurements:

- Timestamp of every packet
- Timestamp the first packet in and last packet out on a port per flow
- Ability to capture protocol event timestamp
- Ability to capture link event timestamp
- Ability to monitor receive rate and timestamp when "Below" thresholds are crossed
- Ability to monitor receive rate and timestamp when "Above" thresholds are crossed
- Ability to timestamp link event (up/down)

The diagram below shows, when traffic drops below threshold value on primary path (Blue line), it will latch tDP-below1 timestamp and when traffic reaches above threshold value on a secondary path (Red line), it will latch tDP-above2 timestamp. This timestamp will give data-plane convergence time.



DP-DP Convergence time = tDP Above timestamp – tDP Below timestamp

Figure 37: CP/DP Convergence Time, calculation



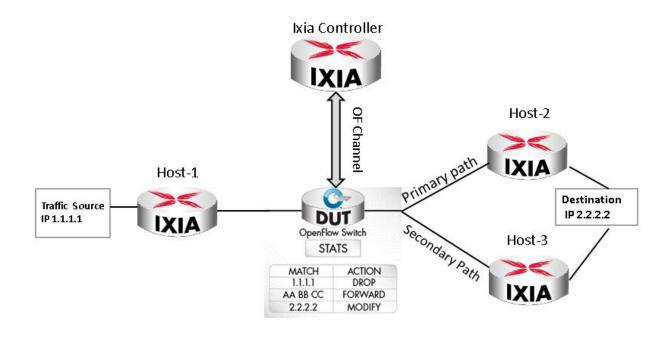


Figure 38: Switch Flow Failover Performance Test, test setup

Step-by-Step Instructions

1. Reserve 4 Ixia port (1 for controller and 3 for data-plane traffic)

hassis 🕂 Add Chass	is 💥 😂 🌮 More 🗸 All ports	•	Ports i	n confi	guration 🖶 Add Offline Ports	All ports
Chassis/Card/Port	Туре	¢		State	Name	Chassis/Card/Port
/ 🥥 10.200.134.41	ixos 6.40.0.71 eb, protocol 7.00.0.486		1 ▶	0	Host1	10.200.134.41:02:13
👻 耳 Card 02	16 PORT 10/100/1000 LSM XMV16		2	0	Host2	10.200.134.41:02:14
Opt 01	10/100/1000 Base T		3	0	Host3	10.200.134.41:02:15
Port 02	10/100/1000 Base T	Add ports	4	0	Controller	10.200.134.41:02:16
Ort 03	10/100/1000 Base T	Add ports				
Ø Port 04	10/100/1000 Base T	>>>>				
Ort 05	10/100/1000 Base T					
Ort 06	10/100/1000 Base T	Assign to remaining				
Ø Port 07	10/100/1000 Base T	remaining				
A						

Figure 39: Port Selection window

2. Enable OpenFlow on all 4 ports by selecting the OpenFlow check box on the RoutingSwitching tab on the Protocols window.

Overview	Routi	ng/Switching MPLS Multicast	Carrier Eth	emet	Access	Authentication	Data Cen	ter Bridging 🛛 W	ireless		_
Cenario		Port Description	Port Owner	Link	ARP	PING for IPv4	BFD	BGP/BGP+	EIGRP	ISIS L2/L3	OpenFla
Ports	1	Controller - 10/100/1000 Base	IxNetwor	0	N	Г	Г	Г	Г	Г	N
Chassis	2	Host1 - 10/100/1000 Base T	IxNetwor	0	N	Γ	Γ	Γ	Γ	Γ	
	3	Host2 - 10/100/1000 Base T	IxNetwor	0	◄		Γ		Γ	Γ	
🙀 Protocols	4	Host3 - 10/100/1000 Base T	IxNetwor	0	☑				Γ	Γ	

Figure 40: RoutingSwitching tab, Protocols window

3. Go to **Connected Interface** tab to configure Emulated Controller IP Address and **Gateway Address**.

Use OpenFlow switch's IP address if you have only one switch. Ensure that ARP is resolved for for OF Channel. Do not configure anything on host ports.

Protocols Protocol T	Send ARP Send NS raffic Up ID Ping Refrest	Add Protocols +	Add Interface Add Multiple Interfaces Remove Interface	🖶 Add 💥 Rem	IPv4 🔂 Adı ove IPv4 💥 Rei
ACUO	ns	Dullu			
uli Overview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Interview Intervi	Connected Interfaces Uncon	nnected Interfaces	faces) III Controller GRE Tunnels Discover er Gateway IV NS on Link I	ed Neighbors Jp I Ser	Interface Addressind Single NS per Gate
✓	Interface Descripti	on Enable	IPv4 Address (10.0.x.x - Reserved IP)	IP∨4 Mask Width	Gateway
- 🕀 Protocols	1 Connected - Protoco	olint 🔽 🔪	10.200.134.233	24	10.200.134.234
Protocol Interfaces Controller					

Figure 41: Connected Interface tab

4. Go to Ports tab and select the **Port Role**.

You can select any of the following:

- a. **Control**: for Controller port
- b. Traffic: for host ports

Overview	Diag	ram Ports	Devices Interfac	es OF Channels	Flow Ranges Actions Traff	ic Endpoints
Scenario		Port	Protocol State	Number of Devices	Number of Traffic Endpoints	Port Role
orts	1	Controller	1	1	NA	Control
Chassis	2	Host1		NA	1	Traffic
	3	Host2		NA	1	Traffic
otocols	4	Host3		NA	1	Traffic
Protocol Interfaces OpenFlow Controller Host1 Host2 Host3						

Figure 42: Ports Tab

5. Go to **Devices** tab and configure **Number Of Interfaces** as *1*. The number of interfaces equals the number of emulated NICs of a controller.

0)) Overview	d > f			OpenFlow →	hannels Flow Ranges	Actions 1	Fraffic Endpoints
-		Port	Enable	Description	Device Role	Version	Number of Interfaces
Ports Chassis	1	Controller	प	Device-1	Controller	1.0.0	1
 Protocols Protocol Interfaces 							

Figure 43: Devices tab

6. Go to **Interfacees** tab and assign the interface previously created under protocol interface. This interface is used for the control-plane (OF Channel). Configure **Number** of **Channels** as *1*.

Overview	< > 🔂 🕀 Protocols > 🔁 OpenFlow >
	Diagram Ports Devices Interfaces OF Channels Flow Ranges Actio
🖌 🥯 Ports	Biogram From Booked and Booked From Franges From Franges
🛱 Chassis	To change number of Interfaces, select 'Devices' tab, and enter number in 'Numbe
Protocols	Enable Protocol Interface Number of OF Channels
Protocol Interfaces	1 Connected - ProtocolInterface - 100:01 -
OpenFlow	Unassioned Interface
🕨 🔂 Static	Connected - Protocolinterface - 100:01 - 4

7. Go to **OF Channels** tab and enter DUT IP address in **Remote IP** field. Enter Number of Flow Ranges as 2.

۹ > ۲	🚡 🤀 Protoc	-	OpenFlow >							
Diagram	i Ports De	vices Int	erfaces OF Char	Flow Range	s Actions Tra	affic Endpoints				
To cha	nge number of	OF Channe	els, select 'Interfa	ces' tab, and enter	number in 'Numbe	er of OF Channel	ls' field			\frown
	Interface	Enable	Description	Local IP	Remote IP	Use Datapath ID	Datapath ID	Datapath ID (In Hex)	Startup Feature Request	Number of Flow Ranges
1	Connected -	•	OFChannel-1	10.200.134.233	10.200.134.234		0	0	N	2

 Under Flow Ranges tab, configure Ethernet Type, Source and Destination IP address. Use wild card (*) for remaining all fields. Use same IP address for both ranges. Configure correct In Port field with the switch port number that is connected to Ixia host port generating traffic.

Diagram	Ports	Devices	Interfaces	OF Channels	Flow Rang	Jes Act	ions Traff	fic Endpoints					_				
	OF Channel	Enable	Description	Number of Flows	Configure Range	In Port	Ethernet Source	Ethernet Destination		VLAN ID	VLAN Priority	IPv4 Source ((addr/mask)	Pv4 Destination (addr/mask)	IP Protocol	IP DSCP	Transport Source/ICMP	Transport Destination/ICMP Code
1 0)FChann	2	Primary	1		1	*	*	0800	*	*	1.1.1.1/24	2.2.2.2/24	*	*	*	*
2		V	Secondary	1		1	*	*	0800	*	*	1.1.1.1/24	2.2.2.2/24	*	*	*	*

Figure 44: Flow Ranges tab

9. Create **Number of Action** from config tab. Change **Match Type** to *Strict* and **Priority** value for both flows. The flow with higher priority value gets forwarded first.

de la constante de la constant		cols > 💮 C		annels Flow	Ranges	Actions Tra	affic Endpoint	5		
			•		1000				Do not Add on	
	OF Channel	Match Type	(sec)	Hard Timeout (sec)	Priority	Send Flow Removed	Check Overlap	Emergency Flow	Do not Add on Channel Up	Actions
1	OFChannel-1	Strict	0	0	10					1
2		Strict	0	0	5				Γ	1
\ Match										

Figure 45: Flow Ranges tab (2),

10. Go to Actions tab and select Action Type as *OutPut* and **Output Port Type** as *Custom/Manual*. Enter the '**Output Port**' value of the switch where the traffic will be forwarded to.

Flow Ranges	Action Type	Output Port Type	Output Port	Max Byte Length
 Primary - OFChannel-1 - Conn	Output 💌	Custom/Manual	2	0
Secondary - OFChannel-1 - C	Output	Custom/Manual	3	0

Figure 46: Actions tab

11. Start OpenFlow protocol using the OpenFlow control on the ribbon, and make sure OF Channel comes up.

Protocols OpenFlow OpenFlow Actions Gr	Traffic Add oup ID Protoc	Start Open									
Actions	Build	Selected	Grid	d i							
u∭ Overview ¤4 Scenario	Devices In	Protocols > 🔁 Op terfaces 0F Channels number of Interfaces, s	Flow Ranges			of Interfaces' field	1				
Ports	De	Device Enable	Protocol Interfa	Channe	els Echo	Interval T	ible Echo Timeout Timeout Option	Multiplier / Timeout Value		Interval (ms	ec) LLDP
Protocols Protocol Interfaces	Dev	ice-1 - Con 🔽	Connected - Prot		1	10	Timeout		000		000
OpenFlow Gontroller Running Hi Host1											
OpenFlow Controller Running Host1 Host2 Host3		t Views Port	CPU Statistics	OpenFlow C	ontroller Agg	regated Statis	tics				
OpenFlow			CPU Statistics	OF Channel	Ontroller Agg OF Channel C onfigured Up	regated Statist OF Channel Le arned Up		Hellos Tx H		o Requests Tx	Echo Replies I
	Stat Na		Port Name	OF Channel	OF Channel C	OF Channel Le	OF Channel Flap	Hellos Tx H		o Requests Tx	Echo Replies I
OpenFlow DenFlow DenFlow DenFlow DentFlow DentFlow DentFlow Host1 DentFlow DentFl	Stat N.	ame	Port Name	OF Channel	OF Channel C	OF Channel Le	OF Channel Flap	Hellos Tx H		o Requests Tx	Echo Replies I
OpenFlow OpenFlow OpenFlow OpenFlow OpenFlow Host1 Host2 Host3 OpenFlow Static XTraffic	Stat No 1 10.200 2 10.200	ame 1.134.41/Card02/Port:	Port Name 13 Host1 14 Host2	OF Channel	OF Channel C	OF Channel Le	OF Channel Flap	Hellos Tx H		o Requests Tx	Echo Replies F

Figure 47: Controller Running window

To verify the switch capabilities, supported action or any error condition, go to **Learned Information** window. Several tabs as shown in below figure are available on this window. Click **Refresh** button in the ribbon to update this information. Go to **OF Channel Learned Info** tab. It displays several panes. The left pane displays OF Channel information including TCP port, Data path ID, Reply state and any error message received from the Switch. When you select a row (OF Channel), the right pane displays all OpenFlow enabled ports information on that switch.

ocols OpenFlow OpenFlow Traf Actions Group	ffic o ID Actions		dd ocols - uild							
la Quastau	< ≽ 🚮	🔁 OpenFlow 🕨 🚺 Cont	roller Running 🔸 🖹 Learned Inf	formation						
Overview	Learned Info Becords :									
📽 Scenario		y : 0, Flow Stat : 0, Flow Ag	rr Stat - 0. Port Stat - 0.							
•	Vendor Stat : 0, Desc. S	tat : 0, Table Stat : 0, Queue	Config: 0, Queue Stat: 0							
Ports										
Chassis	OF Channel Learned Info	Flow Stat Flow Aggregated S	atat Port Stat Vendor Stat Des	scription Stat Table Stat Que	sue Config Queue Stat Top	ology Learned Info				
	Refresh Learned Info for									
Protocols	Device All	▼ Interface ∆	*							
Protocol Interfaces	Device All	■ Interface All	-							
Protocols Protocol Interfaces OpenFlow	Device All Select the rows to send trip									
Protocol Interfaces OpenFlow Controller Running			th ID Data Path ID (Hex)	Local Port Remote Port Number Number	Reply State	Max Buffer Size		Local IP	Remote IP	Data Path ID
Protocol Interfaces OpenFlow	Select the rows to send trig	gger/stat requests Remote IP Data Pa	th ID Data Path ID (Hex) 524,500 0x0000010200134234		Reply State Feature Reply Received	Max Buffer Size	1	Local IP 10.200.134.233	Remote IP 10.200.134.234	Data Path ID
Protocol Interfaces OpenFlow Controller Running Learned Informs	Select the rows to send trig	gger/stat requests Remote IP Data Pa		Number Number			1 2	10.200.134.233 10.200.134.233	10.200.134.234 10.200.134.234	1,108,102,824,500 1,108,102,824,500
	Select the rows to send trig	gger/stat requests Remote IP Data Pa		Number Number			1 2 3	10 200.134 233 10 200.134 233 10 200.134 233	10.200.134.234 10.200.134.234 10.200.134.234	1,108,102,824,500 1,108,102,824,500 1,108,102,824,500
Protocol Interfaces OpenFlow Controller Running E Controller Running Charles Device1 Host1	Select the rows to send trig	gger/stat requests Remote IP Data Pa		Number Number			1 2 3 4	10.200.134.233 10.200.134.233 10.200.134.233 10.200.134.233	10.200.134.234 10.200.134.234 10.200.134.234 10.200.134.234 10.200.134.234	1,108,102,824,500 1,108,102,824,500 1,108,102,824,500 1,108,102,824,500
Protocol Interfaces Controller Running Controller Running Controller Running Controller Running Controller Running Controller Running Loarned Inform H Host1 H Host3	Select the rows to send trig	gger/stat requests Remote IP Data Pa		Number Number			1 2 3 4 5	10.200.134.233 10.200.134.233 10.200.134.233 10.200.134.233 10.200.134.233 10.200.134.233	10.200.134.234 10.200.134.234 10.200.134.234 10.200.134.234 10.200.134.234 10.200.134.234	1,108,102,824,500 1,108,102,824,500 1,108,102,824,500 1,108,102,824,500 1,108,102,824,500 1,108,102,824,500
Protocol Interfaces OpenFlow Il Controller Running Il Controller Running Il Host1 Il Host3 Static	Select the rows to send trig	gger/stat requests Remote IP Data Pa		Number Number			1 2 3 4 5 6	10.200.134.233 10.200.134.233 10.200.134.233 10.200.134.233 10.200.134.233 10.200.134.233	10.200.134.234 10.200.134.234 10.200.134.234 10.200.134.234 10.200.134.234 10.200.134.234	1,108,102,824,500 1,108,102,824,500 1,108,102,824,500 1,108,102,824,500 1,108,102,824,500 1,108,102,824,500
Protocol Interfaces OpenFlow If Controller Running Elecaned Inform B Device1 Host1 Host2	Select the rows to send trig	gger/stat requests Remote IP Data Pa		Number Number			1 2 3 4 5 6 7	10.200.134.233 10.200.134.233 10.200.134.233 10.200.134.233 10.200.134.233 10.200.134.233	10.200.134.234 10.200.134.234 10.200.134.234 10.200.134.234 10.200.134.234 10.200.134.234	1,108,102,824,500 1,108,102,824,500 1,108,102,824,500 1,108,102,824,500 1,108,102,824,500 1,108,102,824,500
Protocol Interfaces Proto	Select the rows to send trig	gger/stat requests Remote IP Data Pa		Number Number			1 2 3 4 5 6 7 8	10.200.134.233 10.200.134.233 10.200.134.233 10.200.134.233 10.200.134.233 10.200.134.233	10.200.134.234 10.200.134.234 10.200.134.234 10.200.134.234 10.200.134.234 10.200.134.234	1,108,102,824,500 1,108,102,824,500 1,108,102,824,500 1,108,102,824,500 1,108,102,824,500 1,108,102,824,500
Protocol Interfaces OpenFlow Econtroller Running Electrod Inform Hots1 Host3 Static	Select the rows to send trig	gger/stat requests Remote IP Data Pa		Number Number			1 2 3 4 5 6 7 7 8 8	10.200.134.233 10.200.134.233 10.200.134.233 10.200.134.233 10.200.134.233 10.200.134.233 10.200.134.233 10.200.134.233	10.200.134.234 10.200.134.234 10.200.134.234 10.200.134.234 10.200.134.234 10.200.134.234 10.200.134.234	1,108,102,824,500 1,108,102,824,500 1,108,102,824,500 1,108,102,824,500 1,108,102,824,500 1,108,102,824,500 1,108,102,824,500

Figure 48: OF Channel Learned Info

From **OF Channel Learned Info** tab use **On Demand Messages** button to request switch to send flow table information.

🚳 🗋 🗁 🔚 + 🐴 + 📚 🖉	2 • 🖲 💭 • 🔲 📶 🎲 🖘 👘 Prote	ocols Tools IxNetwork [ProntoDemo.ixncfg]
File Home Automation	Results / Reports Views Cor	nfiguration
Protocols OpenFlow OpenFlow Actions	affic Refresh OF On Demand Messages OF Channels Actions	Add Protocols - Build
Overview		Controller Running 🕨 🖹 Learned Information
	Learned Info Records :	Open Flow Learned Info Trigger Settings
■x [®] Scenario	OF Channel : 1, Topology : 0, Flow Stat : 7, Vendor Stat : 0, Desc. Stat : 0, Table Stat :	Flow Stat Flow Aggregated Stat Port Stat Vendor Stat Vendor Message Descr
✓ OPorts	OF Channel Learned Info Flow Stat Flow Ag	Flow Stat
La Chassis	Refresh Learned Info for:	Table ID All Tables 💽 255
 Protocols Protocol Interfaces 	Device All Interface	Out Port OFPP_NONE
🗸 🤂 OpenFlow	Select the rows to send trigger/stat requests	Response Timeout 5,000 🗖 Match Capability
E Learned Informa	Local IP Remote IP	Match Criteria
Device-1	1 10.200.134.233 10.200.134.23 1	In Port *
Host1		Ethernet Type
Host3		
		Ethernet Source *
 Contraction Contract		Ethernet Destination *
⇒⊄ L2-3 Flow Groups	✓	VLAN ID X VLAN Priority X
③ Impairments		IP DSCP T IP Protocol
QuickTests	Select Views Port CPU Statis	
	Select Views Port CPU Statis	IPv4 Source/Mask * IPv4 * *
Aptures	Stat Name Port Na > 1 10.200.134.41/Card02/Port13 Host1	Transport Source/ICMP Type * Destination/ICMP
	2 10.200.134.41/Card02/Port14 Host2	
	3 10.200.134.41/Card02/Port15 Host3	OK Cancel Help

Figure 49: OpenFlow Learned Info Trigger Settings window

To verify flow table information, go to **Flow Stat** tab and ensure that switch has correct flow entries to match the fields defined earlier in the flow range. Enter port and wild card entry for non-matching field.

Overview	< > 🕻	🕀 Protocols	> 🔂 OpenFlow	Controll	er Running → 🖹	Learned	Information	1							
see Scenario	OF CI		gy:0,Flow Stat:2 Stat:0,Table Stat												
← ⊖ Ports			Flow Stat	ggregated Stat	Port Stat Vend	lor Stat	Description S	tat Table Stat Queu	ie Config	Queue Stat	Topology Le	amed Info	_		
Protocols Protocol Interfaces		Local IP	Remote IP	Latency (usec)	Reply State	In Port	Ethernet Source	Ethernet Destination	Ethernet Type	VLAN ID	VLAN Priority	IPv4 Source	IPv4 Destination	P Protocol	IP DSCP
OpenFlow	1	10.200.134.2	10.200.134.234	1283	Reply Received	1	*	*	0×800	*	*	1.1.1.1/24	2.2.2.2/24	*	*
Controller Running	2	10.200.134.2	10.200.134.234	1283	Reply Received		×	*	0x800	*	×	1.1.1.1/24	2.2.2.2/24	*	×

Create Traffic endpoints on host ports using the **Generate Traffic Endpoint** wizard. This option is available on the **Flow Ranges** tab.

Protocols OpenFlow OpenFlow Creations		Add Protocols + Build		enerate Traffi	Click th button	is									
₀[] Overview ∞ <mark>: </mark> Scenario	Diagram		otocols) Devices	Interfaces	ow ▶ OF Channel:	s Flow Rang	jes Ac	ions Traf	fic Endpoints						
✓ OPOTS		OF Channel		Description	Number of Flows	Configure Range	In Port	Ethernet Source	Ethernet Destination	Ethernet Type	VLAN ID	VLAN Priority	(addr/mask)	IPv4 Destination (addr/mask)	IP Protocol
Lassis	2	OFChann	7 7	Primary Secondary	1		1	*	*	0800 0800	*	*	1.1.1.1/24 1.1.1.1/24	2.2.2.2/24 2.2.2.2/24	*
Protocols Protocol Interfaces Protocol Interfaces PoperFlow E Controller Running Learned Informatic															

Figure 50: Flow Ranges tab

The following steps will help you use the **OpenFlow Traffic Converter Wizard**. This will create the corresponding traffic end points for the Flow Range values on Ixia ports.

a. Select host ports where Traffic Endpoints will be created and click Next.

elect P	'ort(s) for Wiza	ard Configuration	
	Enable	Port Description	
1	Г	Controller - 10/100/1000 Base T	
2	N	Host1 - 10/100/1000 Base T	
3	N	Host2 - 10/100/1000 Base T	
4	<u> </u>	Host3 - 10/100/1000 Base T	

Figure 51: OpenFlow Traffic Converter Wizard – Port Select – Name window

b. Select both Primary/Secondary flow range to be included in traffic.

Flow	Ranges	
	Flow Range	Include In Traffic
1	Primary - OFChannel-1 - Connected - ProtocolInterface - 100:04 - 5 - Device-1 - C	<u> </u>
2	Secondary - OFChannel-1 - Connected - ProtocolInterface - 100:04 - 5 - Device-1	

Figure 52: OpenFlow Traffic Converter Wizard – Select Flow Ranges - Name

c. Map the Traffic source port in the following figure Host-1, with DUT In port.

This will enable IxNetwork to map the traffic ports to switch ports

Figure 53: OpenFlow Traffic Concerter Wizard – DUT In Port To Ixia Port Mapping – Name window

Map traffic receiving ports with DUT's output port.
 This will enable IxNetwork to map the traffic ports to switch ports

DUT	Out Ports		
	DUT Out Port	User Flow Ranges	Ixia Port (Traffic Dst)
1	2	Primary - OFChannel-1 - Connected - Prot	Host2
2	3	Secondary - OFChannel-1 - Connected - P	Host3

Figure 54: OpenFlow Traffic Converter Wizard – DUT Out Port To Ixia Port Mapping – Name window

- e. Leave everything default on next two windows.
- f. Select **Generate and Overwrite Existing Configuration** check box to remove previously generated traffic endpoint and click on finish.

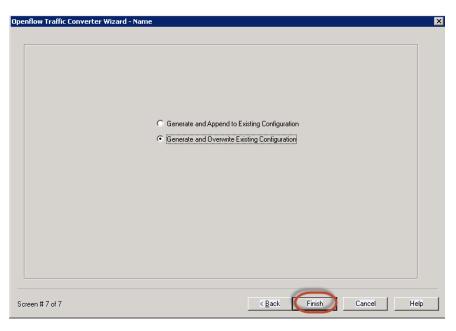


Figure 55: OpenFlow Traffic Converter Wizard – Name window

g. Go to each host port and ensure the wizard has generated correct traffic endpoint

Overview	< > 🕻	у 💮 Р	rotocols →	🔁 OpenFlo	ow ►				
OUI Overview	Diagram	Ports	Devices	Interfaces	OF Channels	Flow Rai	nges Actions	Traffic Endp	oints
■< <mark>=</mark> Scenario	r r		f	· ·	- Dud				
		Port	Name	Interface	e IPv4 Address	Mask	IP DSCP	IP Protocol	
✓ ⊖ Ports	1	Host1	Traffic - 1	NA	1.1.1.1	24	0	TCP	NA
Lassis	2	Host2	Traffic - 1	NA	2.2.2.2	24	0	TCP	NA
→ Protocols	3	Host3	Traffic - 1	NA	2.2.2.2	24	0	TCP	NA
Protocol Interfaces									
 L2-3 Traffic Items L2-3 Flow Groups 		,							
Impairments	∖ Traffic	λ Prope	erties 👌 Eth	hernet ∖ VLA	AN Network	Transp	oort /		

12. Go to **Traffic Options** window and select **Data Plane Event Monitor** check box and set desired data-plane threshold limit.

L2-3 Traffic - Traffic - Actions - Actions -	3 Edit Traffic Edit Flow Regenerate	Delete		Grid/Column Profiles + Group Rows By +	Please select one or more Flow Groups	
Run	Test Options					
g∭ Overview ■ Ccenario	X Traffic Options		fic Options istics Measurements Global Settin —Available Sets of Statistics -	igs	••	
👻 😝 Ports	Hereit QuickTests Options	Se	Statistics Set	Settings		Description
Lassis	Stat Viewer Options		Inter-arrival time/rate	Sound		Delta of Receive Time of two consecutive packets
			Sequence Checking			Per Flow Ordering, Loss or Duplication of Packets Measurements on Receive Ports
Host1			Advanced Sequence Checkin	g		Enables a more accurate way to compute the lost packets.
		C	CP/DP Convergence			Control Plane and Data Plane integrated time stamping for calculating convergence measurements More
Classification (Classification) (Classif	- Y		Control Plane Even	ts		Control Plane (Protocol) State Change or Event Timestamps used for convergence measurement
 QuickTests Captures 	0	(Data Plane Events - Rate Monito.			Receive Ports Rate Monitoring to detect Convergence event and capture timestamp
	Vetv		Data Plane Threshold (%	6) 95		Enter data bas threshold percentage for DP/IP event a dhip poingt. The data it is 30 percent. This pencera a above threshold timestamp and a below threshold timestamp when the rate of packets received on any PGID po above or below the predefined rate. Example: it you are receiving on 4 post, and you went to test disabing a single point, the rating will go time 25% to 33% on each, so you want threshold around 30%.
			Data Plane Jitter Windo	999 10 ms		Precision time interval to be used for rate calculation on the receive side (required by Jitter measurements)

Figure 56: Traffic Options window

- 13. Go to **Traffic Wizard** window to create traffic flow between Host-1 to Host-2 and Host-3.
 - a. Select **Traffic** from the tree and click on **Add L2-3 Traffic** button in the ribbon. It will open **Advance Traffic Wizard**.

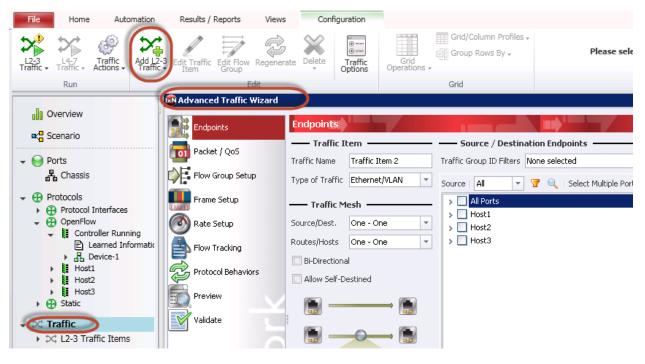


Figure 57: Advanced Traffic Wizard

b. Select **Type of Traffic** as IPv4and use **OpenFlow** encapsulation filter for **Source** and **Destination** endpoints.

Advanced Traffic Wizard			
Endpoints	Endpoints		
Packet / QoS	Traffic Item		
· · · ·	Traffic Name Traffic Item 2	Traffic Group ID Filters None selected	
Flow Group Setup	Type of Traffic IPv4	Source All 🛛 🖓 🔍 Select Multiple Ports 👻	Destination OpenF
Frame Setup	Traffic Mesh	All Inon-MPLS	Select Multiple Ports 👻
🚳 Rate Setup	Source/Dest. One - One -	L2VPN	> All Ports
Flow Tracking	Routes/Hosts One - One	L3VPN MPLS es 6PE 1.1/24/1	 Host1 Host2 Host3
Protocol Behaviors	Allow Self-Destined	> HBGP-VPLS	
Preview		> CMAC-In-MAC Data Center MVPN-P2MP	
Validate		MPLS-TP LISP TRILL	
		FabricPath OpenFlow	

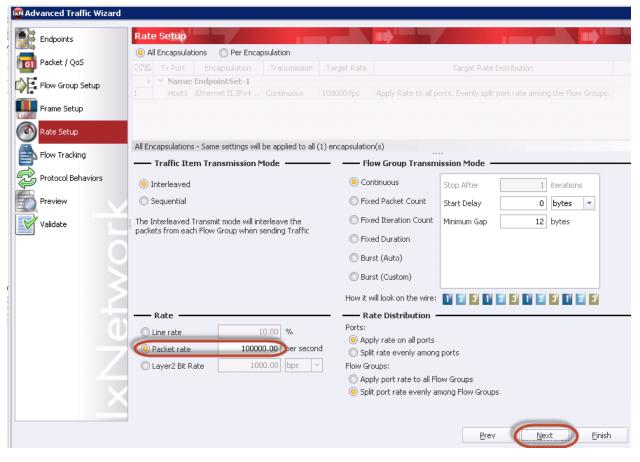
Figure 58: Advanced Traffic Wizard, Endpoints window

c. Select **Host-1** as traffic source and **Host-2** and **Host-3** as traffic destination. Make sure the **Merge Destination Range** check box is selected. This ensures that unique flow is created based on destination IP address.

vanced Traffic Wizard	d		
Endpoints	Endpoints		
Peaket / Oac	Traffic Item	Source / Destination Endpoints	
Packet / QoS	Traffic Name Traffic Item 2	Traffic Group ID Filters None selected	
Flow Group Setup	Type of Traffic IPv4 💌	Source 🛛 🗐 👻 🍞 🔍 Select Multiple Ports 👻	Destination OpenF 🔻 🍸 🤇
Frame Setup	Traffic Mesh	All Ports	Select Multiple Ports 👻
Rate Setup	Source/Dest. One - One -	✓ ✓ Host1 ✓ ✓ Open-Flow	> 🗹 All Ports
Flow Tracking	Routes/Hosts One - One 💌	V V IP Ranges	> Host1
-	Bi-Directional	▼ 1.1.1.1/24/1	🗸 🔽 Open-Flow
Protocol Behaviors	Allow Self-Destined	> Host3	. V IP Ranges
Preview		> Controller	 ✓ 2.2.2.2/24/1 ✓ ✓ Host3 ✓ ✓ Open-Flow
Validate			V V IP Ranges
			☑ 2.2.2.2/24/1
		🕞 🛛 🗶 — Endpoint Sets —	J
		· · · · · · · · · · · · · · · · · · ·	Indpoints Traffic Groups
	Number of hosts per Route 1	Name: EndpointSet-1	Nees calculated
	Merge Destination Ranges	Ethernet II.IPv4 1 Endpoints 1 Endpoints Name: EndpointSet-2	None selected
	Uncheck this option to test overlapping	2 <new> <new> <new></new></new></new>	None selected
	VPN addresses		

Figure 59: Advanced Traffic Wizard, Source/Destination Endpoints mapping

d. Leave default values on Packet/QoS, Flow group setup, and frame setup windows.



e. Set the desired traffic load on Rate Setup window and click Next.

Figure 60: Advanced Traffic Wizard, Rate Setup window

f. On Flow Tracking window, select Source/Dest Value Pair and Dest Endpoint as tracking option. Click Next.

🔊 Advanced Traffic Wizard									
Endpoints	Flow Tracking		10				7		
		by		Custor	n Overrie	de —			
Packet / QoS	🗹 Traffic Item			🔲 One - Or		4			
ALZ .	Source/Dest End	point Pair				u			
Flow Group Setup	🗹 Source/Dest Val	ue Pair		Offset from	Root		-		
Frame Setup	Source/Dest Por	t Pair		Offset			0 bits		
Line Setup	Source Endpoint			Field width	32 Bits				
Kale selup	Dest Endpoint		=		JOZ DIUS				
	Source Port			Values					
	📃 Traffic Group ID					0			
	MPLS Flow Desc	riptor							
Protocol Behaviors	📃 Frame Size								
and the second s	Flow Group								
Preview	📃 Ethernet II : De								
Validate	Ethernet II : So		s						
	Ethernet II : Eth								
	Ethernet II : PF								
	IPv4 : Preceden		¥						
	Egress Track	cing —					cy Bin Measure		
	🔲 Enable Egress	Tracking					Latency Bin Meas	7	
	+ -				Nu	umbers of	f Bins 8	Minimum step size	: 0.02 us
	Ethernet:Outer	Encapsulation	Ethernet					Less Than or Equal To	
					1	- F			1.00
		Offset	Outer VLAN Pr	iority (🔻			1.00		1.42
							1.42		
					4				
	4 F								4.00
					14.		/ 00		E 22
	1 2 3	4 5 6	7 8 9	10 11	12 13	14 15	5 16 17 1	18 19 20 21 3	22 Ingress
	1 2 3	7 3 0	/ 0 9	10 11	12 13	14 1;	5 16 17 1	10 19 20 21 A	~~
								Prev Next	Einish
								Dev Mext	

Figure 61: Advanced Traffic Wizard, Flow Tracking window

g. Skip **Protocol Behaviors** window and go to **Preview** window to view how the traffic flow looks like and click **Finish** button.

💀 Advanced Traffic Wizard										. 🗆 ×
Endpoints Pro	eview					15			lx1	A I
Packet / Qo5	Flow Gr	oups/Packets —				🧿 Current Traf	fic Item 🔘 All Ti	raffic Items View	Flow Groups/Pack	ets
Flow Group Setup		Flow Group			Tral	fic Item				-
Frame Setup	Port: H Traffic	10501 Item 1-EndpointSet-1 - Flo	w Group 0001	Traffic Item 1					Click this button	
Rate Setup										
Flow Tracking										
Protocol Behaviors										
Preview	– 1 Packets for	flow group: Traffic Item 1-I	EndpointSet-1 - Elow G	iroup 0001						
		Destination MAC Address			PFC Queue	Precedence	Source Address	Destination Address	TCP-Source-Port	TCP-
			00:00:00:00:00:00	800	0	000 Routine	1.1.1.1	2.2.2.2	1	1
xNetwo										
	1	4 * * * •						_		•
						Prev	Next	<u>Einish</u> <u>C</u> a	ancel He	:lp

Figure 62: Advanced Traffic Wizard, Preview window

14. Click L2-3 Traffic button to push the traffic on port and start traffic.

💷 🗋 🗁 🔚 - 🦓 - 🔭 🕞 File Home Automation	2 • ● □ • □ □ ↓ • Traffic Tools Results / Reports Views	IxNetwork [Pro
L223 L223 Traffic Traffic Actions	2-3 Edit Traffic Edit Flow Regenerate Delete Traffic Options	Grid Operations + Grid/Column Profiles + 0%
Run	Edit	Grid Rate C
	< ≽ 🚮 💢 Traffic 🕨 💢 L2-3 Traffic Items 🕨 💢 Tr	ffic Item 1
0 Overview	Flow Groups Topology Endpoint Sets	
Cenario	Transmit State Suspend Tx Port	R× Ports Flow Group Nam
👻 📦 Ports	V O Traffic Item Name: Traffic Ite	
L Chassis	1 Host1	Host2; Host3; Traffic Item 1-Endpoin
 Protocols Protocol Interfaces OpenFlow Controller Running Learned Informati Bovice-1 Host1 Host2 Host3 Static X Traffic X L2-3 Traffic Items X L2-3 Flow Groups 	Please wait Apply Traffic: Completed Successfully. 10 Done)% Cancel

Result Analysis

1. Verify that there is no traffic loss and traffic is flowing through the primary path (which has highest priority, as configured earlier) on the switch.

Tra	affic Item	Tx Frames	Rx Expecte	d Frames	Rx Frames	Frames Delta	Loss %	Tx Fran	ne Rate	Rx Fram	ne Rate
Tra	affic Item 1	56,021,761		56,021,761	56,021,760	1		.000 100	,000.000	100,0	000.00
1	Select Views	Traffic Item Statistics	Flow Statistic	3							
	Select Views	Traffic Item Statistics	Traffic Itom	Source/Dest Endpo		Je Dest Endpoint		Rx Expected Frames	R× Frames	Frames Delta	Loss %
-	,		Traffic Itom		Pair	Dest Endpoint			Rx Frames		Loss %

2. While traffic is running, go to OpenFlow controller flow range and **disable Primary** flow. This sends Flow-Mod delete command to switch. Switch removes the Primary Flow entry and since there is only one flow entry in its Flow Table it will start forwarding packets out on the secondary path output port.

Overview	< > C	S Interfaces		OpenFlow >										
✓		OF Channel	Enable	Description	Number of Flows	Configure Range	In Port	Ethernet Source	Ethernet Destination	Ethernet Type	VLAN ID	VLAN Priority	IPv4 Source (addr/mask)	IP∨4 Destination (addr/mask)
Lassis	1	OFChannel-1		Primary	1		1	*	*	0800	*	*	1.1.1/24	2.2.2.2/24
	2		T	Secondary	1		1	*	*	0800	*	*	1.1.1/24	2.2.2.2/24

3. Go to traffic **Flow Statistics** window and verify that the traffic gets switched over to secondary path towards host-3. And, go to **Traffic Item Statistics** tab to verify there is no traffic loss.

-(a	Select Views	Flow Statistics Tr	affic Item Statist	CS									
	Tx Port	R× Port	Traffic Item	Source/Dest Endpoint Pair	Source/Dest Value Pair	Dest Endpoint	T× Frames	Rx Expected Frames	Rx Frames	Frames Delta	Loss %	Tx Frame Rate	R× Frame Rate
+ 1	Host1	Host2	Traffic Item 1	1.1.1.1-2.2.2.2	1.1.1.1-2.2.2.2	2.2.2.2	120,021,761	120,021,761	110,114,746	9,907,015	8.254	100,000.000	0.000
2	Host1	Host3	Traffic Item 1	1.1.1.1-2.2.2.2	1.1.1.1-2.2.2.2	2.2.2.2	120,021,761	120,021,761	9,907,014	110,114,747	91.746	100,000.000	100,000.000

4. From traffic item statistics view, perform drill down per destination endpoint (right click on traffic item, select drill down per destination option). This will create User Defined Statistics view tab. On this tab, you will notice **DP/DP Convergence Time** on far right hand side (you can move this column in the beginning by dragging the column header). This field provides data-plane event convergence time in micro seconds.

K	1	Back 🔻 👧								
_	_	Dest Endpoint	Tx Frames	Rx Expected Frames	Rx Frames	Frames Delta	Loss %	DP/DP Convergence Time (us)	Tx Frame Rate	Rx Frame Rate
۶.	1	2.2.2.2	6,386,509	6,386,509	6,386,507	2	0.000	11,900	100,000.000	100,000.00

5. Go to **Flow Statistics** to monitor DP-Above and DP-Below timestamp (located in far right corner) to confirm DP/DP convergence time accuracy.

DP-DP Convergence time = tDP-Above time stamp – tDP-Below timestamp

-[2]	Select Views OpenFlow Controller Aggregated Statistics Flow Statistics User Defined Statistics Traffic Item Statistics											
	Tx Port	Rx Port	Traffic Item	Source/Dest Endpoint Pair	Source/Dest Value Pair	Dest Endpoint	DP Below Threshold Timestamp	DP Above Threshold Timestamp				
▶ 1	Host1	Host2	Traffic Item 1	1.1.1.1-2.2.2.2	1.1.1.1-2.2.2.2	2.2.2.2	00:00:55.929	00:00:00.000				
2	Host1	Host3	Traffic Item 1	1.1.1.1-2.2.2.2	1.1.1.1-2.2.2.2	2.2.2.2	00:17:40.677	00:00:55.941				

6. Prior to next control-plane trigger event, perform **Clear CP/DP Convergence Statistics** to get accurate results for the next convergence event on the switch.

Test Case: Switch Flow Failover Performance Test

Clear All Ctatistics - Customize Traffic View	Ingress/Egress Statistics +	Stat. View Profiles +	Add to Ac New + Exi	dd to sting - Snapshot -	More Actions +	Overview Statistics	Port	. Itallic .	Hew New	Custom View Wizard	Test Res Picker
Clear All Statistics		Customize	Custom Gr	raph Snap	shot			View Sets		New V	iew
Clear Traffic/Ports Statistics		🕻 Traffic 🕨	🗙 L2-3 Traffi	c Items 🔸							
Clear CP/DP Convergence Statistic	cs	insmit State	Traffic	: Item Name	Enabled	Flow Groups	;	Tx Ports	Rx Por	ts	Endpoi
Clear Protocols Statistics		10 📕	Traffic Item	1	V		<u>1</u>	<u>1</u>		2	
(Access / Auth / DCE / NextGen S	itatistics)										
		ettings Trac	king and Later		m Statistics	User Defined	Statistics				
	🌾 Back	- 👧	Fraffic Item	Dest Endpoint							
Traffic Item 1	Dest E	indpoint	Tx Frames	Rx Expected Frames	Rx Frames	Frames Delta	Loss %	DP/DP Convergence Time (u	s) Tx Frame	Rate Rx Fra	ame Rate
CL2-3 Flow Groups	▶ 1 2.2.2.	2	3,586,317	3,586,31	7 3,586,315	2	0.000	19	,639 100,00	0.000 10	0,000.000
Impairments											

Conclusions

This test allows you to validate DUT's ability to detect the failure and switch traffic to alternate path as fast as possible without significant packet loss. It also provides accurate traffic convergence measurements.

Variables

1. TrueView convergence test also provides accurate measurement for control-plane to data-plane convergence time. To perform this test, user should select control-plane events check box in step#17. All other steps remain the same.

Go to Statistics view and track by destination endpoint, you should notice CP/DP convergence Time column.

2. Same test can be repeated for various traffic rates, number of flows and threshold values.

Test case: OpenFlow Controller Scalability Test

Overview

SDN continues to gain momentum in the networking industry. The OpenFlow protocol is widely accepted and leading the SDN trend. Almost all major network equipment manufacturers as well as startups have shown interest in OpenFlow and developing OpenFlow Controller, OpenFlow Switch, or both in their product portfolio.

Ixia continues to develop OpenFlow protocol emulation. Ixia has introduced v1.0 Controller emulation in 2012 and now is introducing v1.0 Switch emulation. Using OpenFlow switch emulation, one can validate basic functionality of the OpenFlow controller. Also, OpenFlow switch emulation helps in performance measurement and scalability.

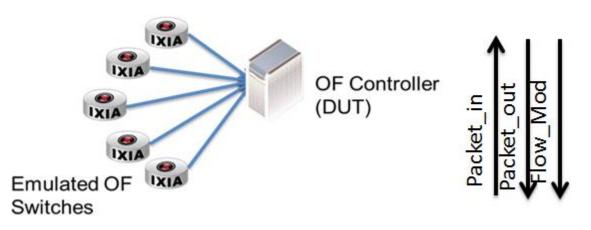
Objective

The objective of this test case is to verify functionality and scalability of the OpenFlow controller by performing following tasks:

- Create multiple switch emulation and bring up OF channel using single Ixia port,
- Push thousands of flows with different match/actions to ensure that controller can push the flows correctly.
- Generate various messages to the controller, such as packet_ins, port status message, vendor message, and error message to ensure that controller is capable to respond each message timely and accurately.

For this test case, use 2 Ixia ports connected in back-to-back mode. One port is emulating OpenFlow controller and the other port is emulating multiple OpenFlow switches.

Setup

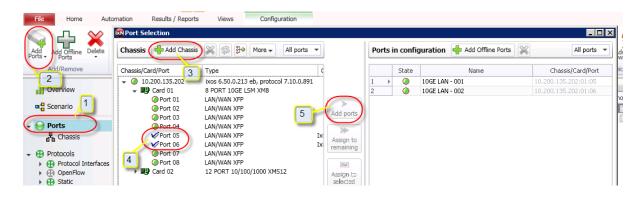


Step-by-Step Instructions

The following steps describe the procedure for performing the test.

1. Reserve 1 Ixia port

Note: This example uses 2 Ixia ports connected in back-to-back mode. One port is emulating OF Controller and other port is emulating OF Switch



2. In the **Protocols** Window, select **OpenFlow** checkbox to enable the OpenFlow.

Overview		g/Switching		lulticast	Carrie	r Etherne	t Acce	ess Au	thentication	Data Ce	enter Bridging	g Wirel	ess						
-	-	Port	Description	Port Owner	Link	ARP	PING	BFD	BGP/BGP+	EIGRP	ISIS L2/L3	LACP	LISP	OpenFlow	OSPF	OSPFv3	RIP	RIPng	STP
Ports	$\frac{1}{2}$		001 - LANAVAN 002 - LANAVAN		0	ঘ	Г	П	Г	Г		Г	П	ম	Г		Г	Г	Г
Protocols Protocol Interfaces OpenFlow Static		•					-			A	A								

 Create 5 protocol interfaces (to emulate 5 OF Switches). Configure IP addresses of emulated OF Switches and Gateway address from the Connected Interface tab in the Protocol Interfaces window. For OF Channel, ensure that ARP is resolved.

u∭ Overview ¤¶ Scenario	Conn	ected Interfaces		erfaces 🕨 🚺 OF_Switch ed Interfaces 📄 GRE Tur	inels Dis	scovered Neighbors
Ports			-	perGateway 🔽 NS on Link	Up ⊽ Ser IPv4 Mask	
6 Chassis		Interface Description	Enable	(10.0.x.x - Reserved IP)	Width	Gateway
A Protocols	1	Connected - Protocolint	ব	50.0.0.2	24	50.0.0.1
Protocol Interfaces	2	Connected - Protocolint	•	50.0.0.3	24	50.0.0.1
OF Controller	3	Connected - Protocolint	N	50.0.0.4	24	50.0.0.1
OF_Switch	4	Connected - Protocolint	•	50.0.0.5	24	50.0.0.1
OpenFlow	5	Connected - ProtocolInt	ম	50.0.0.6	24	50.0.0.1
H Static						

4. Define the port role by selecting the role as **Control** from the **Port Role** list in the **Ports** tab in the **OpenFlow** window.

5. Define **Number of Devices** as 5 in the **Ports** tab.

0 Overview	< > Dia	gram Protoc	ols → 💮 Openi Devices Ir	<mark>Flow ▶</mark> Iterfaces OFChann	els Flow Ran	ges Actions Co	ntroller Ta
■K [®] Scenario		Port	Protocol State		Number of Traffic Endpoints		
🗕 😔 Ports	1	OF_Controller		1	NA	Control	
Chassis	2	OF_Switch		5	NA	Control	
Protocols Protocol Interfaces OF_Controller OF Switch OpenFlow OF_Controller OF_Switch OF_Switch Static							

6. Click the **Devices** tab. Modify the **Device Role** to **Switch**. Also, select **Enable Version 1.0.0** checkbox.

Coverview	Vote :	ies Inte	rfaces OF Ch		vitch ▶ anges Actions Contr e saved along with IxNetwork
Ports		Enable	Description (Device Role	Enable Version 1.0.0
Diretocale	1	ন	Device-1	Switch	ম
Protocols Protocols	2		Device-2	Switch	
Protocol Interfaces OF Controller	3	•	Device-3	Switch	
OF_Controller OF_Switch	4	•	Device-4	Switch	
	5	•	Device-5	Switch	
OF_Controller OF_Switch Static Traffic					

 Click the Interfaces tab. Assign the Protocol Interfaces that you created in the Protocol Interface window. This interface is used for the control-plane (OF Channel). Configure Number of Channels as 1. Leave all other parameters as default.

Cverview				els Flow Ranges Actions Control		ontroll
Ports		hange number of Interface	es, select '	Devices' tab, and enter number in 'Number of In		
Chassis		Device Description	Enable	Protocol Interface	Number of OF Channels	Periodi Echo
Protocols	1	Device-1 - OF_Switc	N	Connected - ProtocolInterface - 100:02 - 4	1	N
Protocol Interfaces	2	Device-2 - OF_Switc	V	Connected - ProtocolInterface - 100:02 - 5	1	N
OF Controller	3	Device-3 - OF_Switc		Connected - ProtocolInterface - 100:02 - 6	1	N
OF_Switch	4	Device-4 - OF_Switc		Connected - ProtocolInterface - 100:02 - 7	1	N
	5	Device-5 - OF_Switc	N	Connected - ProtocolInterface - 100:02 - 8 💌	1	N
OpenFlow OF Controller OF Switch Static	5	Device-5 - OF_Switc		Connected - Protocolinterface - 100:02 - 8		

8. Click **OF Channels** tab. Enter the IP address of OpenFlow Controller for **Remote IP** and select the **Enable** checkbox. Also change switch name in the **Description** column.

Overview		-	-	OpenFlow 🕨 🚺		r r
💦 Scenario	Devices	Interfac	es OF	Channels F	low Ranges	Actions 0
Ports		Interface	Enable	Description	Local IP	Remote IP
Lassis		nnected -	<u> </u>	SV/1	50.0.0.2	50.0.0.1
Protocols		nnected -	ম ম	SW2 SW3	50.0.0.3 50.0.0.4	50.0.0.1 50.0.0.1
Protocol Interfaces		nnected -	ন	SW4	50.0.0.5	50.0.0.1
OpenFlow OF_Controller	5 Co	nnected -	ন	SW5	50.0.0.6	50.0.0.1
 H Static Traffic Impairments QuickTests 						
★ Captures	OF Chann					

 In the OF Channels – Switch tab, change Number of Table Ranges to 4 and leave all parameter as default. However, if it is required to test OF Controller with different capabilities, datapath ID, supported actions, and so on, then those parameters can be changed from this tab.

es Inter	faces	OF Cha		Flow Ranges Actions Contro	oller Tables Controller Table Flov	vitunges II	istruction	Instruction Act	ions Switch			Switch PacketIn	
Descript	ion I	Datapath	Datapath	Capabilities	Supported Actions	Manufacturer	Hardware	Software	Serial Number	Datapath	Max. Packet	Store Flows	Number of F
Descript	lion	ID	ID (In	Capapilities	Supported Actions	Description	Description	Description	Senarnumber	Description	In Bytes	Store nows	Ranges
OFChanne	:1-1	1	1	Flow Statistics,Table Statistics,Port	Output,Set VLAN ID,Set VLAN Priority	lxia	lxia-001	IxNetwork-001	IXIA-2012-001	bxiacom-001	128	ম	
OFChanne	! -1	1	1	Flow Statistics,Table Statistics,Port	Output,Set VLAN ID,Set VLAN Priority	lxia	lxia-001	IxNetwork-001	IXIA-2012-001	biacom-001	128	N	
OFChanne	! -1	1	1	Flow Statistics,Table Statistics,Port	Output,Set VLAN ID,Set VLAN Priority	lxia	lxia-001	IxNetwork-001	IXIA-2012-001	biacom-001	128	N	
OFChanne	:1-1	1	1	Flow Statistics,Table Statistics,Port	Output,Set VLAN ID,Set VLAN Priority	l×ia	lxia-001	IxNetwork-001	IXIA-2012-001	biacom-001	128	ন	
OFChanne	 -1	1	1	Flow Statistics.Table Statistics.Port	Output, Set VLAN ID, Set VLAN Priority	lxia	lxia-001	IxNetwork-001	IXIA-2012-001	biacom-001	128		

OF Channels \ Controller (Switch)

10. Click **Switch Ports** tab, and enable the **port range**. Change **Number of ports** to 24, **Ethernet Address** for each switch. Other parameters, such as port state, configuration, supported/advertised features, and so on, can be changed from this section.

Note: Configure Range or Split window can be used to define start/step value to create uniqueness

1 OFChannel-1 🔽 2 OFChannel-1 🔽	nable Numbe Port	of Configure	ange Bert Numbe		1									
2 OFChannel-1			ange Forrivanise	Ethernet Address	Port Name	Config	State	Current Features	Advertised Features	Supported Features	Start Val	e Step Value	Repeat Count	Wrap Count
	7	24	1	00 00 00 00 00 01	ixia-001	Port Down,No STP,No Re	Link Down,STP Listen,STP	Copper medi	Copper med	Copper medi	1 ixia-001	1	1	24
	2	24	1	00 00 01 00 00 01	ixia-001	Port Down,No STP,No Re	Link Down,STP Listen,STP	Copper medi	Copper med	Copper medi	2 ixia-001	1	1	24
3 OF Channel-1	2	24	1	00 00 02 00 00 01	ixia-001	Port Down,No STP,No Re	Link Down,STP Listen,STP	Copper medi	Copper med	Copper medi	3 ixia-001	1	1	24
4 OFChannel-1	2	24	1	00 00 03 00 00 01	ixia-001	Port Down No STP No Re	Link Down,STP Listen,STP	Copper medi	Cope Sont	(appendented)	4 ixia-001	1	1	24
5 OFChannel-1	v	24	1	00 00 04 00 00 01	ixia-001	Port Down No STP No Re	Link Down,STP Listen,STP	Copper medi	Window	opper medi	5 ixia-001	1	1	24

11. In the **Switch Tables** tab, make following changes:

- **Table ID –** Define unique table IDs for each switch
- Table Name (optional) Give meaningful name
- Max Entries Desired number of flows that each table can hold
- Wild Card Supported Enable/Disable checkbox for any field that requires wildcard support. For example, if you disable wildcard support for VLAN ID and if switch receives any flow that contains wildcard for VLAN ID field, then it does not install the flow in that table

The following example (below snapshot) shows that each switch has 4 tables. All 5 switches have same tables.

It is defined as:

- **Table 1 –** Emergency, Switch uses these flows if the OF channel connection to the controller gets reset or lost
- **Table 2 –** Table with no wildcard support, it means this table does not accept any flows that have wildcard character in it.
- **Table 3 –** Table with no wildcard support for VLAN priority, this table does not accept any flows that has wildcard set for VLAN priority field
- Table 4 Table with all wildcard, this table accepts any flows that has wildcard or no wildcard

s Interfac	es OF C	hannels Flow	Ranges	Actions Controlle	r Tables C	controller Table Flow Ranges Instructi	on Instruction Actions	Switch Ports Switch 1
OF Channel	Number of Tables	Configure Range	Table Id	Table Name	Max Entries	Wildcards Supported		
SVV1 - SVV1 -	1		254	Emergency	100	Switch input port,VLAN ID,Ethernet s		
	1		0	Table_noWildcard	500	Select WildCarded Fields		
	1		1	Table_noVLANpriority	500	Switch input port,VLAN ID,Ethernet s		
	1		2	TableAllEnabled	500	Switch input port,VLAN ID,Ethernet s		
SW2 - SW2 -	1		254	Emergency	100	Switch input port,VLAN ID,Ethernet s		
	1		0	Table_noVvildcard	500	Select WildCarded Fields		
	1		1	Table_noVLANpriority	500	Switch input port,VLAN ID,Ethernet s		
	1		2	TableAllEnabled	500	Switch input port,VLAN ID,Ethernet s		
	1		254	Emergency	100	Switch input port,VLAN ID,Ethernet s		
	1		0	Table_noVvildcard	500	Select WildCarded Fields		
	1		1	Table_noVLANpriority	500	Switch input port,VLAN ID,Ethernet s		
	1		2	TableAllEnabled	500	Switch input port,VLAN ID,Ethernet s		
SVV4 - SVV4 -	1		254	Emergency	100	Switch input port,VLAN ID,Ethernet s		
	1		0	Table_noWildcard	500	Select WildCarded Fields		
	1		1	Table_noVLANpriority	500	Switch input port,VLAN ID,Ethernet s		
	1		2	TableAllEnabled	500	Switch input port,VLAN ID,Ethernet s		
SWS - SWS -	1		254	Emergency	100	Switch input port,VLAN ID,Ethernet s		
	1		0	Table_noVVildcard	500	Select WildCarded Fields		
	1		1	Table noVLANpriority	500	Switch input port,VLAN ID,Ethernet s		

Note: Use Copy/Paste functionality to create same table on each switch.

OF Channel	Number of Tables	Configure Range	Table Id	Table Name	Max Entries	Wildcards Supported				
SVAM - SVAM -	1		254	Emergency	100	Sw	itch input port,VLAN	NID,Ethernet s		
	1		0	Table_noWildcard	500		0.1			
	1		1	Table_noVLANpriority	500	S'	New	Ctrl+N		
	1		2	TableAllEnabled	500	S١	Delete	Del		
SW2 - SW2 -	1		254	Emergency	100	S١		Ctrl-C		
	1		0	Table_noWildcard	500		Paste	Christer		
	1		1	Table_noVLANpriority	500	S۱.	Easce	CUITY		
	1		2	TableAllEnabled	500	S١	Increment			
SW3 - SW3 -	1		254	Emergency	100	S١	Increment By			

Select the table > Right click > Copy

OF Channel	Number of Tables	Configure Range	Table Id	Table Name	Max Entries	,	Wildcards Supporte	d
SVV1 - SVV1 -	1		254	Emergency	100	Switch inp	out port,VLAN ID,Eth	nernet s
	1		0	Table_noWildcard	500	Sele	ect WildCarded Field	ls.
	1		1	Table_noVLANpriority	500	Switch inp	out port,VLAN ID,Eth	nernet s
	1		2	TableAllEnabled	500	Switch inp	out port,VLAN ID,Eth	nernet s
SW2 - SW2 -	1		254	Emergency	100	Switch inp	out port,VLAN ID,Eth	nernet s
	1		0	Table_noWildcard	500	Se ^{t.}		
	1		1	Table_noVLANpriority	500	Switch i	New	Ctrl+N
	1		2	TableAllEnabled	500	Switch i	Delete	Del
SW3 - SW3 -	1		254	Emergency	100	Switch i	Copy	Ctrl+C
	1		0	Table_noWildcard	500	Se	Paste	Curl+V
	1		1	Table_noVLANpriority	500	Switch i	Lasta	
	1		2	TableAllEnabled	500	Switch i	Increment	
SVV4 - SVV4 -	1		254	Emergency	100	Switch i	Increment By	

For paste, select the table > Right click > **Paste**

12. Start **OpenFlow** protocol.

Protocols OpenFlow Actions	Traffic oup ID	Add Protocols - Build	Stop	OpenFlow OpenFlow ected	Grid Operations + Grid		
ulli Overview ¤∰ Scenario	< > C				I OF_Switch →	Actions	Controller Tables Co
		Interface	Enable	Description	Local IP	Remote IP	Enable Hello Element
La Chassis	1	SW1 - SW1 -	ন	SW1	50.0.0.2	50.0.0.1	
	2	SW2 - SW2 -		SW2	50.0.0.3	50.0.0.1	Ē
👻 🤁 Protocols	3	SW3 - SW3 -	T	SW3	50.0.0.4	50.0.0.1	Γ
Protocol Interfaces	4	SVV4 - SVV4 -	2	SVV4	50.0.0.5	50.0.0.1	
🗸 💮 OpenFlow	5	SW5 - SW5 -	N	SW5	50.0.0.6	50.0.0.1	Γ
OF_Switch Devices							

13. Enable **OpenFlow Switch Aggregated Statistics** view.

Devi			Channel	Select Views (View Set: Overview Statistics) Create New View Set Show: Overview Statistics AB
1 2 3 4 5	Interface SW1 - SW1 - SW2 - SW2 - SW3 - SW3 - SW4 - SW4 - SW5 - SW5 -	Enable ママ マ	Desci SVV1 SVV2 SVV3 SVV4 SVV5	
1	Select Views Stat Name 10.200.135.202/ 10.200.135.202/	'Card01/P		Image: Strain (Control of Control o

14. Click the pre-defined filter tabs at the bottom of the window to observe statistics like **Sessions, Flow,** and **Error.**

Sessions:

•	Select Views Port CPU	Statistics	Port Statistics	lobal Protocol	Statistics 0	penFlow Switch Aggre	egated Statistics
	Stat Name	Port Name	OF Channel Configur	ed OF Chanr	nel Configured Uj	OF Channel Flap Cour	it 🛛
1	10.200.135.202/Card01/Port05	OF_controller		0		0	0
▶ 2	10.200.135.202/Card01/Port06	OF_Switch	\subset	5		5	0
1.41		- C8- D-	distant Francis Hand		14		
AII	Session Handshake Flow Sta	it Config Pa	cketIN Error Vend	or 😏	I ≪		

Flow:

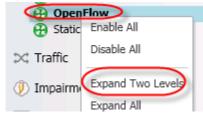
	Select Views Port CPU		Port Statistics	Global Prote	ocol Statistics	OpenFlow Swite	h Aggregated Statistic
	Stat Name	Port Name	Flow Adds Rx	Flow Mods Rx	Flow Dels Rx	Flow Removes Tx	
1	10.200.135.202/Card01/Port05	OF_controller	0	0	0	0	
2	10.200.135.202/Card01/Port06	OF_Switch	1,500	0	0	0	
			\cup				

Error:

	Stat Name	Port Name	Errors Tx	Hello Errors Tx	Request Errors Tx	Action Errors T×	Flow Mod Errors Tx	Port Mod Errors T×	Queue Op Errors To
1	10.200.135.202/Card01/Port05	OF_controller	() () 0	0	0	0	
2	10.200.135.202/Card01/Port06	OF_Switch	() () 0	0	0	0	
			•						

15. Expand **OpenFlow Switch view** and select **Switch Learned Information.**

Note: If your view is in summary mode (which is default), you can select OpenFlow protocol and right click then select **Expand Two Levels** option



16. In the Switch Learned Information tab, click Refresh OF Channels button.

This action generates Feature Reply message to the controller. This message displays useful information like, number of OF Channels, number of tables, capabilities, supported actions, and number of errors.

	esh OF nnels	On Demano Messages	Add Protocol Build											
₀∭ Overview	Le	arned Info R Channel : 5	ecords :) OpenFl	ow 🔸 🚺 OF_Switch R	unning → [Switch Lear	ned Information						
	OF C	hannel Lea fresh Learne vice All	rned Info	_	Learned Info		•]						
 OpenFlow OF_Switch Running 		Local I	Remote IP	Data Path ID	Data Path ID (Hex)	Local Port Number	Remote Port Number	Reply State	Max Buffer Size	Number of Tables	Capabilities	Actions Supported	Session Type	Number of Errors Received
Devices	1	50.0.0.	50.0.0.1	1	0×000000000000000000000000000000000000	50,252	6,633	Feature Reply Sent	1,000	4	0×000000EF	0×00000FFF	Configured	0
🖉 🖹 Switch Learned Informatio	2	50.0.0.	50.0.0.1	1	0x000000000000000000000000000000000000	50,253	6,633	Feature Reply Sent	1,000	4	0x000000EF	0×00000FFF	Configured	0
OF_controller Running	3	50.0.0.	50.0.0.1	1	0x000000000000000000000000000000000000	50,254	6,633	Feature Reply Sent	1,000	4	0x000000EF	0x00000FFF	Configured	0
Static	4		50.0.0.1	1	0×000000000000000000000000000000000000	50,255	6,633	Feature Reply Sent	1,000	4	0×000000EF	0×00000FFF	Configured	0
☆ Traffic	5	50.0.0.	50.0.0.1	1	0x000000000000000000000000000000000000	50,256	6,633	Feature Reply Sent	1,000	4	0x000000EF	0×00000FFF	Configured	0

17. Click **Flow Learned Info** tab, and then click **Refresh Flows** button. It displays flows that were pushed by the controller. It also displays information about the **Match** field.

a∬j Overview a≪¦ Scenario		ed Info Re		• •	-													
		idninet . O, r	low : 70	18														
Ports																		
Chassis	OF Ch	annel Lea	med Ir	fo (Flow Learned In	fo													
E Chassis					_													
Protocols		sh Learned	Info for							-								
Protocol Interfaces	Devic	e All		Interface AI			🗾 OF	All	-									
OpenFlow																		
OF_Switch Running		Remote	Data	Data Path ID (Hex)	In Port	Ethernet Source	Ethernet	Ethernet	VLAN ID	VLAN	IPv4	IPv4	IP	IP DSCP	Transport	Transport	Table ID	Pr
B. Devices		P	Path ID		mon		Destination	Туре		Priority	Source	Destination	Protocol		Source/ICMP Type	Destination/ICMP	Table Ib	
Switch Learned Informatio	1	50.0.0.1	1	0x000000000000000000000000000000000000	1	00:00:05:00:00:62	100:00:06:00:00:62	0x8100										
									401	2		*	*	*	*		1	
OF_controller Running	2	50.0.0.1	1	0x0000000000000000	1	00:00:05:00:00:59	00:00:06:00:00:59	0x8100	401	2	1	*	*	*	*	1	1	
	3	50.0.0.1	1	0×000000000000000000	1 1	00:00:05:00:00:59 00:00:05:00:00:41	00:00:06:00:00:59 00:00:06:00:00:41	0x8100 0x8100	401 401	2			*	٨	A		1	
🔂 Static	2 3 4	50.0.0.1 50.0.0.1	1 1 1	0x000000000000000000000000000000000000	1 1 1	00:00:05:00:00:59 00:00:05:00:00:41 00:00:05:00:00:50	00:00:06:00:00:59 00:00:06:00:00:41 00:00:06:00:00:50	0x8100 0x8100 0x8100	401 401 401	2 2 2	•	*	•	*	A A	•	, 1 1	
🔂 Static	2 3 4 5	50.0.0.1 50.0.0.1 50.0.0.1	1 1 1	0x000000000000000 0x000000000000000 0x000000	1 1 1 1	00:00:05:00:00:59 00:00:05:00:00:41 00:00:05:00:00:50 00:00:05:00:00:1e	00:00:06:00:00:59 00:00:06:00:00:41 00:00:06:00:00:50 00:00:06:00:00:1e	0x8100 0x8100 0x8100 0x8100 0x8100	401 401 401 401	2 2 2 2	•	*	*	*	A A A	*	1 1 1	
Static Traffic	2 3 4 5 6	50.0.0.1 50.0.0.1 50.0.0.1 50.0.0.1	1 1 1 1	0×00000000000000000 0×000000000000000 0×000000	1 1 1 1 1	00:00:05:00:00:59 00:00:05:00:00:41 00:00:05:00:00:50 00:00:05:00:00:1e 00:00:05:00:00:47	00:00:06:00:00:59 00:00:06:00:00:41 00:00:06:00:00:50 00:00:06:00:00:1e 00:00:06:00:00:47	0x8100 0x8100 0x8100 0x8100 0x8100	401 401 401 401 401	2 2 2 2 2	* * * *	* * * *	•	* * * *	A A A A	- 8 8 8 8 8	1 1 1 1 1	
Static Traffic	2 3 4 5 6 7	50.0.0.1 50.0.0.1 50.0.0.1 50.0.0.1 50.0.0.1	1 1 1 1 1	0×000000000000000 0×00000000000000 0×000000	1 1 1 1 1 1 1	00:00:05:00:00:59 00:00:05:00:00:41 00:00:05:00:00:50 00:00:05:00:00:1e 00:00:05:00:00:47 00:00:05:00:00:43	00:00:06:00:00:59 00:00:06:00:00:41 00:00:06:00:00:50 00:00:06:00:00:1e 00:00:06:00:00:47 00:00:06:00:00:43	0x8100 0x8100 0x8100 0x8100 0x8100 0x8100 0x8100	401 401 401 401 401 401	2 2 2 2 2 2 2	8 9 9 9 9 9	* * * * *	*	* * * *	A A A X A	- * * * * *	1 1 1 1 1 1 1	
Static Traffic Impairments	2 3 4 5 6 7 8	50.0.0.1 50.0.0.1 50.0.0.1 50.0.0.1 50.0.0.1 50.0.0.1	1 1 1 1 1 1 1	0x000000000000000 0x00000000000000 0x000000	1 1 1 1 1 1 1 1	00:00:05:00:00:59 00:00:05:00:00:41 00:00:05:00:00:00 00:00:05:00:00:10 00:00:05:00:00:47 00:00:05:00:00:43 00:00:05:00:00:48	00:00:06:00:00:59 00:00:06:00:00:41 00:00:06:00:00:50 00:00:06:00:00:10 00:00:06:00:00:47 00:00:06:00:00:43 00:00:06:00:00:48	0x8100 0x8100 0x8100 0x8100 0x8100 0x8100 0x8100 0x8100	401 401 401 401 401 401 401	2 2 2 2 2 2 2 2 2 2	8 9 2 8 8	* * * * * * *	*	* * * *	A A A X A A	* * * * *	1 1 1 1 1 1 1 1	
Static Traffic Impairments	2 3 4 5 6 7 8 9	50.0.0.1 50.0.0.1 50.0.0.1 50.0.0.1 50.0.0.1 50.0.0.1 50.0.0.1	1 1 1 1 1 1 1 1 1	0x00000000000000000000 0x0000000000000	1 1 1 1 1 1 1 1 1	00:00:05:00:00:59 00:00:05:00:00:41 00:00:05:00:00:00:00 00:00:05:00:00:14 00:00:05:00:00:47 00:00:05:00:00:43 00:00:05:00:00:48 00:00:05:00:00:38	00:00:06:00:00:59 00:00:06:00:00:41 00:00:06:00:00:50 00:00:06:00:00:1e 00:00:06:00:00:47 00:00:06:00:00:43 00:00:06:00:00:48 00:00:06:00:00:3	0x8100 0x8100 0x8100 0x8100 0x8100 0x8100 0x8100 0x8100 0x8100	401 401 401 401 401 401 401 401 401	2 2 2 2 2 2 2 2 2 2 2 2 2	8 9 2 8 8 8 8	* * * * * * * *	* * * * * * *	A A X X A A A A	A A X X A A A	- * * * * *	1 1 1 1 1 1 1 1 1	
Static Traffic Impairments QuickTests	2 3 4 5 6 7 8 9 10	50.0.0.1 50.0.0.1 50.0.0.1 50.0.0.1 50.0.0.1 50.0.0.1 50.0.0.1 50.0.0.1	1 1 1 1 1 1 1 1 1 1	0x000000000000000000000000000000000000	1 1 1 1 1 1 1 1 1 1 1	00:00:05:00:00:59 00:00:05:00:00:41 00:00:05:00:00:50 00:00:05:00:00:10 00:00:05:00:00:47 00:00:05:00:00:43 00:00:05:00:00:43 00:00:05:00:00:21	00.00.06.00.00.59 00.00.06.00.00.41 00.00.06.00.00.50 00.00.06.00.00.1e 00.00.06.00.00.47 00.00.06.00.00.43 00.00.66.00.00.43 00.00.66.00.00.43 00.00.66.00.00.39	0x8100 0x8100 0x8100 0x8100 0x8100 0x8100 0x8100 0x8100 0x8100 0x8100	401 401 401 401 401 401 401 401 401 401	2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	8 8 2 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8	* * * * * * *	* * * * *	* * * * * * *	A A X X A A A A X	- * * * * * * * * * * * * * * * * * * *	1 1 1 1 1 1 1 1 1 1	
Static Traffic Impairments QuickTests	11	50.0.0.1 50.0.0.1 50.0.0.1 50.0.0.1 50.0.0.1 50.0.0.1 50.0.0.1 50.0.0.1 50.0.0.1	1 1 1 1 1 1 1 1 1 1 1	0×0000000000000000000 0×00000000000000	1 1 1 1 1 1 1 1 1 1 1 1 1	00:00:05:00:00:59 00:00:05:00:00:41 00:00:05:00:00:50 00:00:05:00:00:10 00:00:05:00:00:47 00:00:05:00:00:43 00:00:05:00:00:40 00:00:05:00:00:40 00:00:05:00:00:40 00:00:05:00:00:21 00:00:05:00:00:30	00.00.06.00.00.59 00.00.06.00.00.41 00.00.06.00.00.50 00.00.06.00.00.50 00.00.06.00.00.47 00.00.06.00.00.43 00.00.06.00.00.48 00.00.06.00.00.49 00.00.06.00.00.27 00.00.06.00.00.27	0x8100 0x8100 0x8100 0x8100 0x8100 0x8100 0x8100 0x8100 0x8100 0x8100	401 401 401 401 401 401 401 401 401 401	2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	8 5 5 6 7 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8	* * * * * * * * * * * * * *	* * * * * * *	A A X A A A X X	A A A A A A A A A A A A A A A A	- - - - - - - - - - - - - - - - - - -	1 1 1 1 1 1 1 1 1	
Static Traffic Impairments QuickTests		50.0.0.1 50.0.0.1 50.0.0.1 50.0.0.1 50.0.0.1 50.0.0.1 50.0.0.1 50.0.0.1	1 1 1 1 1 1 1 1 1 1 1 1 1	0x000000000000000000000000000000000000	1 1 1 1 1 1 1 1 1 1 1 1 1 1	00:00:05:00:00:59 00:00:05:00:00:41 00:00:05:00:00:50 00:00:05:00:00:10 00:00:05:00:00:47 00:00:05:00:00:43 00:00:05:00:00:40 00:00:05:00:00:40 00:00:05:00:00:40 00:00:05:00:00:21 00:00:05:00:00:30	00.00.06.00.00.59 00.00.06.00.00.41 00.00.06.00.00.50 00.00.06.00.00.1e 00.00.06.00.00.47 00.00.06.00.00.43 00.00.66.00.00.43 00.00.66.00.00.43 00.00.66.00.00.39	0x8100 0x8100 0x8100 0x8100 0x8100 0x8100 0x8100 0x8100 0x8100 0x8100	401 401 401 401 401 401 401 401 401 401	2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	8 8 2 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8	* * * * * * *	* * * * *	* * * * * * *	A A X X A A A A X	- * * * * * * * * * * * * * * * * * * *	1 1 1 1 1 1 1 1 1 1	
Barcarder Running Store Traffic Impairments QuickTeets Captures	11	50.0.0.1 50.0.0.1 50.0.0.1 50.0.0.1 50.0.0.1 50.0.0.1 50.0.0.1 50.0.0.1 50.0.0.1	1 1 1 1 1 1 1 1 1 1 1 1 1 1	0×00000000000000000000 0×0000000000000	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	$\begin{array}{c} 00:00:05:00:00:59\\ 00:00:05:00:00:41\\ 00:00:05:00:00:10\\ 00:00:05:00:00:10\\ 00:00:05:00:00:47\\ 00:00:05:00:00:43\\ 00:00:05:00:00:43\\ 00:00:05:00:00:26\\ 00:00:05:00:00:26\\ 00:00:05:00:00:30\\ 00:00:05:00:00:30\\ 00:00:05:00:00:30\\ 00:00:05:00:00:30\\ 00:00:05:00:00:20\\ 00:00:05:00:00:20\\ 00:00:05:00:00:20\\ 00:00:05:00:00:20\\ 00:00:05:00:00:20\\ 00:00:05:00:00:20\\ 00:00:05:00:00:20\\ 00:00:05:00:00:20\\ 00:00:00:00:20\\ 00:00:00:00:20\\ 00:00:00:00:20\\ 00:00:00:00:20\\ 00:00:00:00:20\\ 00:00:00:00:20\\ 00:00:00:00:20\\ 00:00:00:00:20\\ 00:00:00:00:00:20\\ 00:00:00:00:00:00\\ 00:00:00:00:00:00\\ 00:00:00:00:00:00\\ 00:00:00:00:00:00\\ 00:00:00:00:00:00\\ 00:00:00:00:00:00\\ 00:00:00:00:00:00\\ 00:00:00:00:00:00\\ 00:00:00:00:00:00\\ 00:00:00:00:00:00\\ 00:00:00:00:00:00\\ 00:00:00:00:00:00\\ 00:00:00:00:00:00\\ 00:00:00:00:00:00\\ 00:00:00:00:00:00\\ 00:00:00:00:00:00\\ 00:00:00:00:00:00\\ 00:00:00:00:00:00\\ 00:00:00:00:00:00\\ 00:00:00:00:00:00\\ 00:00:00:00:00:00\\ 00:00:00:00:00:00\\ 00:00:00:00:00:00\\ 00:00:00:00:00:00\\ 00:00:00:00:00:00\\ 00:00:00:00:00:00\\ 00:00:00:00:00:00\\ 00:00:00:00:00:00\\ 00:00:00:00:00:00\\ 00:00:00:00:00:00\\ 00:00:00:00:00:00\\ 00:00:00:00:00:00\\ 00:00:00:00:00:00\\ 00:00:00:00:00:00\\ 00:00:00:00:00:00\\ 00:00:00:00:00:00\\ 00:00:00:00:00:00\\ 00:00:00:00:00:00\\ 00:00:00:00:00:00\\ 00:00:00:00:00:00\\ 00:00:00:00:00:00\\ 00:00:00:00:00:00\\ 00:00:00:00:00:00\\ 00:00:00:00:00:00\\ 00:00:00:00:00:00\\ 00:00:00:00:00:00\\ 00:00:00:00:00:00\\ 00:00:00:00:00\\ 00:00:00:00:00\\ 00:00:00:00:00\\ 00:00:00:00:00\\ 00:00:00:00:00\\ 00:00:00:00:00\\ 00:00:00:00:00\\ 00:00:00:00\\ 00:00:00:00:00\\ 00:00:00:00:00\\ 00:00:00:00:00:00\\ 00:00:00:00:00:00\\ 00:00:00:00:00:00\\ 00:00:00:00:00:00\\ 00:00:00:00:00:00\\ 00:00:00:00:00:00\\ 00:00:00:00:00:00\\ 00:00:00:00:00\\ 00:00:00:00:00\\ 00:00:00:00:00\\ 00:00:00:00:00:00\\ 00:00:00:00:00:00\\ 00:00:00:00:00\\ 00:00:00:00:00\\ 00:00:00:00:00\\ 00:00:00:00:00\\ 00:00:00:00:00\\ 00:00:00:00:00\\ 00:00:00:00:00\\ 00:00:00:00:00:00\\ 00:00:00:00:00:00\\ 00:00:00:00:00:00\\ 00:00:00:00:00:00\\ 00:00:00:00:00:00\\ 00:00:00:00:00:00$	00.00.06.00.00.59 00.00.06.00.00.41 00.00.06.00.00.50 00.00.06.00.00.50 00.00.06.00.00.47 00.00.06.00.00.43 00.00.06.00.00.48 00.00.06.00.00.49 00.00.06.00.00.27 00.00.06.00.00.27	0x8100 0x8100 0x8100 0x8100 0x8100 0x8100 0x8100 0x8100 0x8100 0x8100 0x8100	401 401 401 401 401 401 401 401 401 401	2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	8 5 5 6 7 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8	* * * * * * * * * * * * * *	* * * * *	A A X A A A X X	A A A A A A A A A A A A A A A A	- - - - - - - - - - - - - - - - - - -	1 1 1 1 1 1 1 1 1 1 1 1	

18. To see list of **ACTIONS** associated to the flow, reduce the left window pane size, select the desired flow, and observe actions in the split window.

Ona	innel Lea	arned Ir	nfo (Flow Learned I	nfo											
Refres	h Learned	Info for:	-						_						
evice	All		▼ Interface AI			OF OF	All	-	3						
	Remote IP	Data Path ID	Data Path ID (Hex)	In Port	Ethernet Source	Ethernet Destination	Ethernet Type	VLAN ID	VLAN A		Flow Index	Action Type	Output Port	Max Byte Length	Queue IE
	50.0.0.1	1	0×0000000000000000	1	00:00:05:00:00:62	00:00:06:00:00:62	0x8100	401	2	1	1	Set VLAN ID	NA	NA	NA
	50.0.0.1	1	0x000000000000000000000000000000000000	1	00:00:05:00:00:59	00:00:06:00:00:59	0x8100	401	2	2	1	Output	2	0	NA
	50.0.0.1	1	0x000000000000000000000000000000000000	1	00:00:05:00:00:41	00:00:06:00:00:41	0x8100	401	2						
	50.0.0.1	1	0x000000000000000000000000000000000000	1	00:00:05:00:00:50	00:00:06:00:00:50	0x8100	401	2		/				
	SUUD:	1	0x000000000000000000000000000000000000	1	00:00:05:00:00:1e	00:00:06:00:00:1e	0x8100	401	2			r			
Sei	ect _{o.o}	1	0×000000000000000000000000000000000000	1	00:00:05:00:00:47	00:00:06:00:00:47	0x8100	401	2						
FIC	₩0.0.0	1	0×000000000000000000000000000000000000	1	00:00:05:00:00:43	00:00:06:00:00:43	0x8100	401	2	I (Actions				
	50.0.0.1	1	0×000000000000000000000000000000000000	1	00:00:05:00:00:4a	00:00:06:00:00:4a	0x8100	401	2		associated				
	50.0.0.1	1	0×000000000000000000000000000000000000	1		00:00:06:00:00:03		401	2		to the flow				
	50.0.0.1	1	0×000000000000000000000000000000000000	1	00:00:05:00:00:2f	00:00:06:00:00:2f	0x8122	101	2			,			
	50.0.0.1	1	0×000000000000000000000000000000000000	1	00:00:05:00:00:3e	00:00:06:00:00:3e	0x8L0Åi	ag this	1	1					
	50.0.0.1	1	0×000000000000000000000000000000000000	1		00:00:06:00:00:20		ndow to	2						
	00101011							he left	2						
	50.0.0.1	1	0x000000000000000000000000000000000000	1	00:00:05:00:00:0a	00:00:06:00:00:0a	OXC UU-	401	2						

19. Use the **Device filter** to see learned flow information for a particular device.

OF C	hannel Lear	med I	nfo Flow Learned In	fo					
	esh Learned I ce SW2	nfo fo				▼ OF	All	-	1
	SW1 SW2		ta Path ID (Hex)	In Port	Ethernet Source	Ethernet Destination	Ethernet Type	VLAN ID	VLAN Priority
1	SW4		000000000000000000000000000000000000000	1	00:00:05:00:00:62	00:00:06:00:00:62		401	2
2]SW5		000000000000000	1	00:00:05:00:00:59	00:00:06:00:00:59	0x8100	401	2
3	50.0.0.1	1	0x000000000000000000	1	00:00:05:00:00:41	00:00:06:00:00:41	0x8100	401	2
4	50.0.0.1	1	0x00000000000000000	1	00:00:05:00:00:50	00:00:06:00:00:50	0x8100	401	2
5	50.0.0.1	1	0x00000000000000000	1	00:00:05:00:00:1e	00:00:06:00:00:1e	0x8100	401	2
3	50.0.0.1	1	0x00000000000000000	1	00:00:05:00:00:47	00:00:06:00:00:47	0x8100	401	2
7	50.0.0.1	1	0x00000000000000000	1	00:00:05:00:00:43	00:00:06:00:00:43	0x8100	401	2
3	50.0.0.1	1	0x0000000000000000	1	00:00:05:00:00:4a	00:00:06:00:00:4a	0x8100	401	2
9	50.0.0.1	1	0x0000000000000000	1	00:00:05:00:00:03	00:00:06:00:00:03	0x8100	401	2
10	50.0.0.1	1	0x0000000000000000	1	00:00:05:00:00:2f	00:00:06:00:00:2f	0x8100	401	2
11	50.0.0.1	1	0x0000000000000000	1	00:00:05:00:00:3e	00:00:06:00:00:3e	0x8100	401	2
12	50.0.0.1	1	0x0000000000000000	1	00:00:05:00:00:20	00:00:06:00:00:20	0x8100	401	2
13	50.0.0.1	1	0x00000000000000000	1	00:00:05:00:00:0a	00:00:06:00:00:0a	0x8100	401	2
10								401	

Conclusions

This test case validates OpenFlow Controller's functionality and scalability by establishing multiple OpenFlow channels (TCP or secure TLS) with the emulated switches. Also, it can push thousands of flows with various match/actions and validate its accuracy from the learned information. In addition to that from the switch, you can generate other messages, such as Packet_in, port status message, and various error messages like flow_table_full, bad stat requests to ensure controller can handle these in coming message appropriately.

Variables

Use the following variables to test controller's scalability:

- Add large number of OpenFlow switches with different set of capabilities, configuration, and supported features/actions
- Generate various packet_in profiles and generate packet_in messages to the controller to validate the responsiveness of the controller

Test case: Packet_out Rate Calculation

Overview

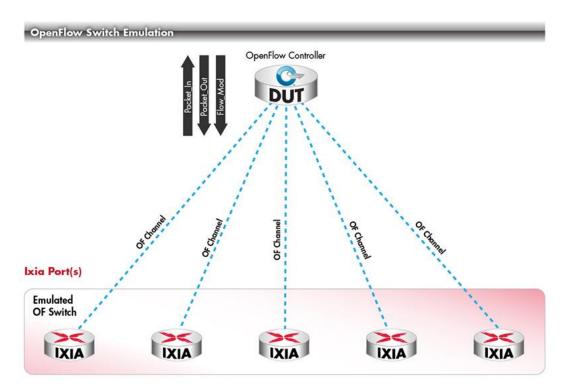
In the event, if OpenFlow switch receives any packets that do not have matching flow entry in its table, then it normally consults OpenFlow controller by generating packet_in message to the controller and let controller make the decision. Therefore, it is very important to test controller's responsiveness and make sure it learns and builds correct flow table for each switch as per the configured policy.

If the controller is not able to handle incoming packet_in message in timely manner, then it causes packet drops, higher latency, and network disruption.

Objective

This test case measures controller's responsiveness and accuracy of packet_in handling. Using packet in range you can generate various types of packet_in messages and measure the packet_out/flow_mod response time.

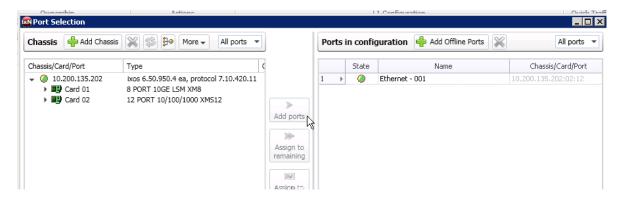
Setup



Step-by-Step Instructions

The following steps describe the procedure for performing the test.

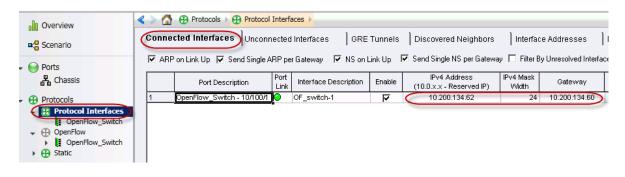
1. Reserve 1 Ixia port for OpenFlow switch emulation.



2. In the **Protocols** window, select **OpenFlow** checkbox to enable OpenFlow on port.

Overview	< >	🚹 🤂 Protocols 🔸												
Scenario	Routi	ng/Switching MPLS Mu	lticast	Carrie	er Etherne	et Acce	ss Aut	thentication	Data Ce	enter Bridging) Wirel	ess		
-		Port Description	Port Owner	Link	ARP	PING	BFD	BGP/BGP+	EIGRP	ISIS L2/L3	LACP	LISP	OpenFlow	OSPF
✓	1	Ethernet - 001 - 10/100/1000	IxNetwor	0	ম		Γ	Γ		Γ				Γ
Protocols														
OpenFlow Ethernet - 001 Static					\mathbb{R}									

 Click the Connected Interface tab to configure the emulated OpenFlow switch, IP address, and Gateway address in the Protocol Interfaces window. For OF Channel, ensure that ARP is resolved.

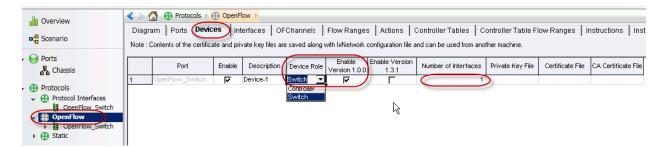


4. Define the **Number of Devices** and the port role as **control** by selecting the role from the **Port Role** list on the **Ports** tab on the **OpenFlow** window.

Note: Number of Devices option allows creating multiple OpenFlow Switch emulation on a single physical Ixia port. Make sure, unique protocol interface is created and assigned to each emulated switch.

Overview	< >	🚹 🤁 Protocols > 🔁 OpenFlow >				
	Diagra	am Ports Devices Interfaces	OFChannels	Flow Rang	es Actions	Controller Tak
■ Scenario		Port	Protocol State	Number of Devices	Number of Traffic Endpoints	Port Role
- ⊖ Ports Parts Ports	1	OpenFlow_Switch			NA	Control

- 5. Click the **Devices** tab and configure following parameters:
 - Device Role as Switch
 - Enable version v1.0.0 (v1.3.1 is not currently supported)
 - Number of Interfaces as 1
 - If secured TLS OF channel connection is desired then specify key file path (Optional)



6. Click the **Interface** tab of the **OpenFlow** window and assign the **Protocol Interfaces** that you created in the **Protocol Interface** window. This interface is used for the control-plane (OF Channel). Configure **Number of Channels** as *1*

Derview	✓ > Diagr To cha	A ⊕ Protocols) ⊕ Opening am Ports Devices (Interfaces, select ange number of Interfaces, select	erfaces		Flow Ranges		Controller T	ables Controlle	r Table Flow Ranges
 Ports Chassis 		Device Description		Protocol Interface	Number of OF Channels	Periodic Echo	Echo Interval	Enable Echo Timeout	Timeout Option
🖷 🤁 Protocols	1	Device-1 - OpenFlow_Switch		OF_switch-1	1	T	10		Timeout Value
Protocol Interfaces OpenFlow Switch									
OpenFlow OpenFlow_Switch									
Static									

7. In the **OF Channels** tab specify the controller's IP address in **Remote IP** field.

< >	🚮 🤁 Proto	cols 🕨 💮	OpenFlow →	\frown		
Diagra	am Ports	Devices	Interfaces	OFChannels	Flow Ranges	Actions Controller
	Interface	Enable	Description	Local IP	Remote IP	Enable Hello Element
1	OF_switch-1	V	OFChannel-1	10.200.134.62	(10.200.134.60)	Γ
L						
L						
L						
OF Ch	annels Conti	roller ∧ Sv	witch /			

- 8. Click **OF Channels Switch** tab and configure following parameters:
 - Number of Port ranges as 1
 - Number of PacketIn ranges as 2 (This allows you to create different traffic profile)
 - Enable Calculate Packetin reply delay checkbox

< >	🕻 > 🟠 🤁 Protocols > 🔁 OpenFlow >										
Diagr	am Ports	Devices	Interfaces OFC	hannels Flo	w Ranges 💧	Actions Contro	oller Tables Controll	er Table Flov	Ranges Instruction	s Instruction A	ctions Switch Ports
	Datapath Description	Max. Packet In Bytes	Store Flows	Number of Port Ranges	Number of Buffers	Number of Table Ranges	Number of Packetin Ranges	Packetin Tx Burst Size	Inter Packetin Burst Gap (In msec)	Calculate Packetin Reply Delay	Packetin Reply Timeout (In sec)
1	Ixiacom-001	128	v	1	1,000	2	2	500	1,000	N N	10
-											
	iannels ∑ Con	troller Swit	<u>ф</u> /								

9. In the Switch ports tab, configure Number of Ports as 10.

Enable Numbe Port:	r of Configure Range	Port Number	Ethernet Address	Port Name	Config	State	Current Features
R	10	1	00 00 00 11 11 11	ixia-001	Port Down,No STP,No Receive,No Re	Link Down,STP Listen,STP Learn,STP	Copper medium
	Ports	Ports	Ports	Ports	Ports	Ports	Ports

10. Click **Switch PacketIn Ranges** tab. This tab allows user to create various packetIn traffic profiles. Select **Send PacketIn** checkbox and clear **Enable** checkbox.

😮 🟠 🤁 Protocols) 🚯 OpenFlow) 🚺 OpenFlow_Switch >											
Devices Interfaces OF Channels Flow Ranges Actions Controller Tables Controller Table Flow Ranges Instruction Instruction Actions Switch Ports Switch Tables											
To change number of Packetins, select 'OF Channels' tab, and in 'Switch' page enter number in 'Number of Packetin' field											
			Consult Flow Table	Send Packetin	Packetin Headers	In Port	Configure Range	Packetin Name	Enable	OF Channel	
			Г	ম	Ethernet II.IPv4.Custom	1		Packetin - 0	Г	OFChannel-1	1
			Ē		Ethernet II.IPv4.Custom	2		Packetin - 1			2
			•	<u> </u>							-
			Γ		Ethernet II.IPv4.Custom	2		Packetin - 1			2

11. In the **PacketIn Headers** column, start Packet Editor by clicking the down arrow (right corner of packetIn headers field) as depicted in the following image.

< >	Carl 🔂 Protocols > 🕀 OpenFlow > 其 OpenFlow_Switch >									
De	rices I Int	erface	es OF	Channels Fl	ow Ranges A	tions Cor	ntroller Tables Controller Ta	able Flow Ranges	Instruction I Ins	struction Actions Switch Ports Switch Tables (Switch Packetin Ranges)
	To change number of Packetins, select 'DF Channels' tab, and in 'Switch' page enter number of Packetin' field									
	OF Cha	nnel	Enable	Packetin Name	Configure Range	In Port	Packetin Headers	Send Packetin	Consult Flow Table	
1	OFChan	nel-1	Г	Packetin - 0		1	Ethernet II.IPv4.Custom	ম 🚺	Г	
2				Packetin - 1		2	Ethernet II.IPv4.Custom	N	Γ	

The following image shows sample packet_In packet for IP traffic.

me	Value
B Frame	length: 46
🗸 📅 Ethernet II	
🗸 🧮 Ethernet Header	
Destination MAC Address	00:00:00:00:02
Source MAC Address	00:00:00:00:00:01
💳 Ethernet-Type	<auto> 0x0800</auto>
V 🚮 IPv4	
🗸 🚍 IP Header	
🚥 Version	4
🚥 Header Length	<auto>5</auto>
> 🧮 IP Priority	TOS
💳 Total Length (octets)	<auto> 28</auto>
- Identification	0
> 🧮 Flags	N
🚥 Fragment offset	l o
📥 TTL (Time to live)	64
- Protocol	<auto> 61</auto>
🚥 Header checksum	<auto>0x0000</auto>
- Source Address	1.1.1.1
- Destination Address	2.2.2.2
V EI IP options	
V 🔜 Next option	

Name			Value	Use dropdown	
🗸 🏬 Frame			length: 46	menu to use	
🗸 🚮 Ethernet II		Append/Insert	_	increment/list	
👻 🚍 Ethernet	Header	option can be used			
💳 Destin	nation MAC Address	to add protocols	00:00:00:00:00:02		~
💳 Sourc	e MAC Address		00:00:00:00:00:01		-
💳 Ether	net-Type		<auto> 0x0800</auto>		
Y 🚮 IPv4 🛛 🥑	Append Last	E 😼 🗟 %	o-		
- IP					
			4		*
	Export To File		<auto>5 TOS</auto>		-
) _ (F Insert Before		<auto> 28</auto>		·
	Remove		Q 0		-
			0		-
្ពី 📕	😤 Expand Children		64		-
_ °	🗧 Collapse Children		<auto> 61</auto>		
📥 Heade	er checksum		<auto> 0x0000</auto>		
📥 Sourc	e Address		1.1.1.1		-
💳 Destin	nation Address		2.2.2.2		-
🗸 💳 IP opt	ions				
🗸 🧮 Ne	ext option				

You can use the following options to create different packet types

12. Start OpenFlow protocol

File Home Au	tomation	Results / Reports	Viev	vs Con	figuration				
Protocols OpenFlow OpenFlow	W Traffic Group ID	Switch PacketIn Options +	Add Protoco	Stop	OpenFlow OpenFlow	Grid Operations			
Ac	tions		Build	Sel	ected	Grid			
Overview	< >	🚮 🤁 Protocols	s 🕨 🤁 Op	penFlow 🕨 🚺 🤇	OpenFlow_Swi	tch Running	▶		
scenario	Dev	ices Interface	s OF C	hannels Fl	ow Ranges	Actions	Controller Tables	Controller T	able Flow Range:
🗕 😝 Ports	T	o change number o	of PacketIn	is, select 'OF Ch	annels' tab, an	d in 'Switch' p	age enter number in 'Nu	umber of Packe	tln' field
Chassis		OF Channel	Enable	Packetin Name	Configure Ra	nge in Po	vrt Packetin	Headers	Send Packetin
- 🔂 Protoco	1	OFChannel-1		Packetin - 0		1	Ethernet II.IPv4.C	ustom	
Protocol Interfaces	2		F I	Packetin - 1		2	Ethernet II.IPv4.C	ustom	<u> </u>
OpenFlow_Swi OpenFlow OpenFlow Devices Switch Lea	witch								

13. Select the **OpenFlow Switch Aggregated Statistics** checkbox to view the stats.

To change number of Packetins, s	elect 'OF Channels' tab, and in 'Switch' page enter number in 'Number of PacketIn' field	
OF Channel Enable Pa	💀 Select Views (View Set: Overview Statistics)	l ×
1 OFChannel-1 Pac	😳 Create New View Set Show: Overview Statistics 🕅 🖓 🖓 🖓 Sustom View Wizard 🎬 Test Results Picker 📑 🏰 🏏 🔅	
2 Pac Select Views Port CP Stat Name > 1 10.200.135.202/Card02/Port12	□ ✓ Evenus (Total: 6) □ ✓ Defaults (Total: 6) □ ✓ Ports (Total: 4) ▼ ✓ Port CPU Statistics ▼ Port Statistics ▼ ● ✓ ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● ● </td <td></td>	

14. Make sure **OF channel** is UP.

	Select Views Port CPU	Statistics Por	t Statistics Global Pro	otocol Statistics 🚺	penFlow Switch Aggrega	ted Statistics
	Stat Name	Port Name	OF Channel Configured	OF Channel Configure	ed Up OF Channel Flap Cou	int
▶ 1	10.200.135.202/Card02/Port12	OpenFlow_Switch	1			0
					-	
			\searrow			
1				<u> </u>		
All	Session Handshake Flow Sta	t Config Packet	IN Error Vendor 😳			

15. Click the **Switch PacketIn Ranges** tab, and select the **Enable** checkbox. This generates packet_in message to the controller and monitor the stats.

Note: You can use this enable checkbox while protocol is in Running state. This allows user to generate on-demand packet_in message while protocol is running.

	OF Channel	Enable	Packetin Name	Configure Range	In Port	Packetin Headers	Send Packetin	Consult Flow Table
	OFChannel-1	N	Packetin - 0		1	Ethernet II.IPv4.Custom	<u> </u>	Γ
			Packetin - 1		2	Ethernet II.IPv4.Custom	V	
St	Select Views		t CPU Statistics Port Name ort12 OpenFlow_	Port Statistics			w Switch Aggregate	d Statistics
1 1	.0.200.135.202/	CardU2/Po	ort12 OpenHow_		2			

As an alternative, you can also use **Switch PacketIn Options** button in the ribbon to start/stop or pause packet_in message

Protocols OpenFlow OpenFlow OpenFlow Actions	Traffic Poup ID	Switch PacketIn Options	k	d cols v		Grid erations + Grid			
0 Overview	< >	Send Stop		DpenFlow 🔸 🚺	OpenFlow_Switch	Running 🕨			
🕰 Scenario	Devic	Send Paus		Channels F	low Ranges 🛛 A	ctions Co	ntroller Tables Controller T	able Flow Ranges	Instruction Inst
🗸 😝 Ports	Too	change number o	of Packet	ns, select 'OF Ch	annels' tab, and in '	Switch' page	enter number in 'Number of Packet	In' field	
Chassis		OF Channel	Enable	Packetin Name	Configure Range	In Port	Packetin Headers	Send Packetin	Consult Flow Table
→ → Protocols	1	OFChannel-1	ন	Packetin - 0		1	Ethernet II.IPv4.Custom	ম	Γ
- 🔁 Protocol Interfaces	2		V	Packetin - 1		2	Ethernet II.IPv4.Custom		
OpenFlow_Switch OpenFlow OpenFlow OpenFlow Devices E Switch Learned In									

16. From the protocol tree, expand OpenFlow view and click Switch Learned Information. Then click Refresh OF channel button in the ribbon. This action displays OF channel information and most importantly, it displays Average PacketIn Reply delay calculation in microsecond.

Protocols OpenFlow OpenFlow Trough Actions	sh of Resages Build
Overview	≼ 🔊 🟠 🤁 Protocols > 🤁 OpenFlow > 🙀 OpenFlow_Switch Running > 🖹 Switch Learned Information
Caracteria Scenario	Learned Into Records : D Channel : I-fow: 0
Chassis	OF Channel Learned Info Flow Learned Info
→ Protocols	Refresh Learned Info for.
Protocol Interfaces	Device All Vinterface All V
OpenFlow_Switch	Number of Last Error Last Error Number Max Packet In [Configured PacketIn Configured PacketIn Reply [Average PacketIn Reply Delay]
- 🔁 OpenFlow	Actions Supported Config Flags Session Type Number of Last Error Number Max Packet In Configured PacketIn Reply Packet Reply Average Packet In Reply Delay Errors Received Type Code of Ports Bytes Sent Count Count (nucee)
OpenFlow_Switch Running	1 0x00000FFF No special handling for fragments Configured 0 NA NA 10 128 3 1 12(14)
Devices	
Switch Learned Informatio	
> 🔂 Static	

Note: This is a cumulative statistics, therefore the calculation is based on total packet_in/packet_out sent/received over the period. If your test case requires to measure controller's response time under certain condition then stop/re-start the OpenFlow protocol to get the response time for that period.

17. To verify whether controller has accurately pushed the flow, click the **Flow Learned Info** tab, and then click on **Refresh Flows** button in the ribbon.

		dd ocols -														
Actions		ild Protocols	OpenFlow	DpenFlow_	Switch Running → 🖹 S	witch Lea	arned Information									
ac <mark>e</mark> Scenario		ed Info Records : annel : 1, Flow : 1					1									
✓ Orts Ports Chassis Chassis	OF Cha	annel Learned	nfo Flow Lear	ned Info												
Protocols Protocol Interfaces	- Refres Device	h Learned Info fo	r: Interface	JI	R I	OF	Al	Y								
OpenFlow_Switch OpenFlow OpenFlow_Switch Running		Local IP	Remote IP	Data Path ID	Data Path ID (Hex)	In Port	Ethernet Source	Ethernet Destination	Ethernet Type	VLAN V	/LAN IPv4	Source	IPv4 Destination	IP Protocol	IP DSCP	Transport Sources
Source Learned Informatio State		10.200.134.62	10.200.134.60	1	0x0000000000000000000000000000000000000	2	00:00:00:00:00:02	00:00:00:00:00:00	0x800	65535	0 2.2	2.2/32	1.1.1.1/32	61	0	*
Þ⊄ Traffic																
Impairments	Learne	ed Flows /														

Conclusions

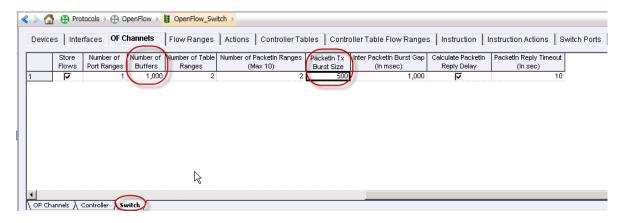
This test case validates:

- How fast the controller is processing incoming packet_ins and sending out packet_out or flow_mod
- Controller's ability to dynamically learn various packet_in types and accurately push the flows to correct switch and the port

Test Variables

Use the following variables to verify the behavior of an OpenFlow controller.

1. Increase the **PacketIn Tx Burst size.** To do that, increasing the **Number of Buffers** count is required.



- 2. Change **Inter PacketIn Burst Gap** settings to see if it has any effect in controller's responsiveness.
- 3. Also, try changing **PacketIn Reply Timeout** setting to see it changes the results
- 4. Create multiple packetIn ranges with different headers and unique packet count.

Test Case: Bandwidth Rate Limiting and QoS validation

Overview

As SDN gradually makes its way into data center networks, the end users' expectation is that it must meet or exceed the benefits offered by traditional networks. So, how can OpenFlow be used to perform rate limiting and QoS traffic engineering?

The OpenFlow v1.3 standard has added Meter/Band functions to support various simple QoS operations such as rate-limiting, QoS remarking, or packet drop. A meter measures the rate of packets assigned to it, and enables control of the packet rate. When installing flows, a controller can attach meters directly to each flow entry, as opposed to queues that are associated to ports.

A meter entry contains the following fields:

- Meter Identifier A 32-bit unsigned integer uniquely identifying the meter.
- Meter Band Each meter has one band. The band specifies the rate at which the band applies and the way packets should be processed. If the current rate of packets exceeds the rate of the band, the packets are processed in the way specified by the band.

A meter band contains the following fields:

- Band Type Defines how packets are processed. Packets that exceed the band rate are dropped or remarked.
- Rate Defines the lowest rate at which the band can apply.

Objective

This test case helps users to validate meter/band implementation on an OpenFlow-enabled switch. From Ixia's emulated OF Controller we will push high- and low-priority flows with different band types as shown below.

High-Priority flow

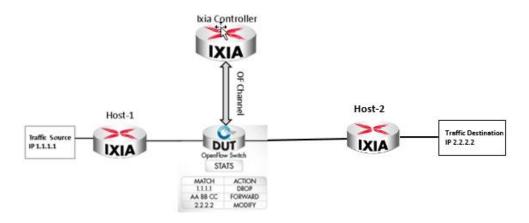
Match = Destination IP address and DSCP = 48 Priority = 1 Instruction = Meter Band Type = DSCP Remark Band Rate = 100 Mbit/sec Apply-Action = Set-field (DSCP value = 0)

Low-Priority flow

Match = Destination IP address and DSCP = 0 Priority = 1 Instruction = Meter Band Type = Drop Band Rate = 250 Mbit/sec

The expectation is, when a switch receives data-plane traffic that matches the rate, it should continue to forward traffic without any packet drop or QoS remarking. When the traffic exceeds the configured rate, for high-priority flow, the switch should start remaking the exceeded packets (above the specified rate) and for low-priority flow, it should start dropping the exceeded traffic (not all)

Setup



Step-by-Step Instructions

The following steps describe how to apply meter/band to each flow entry and validate QoS implementation of an OpenFlow switch

1. Reserve 3 Ixia ports (1 for OF Controller and 2 for data-plane traffic)

Chassis 👇 Add Chas	sis 🞇 😂 🎦 🔥 More 🕶 All ports 💌		Ports	in confi	iguration 🕂 Add Offline Ports	All ports
Chassis/Card/Port	Туре	¢		State	Name	Chassis/Card/Port
+ 🥥 10.200.134.45	ixos 6.70.0.50 eb, protocol 7.30.0.1412		1 →	0	OF_Controller	10.200.134.45:07:05
Card 01	16 PORT 10/100/1000 LSM XMVDC16NG		2	0	Host-1	10.200.134.45:07:06
Eard 02	16 PORT 10/100/1000 LSM XMV16		3	0	Host-2	10.200.134.45:07:07
Eard 05	30 48 PORT XM100GE4CXP+FAN+10GE	Add ports				
🚽 🌉 Card 07	16 PORT FlexAP10G165	Add ports				
🥔 Port 01	RG 01 LAN SFP+ 10GBASE-SR/LR	>>				
🥔 Port 02	RG 01 LANSFP+ 10GBASE-SR/LR	Assign to				
Ort 03	RG 01 LAN SFP+ 10GBASE-SR/LR	remaining	11			
Ø Port 04	RG 01 LAN SFP+ 10GBASE-SR/LR					
VPort 05	RG 02 LAN SFP+ 10GBASE-SR/LR D	()»/	11			
VPort 06	RG 02 LAN SFP+ 10GBASE-SR/LR D		11			
VPort 07	RG 02 LAN SFP+ 10GBASE-SR/LR D		11			
Ort 08	RG 02 LAN SFP+ 10GBASE-SR/LR		11			

2. In the **Protocols** Window, select the **OpenFlow** checkbox to enable OpenFlow

Overview Scenario	Routing	MPLS Multicast	Carrier Eth	emet	Access	Authenticati	on Data	a Center Bridging	Wireless	1				
_		Port Description	Port Owner	Link	ARP	PING	BFD	BGP/BGP+	EIGRP	ISIS L2/L3	LACP	LISP	OpenFlow	OSPF
e Ports	1	Host-1 - LAN SFP+ 10GBASE-	lxNetwor	0	ম	Г	Г	Г	Г	Г	Г	Г	<u>ज</u>	Г
Chassis	2	Host-2 - LAN SFP+ 10GBASE-	lxNetwor	0	2	Γ	Г	Γ	Γ	Г	Γ	Γ	<u> </u>	Ē
	3	OF_Controller - LAN SFP+ 10	IxNetwor	0	V	Γ	Ē	Γ	Г	Γ	Γ	Г		Ē
Protocols Protocol Interfaces OpenFlow Static														

3. Click the **Connected Interface** tab to configure the emulated OpenFlow switch, IP address, and **Gateway** address in the **Protocol Interfaces** window. For OF Channel, ensure that ARP is resolved.

Overview	Conne	cted Interfaces Unconnected Inte	rfaces	GRE Tunnels Dise	covered Nei	ghbors Interface Addresses	DHGPv4 Di	scovered Informati	ion
K Scenario	_			1			1		
2.	Al N	RP on Link Up 🔽 Send Single A	\RP pe	er Gateway 🛛 🔽 NS on L	.ink Up	🔽 Send Single NS per Gatew	ay 🔲 Filter By	Unresolved Inte	erfac
Ports		1	Deut			Dist. A station of	LIDe of Marcale L		
Chassis		Port Description	Port Link	Interface Description	Enable	IPv4 Address (10.0.x.x - Reserved IP)	IPv4 Mask VVidth	Gateway	
Protocols	1	Host-1 - LAN SFP+ 10GBASE	0	[Empty]					
Protocol Interfaces	2	Host-2 - LAN SFP+ 10GBASE	. 🔾	[Empty]					
	2	OF Controller - LAN SFP+ 10		Connected - Protocolint	N	50.0.0.2	24	50.0.0.1	

4. Define the **Number of Devices** and the port role as **control** by selecting the role from the **Port Role** list on the **Ports** tab on the **OpenFlow** window.

Note: The Number of Devices option allows creating multiple OpenFlow Switch emulations on a single physical Ixia port. Make sure a unique protocol interface is created and assigned to each emulated switch.

	Overview Scenario		> 🔏 Show 1 💿 Cor		tch O All	w 🕨					
- (Ports		Diagram	Ports Devic	ces Interfaces	Controller OF	Channels	Flow Ran	iges	Actions	Co
	Chassis			Port	Protocol State	Number of Devices	Number of Endpo		(Port Role	
- 6	Protocols	1	1	Host-1	1	NA		2	T	raffic	1
)	Protocol Interfaces	2	2	Host-2	1	NA		1	T	raffic	
	CopenFlow CopenFlow Static	3	}	OF_Controller) N4	1	0	Control	
•	 L2-3 Traffic Items High_Priority L2-3 Flow Groups 									ß	

- 5. Click the **Devices** tab and configure the following parameters:
 - Device Role as Controller
 - Enable version v1.3
 - Number of Interfaces as 1
 - If a secured TLS OF channel connection is desired then specify key file path (Optional)

Overview	🔦 > 🙍 🤁 Protocols > 🔁 OpenFlow >
Scenario	Chow Tabs: C Controller C Switch C Al
▼ 😝 Ports	Disgram Parts Devices Autors Controller OF Channels Flow Ranges Actions Controller Tables Controller Table Flow Ranges Instruction Actions Groups Buckets Buckets Buckets Note: Controller to the certificate and private key files are saved along with InNetwork configuration file and can be used from another machine.
Protocols Protocol Interfaces	Port Enable Description Device Role Enable Version 1.0.0 Enable Version 1.3.1 Number of Interfaces Private Key File Certificate File CA Certificate File
OpenFlow Static	1 OF_Controle V Device-1 Controler V 1

6. Click the **Interface** tab of the **OpenFlow** window and assign the **Protocol Interfaces** that you created in the **Protocol Interface** window. This interface is used for the control-plane (OF Channel). Configure **Number of Channels** as *1*

Overview	<
	Controller Switch C All
- 😝 Ports 프립 Chassis	Diagram Ports Devices Interfaces Controller OF Channets Flow Ranges Actions Controller Tables Controller Table Flow Ranges Instructions To change number of Interfaces, select 'Devices' tab, and enter number in 'Number of Interfaces' field
Protocols Protocol Interfaces	Device Description Enable Protocol Interface Number of OF Number of OF Switches Swit
OpenFlow Static	1 Device-1 - OF_Control Connected - ProtocolInterfa 1 0 V 10 V

 In the OF Channels tab specify the IP address of the OpenFlow switch in the Remote IP field. Also, configure Number of Tables as 1 and Number of Meters as 2

	-	ocols 🕨 🤆	DenFlow	>														
Show Cor	Tabs: ntroller O	Switch	C All															
Diagram	1 Ports	Devices	Interfaces Co	ontroller OF	Channels F	low Ranges	Actions Controlle	er Tables	Controller Ta	ble Flow Range	is Instructions	Instruction Actions	Groups	Buckets	Bucket A	tions Meters	Bands	Traffic Endpoin
	Interface	Enable	Description	Local IP	Remote IP	Enable Hello Element	Startup Feature Request	Use Datapath		Datapath ID (In Hex)	Start Up Role Request	Start Up Generation ID	Numbe	r of Flow R	anges N	mber of Tables	Number Meter	
1	Connecte	ন	OFChannel-1	50.0.0.2	50.0.0.1	ম	7	Γ	0	0	No Role Request	0			0		1	2

8. Go to the **Controller Tables** tab and configure **Table ID** 0 (default) and **Number of Flow Ranges** to 2

< > 🚮 🤂	Protocols 🕨 🤁 Ope	enFlow 🕨					
Show Tabs: Controller Diagram Port	の Switch の All s Devices Interfa		oller OF Channels	Flow Ranges Ac	tions Controller Table	S Controller Table Flow Ranges	Instructions
OFC	hannel Description	Enable	Table ID	Table Name	Number of Flow Ranges	Features Supported	
1 OFCha	annel-1 - Connected	V 🛛	\bigcirc	Controller Table - 0	2	hstruction,Instruction Miss,Nex	t T
						k	
Controller 1a	ble) { Features } E	xperimenter:	s ∖AII /			r\\	

9. In Controller Table Flow Ranges tab configure 2 flows with Src/Dst MAC and IP address, Ether type and DSCP value.

Jagram	Ports Devices	Interfac	es Controll	er OF Channels	Flow Ra	anges Act	ions	Control	ller Tables Controll	er Table Flow Range	s) Instructions Instru	uction Actions Group	s Buck	ets Bu	cket Actions Mete	rs Bands	Traffic Endpoints	1
lter Po	ort, Ethernet, IPv	4	1	·					-									
C	Controller Table Description	Enable	Table Miss Flow Entry		Number of Flows	Configure Range		Physi cal In	Ethernet Source	Ethernet Source Mask	Ethernet Destination	Ethernet Destination Mask	Ethernet Type	IPv4 Source	IPv4 Source Mask	IPv4 Destination	IPv4 Destination Mask	IP DS
C	Controller Table -	4	Γ	High_Priority	1		131	*	00:00:00:aa:bb:cc	00 00 00 00 00 00 00	00:00:00:00:dd:ff	00 00 00 00 00 00 00	800	1.1.1.1	255.255.255.255	2.2.2.1	255.255.255.255	i 4
		₹	Γ	Low_Priority	1		131	*	00:00:00:11:22:33	00 00 00 00 00 00 00	00:00:44:55:66:77	00 00 00 00 00 00 00	800	1.1.1.1	255.255.255.255	2.2.2.2	255.255.255.255	i (

10. On **Controller Tag Flow Ranges > Config** tab, change **Match type** to Strict and **Number of Instruction** to 2

Diagran	n Ports Devices Inter	rfaces Control	ler OF Channels	Flow Ranges	Actions	Controller T:	ables Con	troller Table F	low Range	Instructions I Instr	uction Actions
lter	Port, Ethernet, IPv4			T How Funger	- nonono	Congoiner 1					
	Controller Table	Send Flow	Check R	eset No Packet	No Puto	ldle	Hard				Number
	Description	Removed		counts Counts	Counts	Timeout	Timeout	Match Type	Priority	Flow Advertise	Instructi
	Controller Table - 0 - OFC	Г	Г		Г	0	0	Strict	0	N	
						0	0	Strict	0	N	l l
				I						P	

11. Go to Instructions tab, change Instruction Type as Meter and configure Meter ID

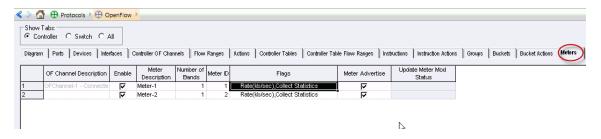
Note: The Meter ID must be the same as per Meters tab

			hannels Flow R	anges	Actions	Controller	Tables	Controller Ta	able Flow Ranges	Instructions	nstruction Act
Ca	ontroller Table Flow Range Description	Description	Instruction Type	Metel	Metadata	Metadata Mask	Table ID	Experimenter	Experimenter E: Data	xperimenter Data Length	Number of Actions
High	n_Priority - Controller Table -	Instruction-1	Meter	1	0	0	_	0		1	0
		Instruction-4	Apply Action	1	0					1	1
Lov	v_Priority - Controller Table -	Instruction-1	Meter	2	0					1	
		Instruction-4	Apply Action	1	0	0	0	0		1	1

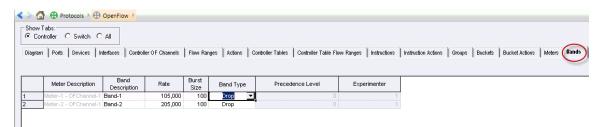
12. On **Instruction Actions** tab, change the **Action Type** as Output and correctly specify **Output port**

'LAN ID VLAN Prio
1
1

13. On **Meters** tab, configure **Meter ID**, enable **Rate (Kb/Sec) and Collect Statistics** flags



14. Go to **Bands** tab, configure desired **Rate** and set the **Band Type**



15. From **Controller Table Flow Ranges** tab launch **Generate Traffic endpoints** wizard. This step is required to create traffic endpoints with matching source/destination flow entry

File Home Automation Re	Results / Reports Views Conf	iguration				
	Update Flow Mod • Protocols •	Traffic Endpoint(s) Grid Operations •				
Actions	Build	Edit Grid				
all Overview ■ Scenario → Ports all Chassis	Show Tabs:]	anges Actions Controller T:	eles Controller Table Flow Ra	ngeo Instructions Instruction Ac	tions Groups Buckets
Protocols Protocol Interfaces	Controller Table Enable	Entry	Flows	In Port Physical In		Ethernet Source Mas
		High Priority	1	131 *	00:00:00:aa:bb:cc	

- 16. Generate Traffic endpoints wizard steps:
 - a. On page#1, select Source/Destination port and hit Next

penflo	w Tra	affic Conve	erter Wizard - Port Select - Name
Sele	et Por	t(s) for Wiza	rd Configuration
		Enable	Port Description
1		N	Host-1 - LAN SFP+ 10GBASE-SR/LR
2		V	Host-2 - LAN SFP+ 10GBASE-SR/LR
3		Г	Host-3 - LAN SFP+ 10GBASE-SR/LR
4		Γ	OF_Controller - LAN SFP+ 10GBASE-SR/LR

b. On page#2, select the **flow range (**in this case **High Priority** flow range) that we want to create **traffic endpoints** and hit **Next**

Openflow Traff	ic Converter Wizard - Select Flow Ranges - Name		
	Flow Range	Include In Traffic	Γ
1 🤇	High_Priority - Controller Table - 0 - OFChannel-1 - Connected - ProtocolInterface -	N	
2	Low_Priority - Controller Table - 0 - OFChannel-1 - Connected - ProtocolInterface -	Г	-
	Ν		

c. On page#3, select the Traffic Source port and hit Next

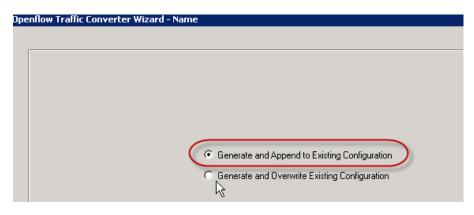
penflow T	raffic Converter Wiza	rd - DUT In Port To Ixia P	ort Mapping - Name	-
	In Ports			
	DUT In Port	User Flow Ranges	Ixia Port (Traffic Src)	
1	131	High_Priority - Controller	Host-1	
			unassigned	K
			Host-1	
			Host-2	

d. On page#4, select Traffic Destination port and hit Next

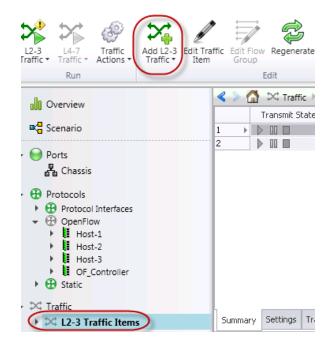
Dpenflow Traffic Converter Wizard - DUT Out Port To Ixia Port Mapping - Name								
	Out Ports							
	DUT Out Port	User Flow Ranges	Ixia Port (Traffic Dst)					
1	132	High_Priority - Controller	Host-2					
		······						

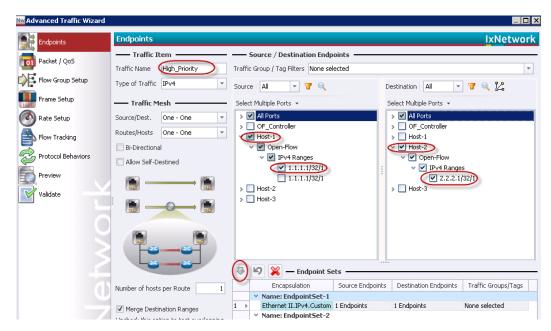
e. On page#5 and 6 verify **source and destination field** information to make sure it is correct

f. On page#7, select right option to apply configuration. The Generate and Append option will add a new traffic endpoint (i.e., it will keep existing endpoints on that port). The 2nd option, Generate and Overwrite, will erase existing endpoints and create new endpoints. So, carefully select this option.



- g. Repeat steps **a to f** for another flow range(in this case **Low Priority flow** range)
- 17. Once the traffic endpoints are created, Use Traffic Wizard to create a traffic stream for High- and Low-Priority flows by following these steps:
 - a. Launch traffic wizard





b. Select source and destination endpoint and hit next

c. On page#2, change IP priority to Diff-serv and set DSCP value

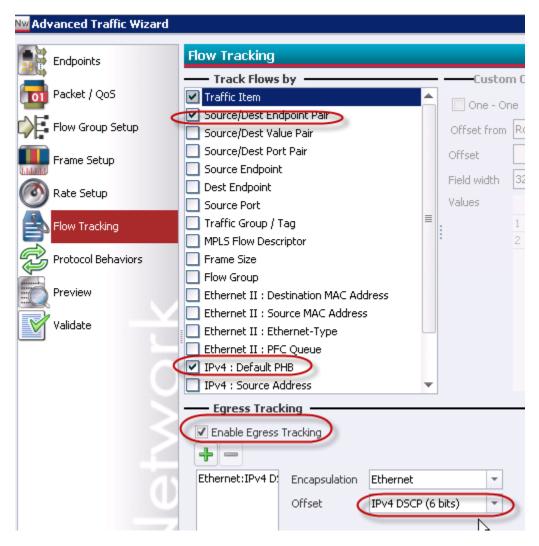
Endpoints	Packet / QoS				<u>Ixl</u>	letworl
	 All Encapsulation 	s 🔘 Per Encapsulation				
Packet / QoS	Name Name				IPv4 : IP Priority	IPv4 : TTL
Flow Group Setup	1 → EndpointSet-1	Ethernet II.IPv4.Custom Host-1				64
Frame Setup	4					
	All Encapsulations - :	Same settings will be applied to all (1)	encapsulation(s)			
Rate Setup	🔍 🖄 🛓 🐧	a 🏫 🔂 🛛 Field Lookup: 🚪	- 2		Go to Stac	k Diagram 🗖
Flow Tracking	Name			/alue		
Protocol Behaviors	V 💵 Frame		1	ength: 128		
Protocol Benaviors	V 🚮 Ether					
Preview		hernet Header				
		Destination MAC Address		<learned info="">00:00:00:00:0 <learned info="">00:00:00:00:00:0</learned></learned>		-
Validate		 Source MAC Address Ethernet-Type 		<learned inro="">00:00:00:00:00:0 <auto> 0x0800</auto></learned>	0:00	
	v 📊 IPv4	Ethernet-Type		CAUTO > 0X0800		
		Header				
		Version				-
		Header Length		<auto> 5</auto>		
		IP Priority		Diff-serv		Ŧ
		Diff-serv				
		🗸 🧮 Per Hop Behavior	[Default PHB		-
		🗸 🚍 Default PHB				
		Default PHB	•	18		-
		- Unused	(0x0		-
				<auto> 110</auto>		
)		Ψ.
Ž		Total Length (octets) Identification		<auto> 110)</auto>	Offset : 0 Length :	[

- d. Leave Flow Group setup page as it is
- e. On Frame Setup page, specify desired Frame Size

f. On **Rate Setup** page, configure L2 packet rate to matching band rate (in this case for High Priority flow, we are setting 100Mbps)

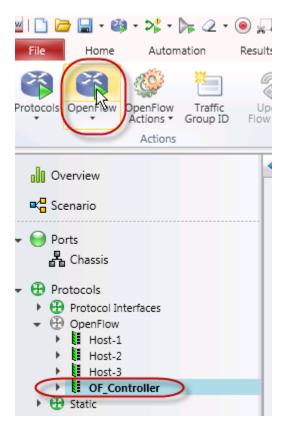
w Advanced Traffic Wizard			
Endpoints	Rate Setup		
	All Encapsulations	🔘 Per Encapsulat	ion
Packet / QoS	図書 Tx Port		Transmission
Flow Group Setup	1 N Host-1		
Frame Setup	4		
Rate Setup	All Encapsulations - San	ne settings will be ap	
	 France item fra Interleaved 	ansmission Mode	
Protocol Behaviors	O Sequential		
Preview	The Interleaved Transm packets from each Flow		
Validate	1		
	🛛 🔲 Round Robin Packel	: Ordering	
	1		
	Rate		
	🔘 Line rate	50.0000	%
	🔘 Packet rate	10000.00	per second
	💿 Layer2 Bit Rate	100.00	Mbps 🔹

g. On Flow Tracking page, enable Ingress tracking for source/destination pair, IPv4 PHB. Also, enable egress tracking for DSCP



- h. Leave all other page defaults and Finish the wizard
- i. Build traffic stream for Low Priority flow by repeating steps **a to h**. For Low Priority traffic, use **Diff-Serv value 0** and **L2 Bit Rate 200 Mbps**

18. Start OpenFlow protocol



19. Make sure OF channel comes up

DI Overview	Image: Show Tabs: C Controller C Switch C All	
Ports	Devices Interfaces Controller OF Channels Flow Ranges Actions Controller Tables Controller Table Flow Ranges Instr Filter Port, Ethernet, VLAN, IPv4	uction In
🔁 Protocols	Controller Table Description Enable Table Miss Flow Entry Description	Number (
	1 Controller Table - 0 - OFChan Image: Controller Table - 0 - OFChan Image: Controller Table - 0 - OFChan 2 Image: Controller Table - 0 - OFChan Image: Controller Table - 0 - OFChan Image: Controller Table - 0 - OFChan	
⊅⊄ Traffic		
▶ ⊅⊄ L2-3 Traffic Items	Range & Match / Config /	
💢 L2-3 Flow Groups	Select Views OpenFlow Controller Aggregated Statistics	
Impairments	Stat Name Port Name OF Channel Configured OF Channel Configured Up OF Channel Lea	arned Up
🛃 QuickTests	▶ 1 10.200.134.45/Card07/Port05 OF_Controller 1	0

20. Also, check Meter stats to see if OF Controller added Meter along with flow entry

					tistics	
		Stat Name	Port Name	Meter Adds Tx	Meter Mods Tx	Meter Dels Tx
•	1	10.200.134.45/Card07/Port05	OF_Controller	2	0	(
;	2	10.200.134.45/Card07/Port06	Host-1			
	3	10.200.134.45/Card07/Port07	Host-2			
	4	10.200.134.45/Card07/Port08	Host-3			

21. From Controller Learned information, Refresh OF Channel to get status

Protocols OpenFlow OpenFlow Traffic Refi	resh OF annels ons	
Coverview Coverview	Learned Info Records : OF Channel : 1, Topology : 5, Flow Stat : 3, Flo Meter Config Stat : 0, Meter Features Stat : 0, 1 Async Config Stat : 0, Switch Config : 0, Desc.	OF_Controller Running Controller Learned Information Iow Aggr. Stat : 1, Port Stat : 4, Vendor/Exp Stat : 0, Meter Stat : 0, Table Features Stat : 0, Group Stat : 0, Group Description : 0, Gro c. Stat : 1, Table Stat : 1, Queue Config : 0, Queue Stat : 0, Port Fe gregated Stat Port Stat Vendor/Experimenter Stat Description Stat
 Host-3 OF_Controller Running 	Actions Supported Se	Session Type Number of Errors Received
Controller Learned Information Static	1 <u>1 NA C</u>	Configured 140 Reque

22. Trigger on-demand Meter stats, Meter Configuration stat, and Meter Features stat

Proto	cols OpenFlow OpenFlow Actions Group ID	Refresh OF Channels Actions	
		Open Flow Learned Info Trigger Settings 🛛 🛛 🔀	ed i
	Overview	Queue Stat Port Features Meter Stat Meter Configuration Stat Meter Features Stat	-0.
•	Scenario	✓ Meter Stats	Me ript
- 6	Ports		npc tat
	La Chassis		_
- 6	Protocols	Meter ID All 🔽 4.294,967,295)esi
•	Protocol Interfaces		
•	OpenFlow		
	 Host-1 Host-2 		
	Host-3		Nu
	 OF_Controller Running 		Pat
	Devices		
,	Controller Learned Inform		

23. Analyze Meter Stat, Meter Configuration Stat, and Meter Features Stat response from the switch

F Chan leter Co	onfig Stat	opology : 2, Met	er Featur	Stat:3,Flo es Stat:1,1 g:0,Desc.	able Featur	es Stat : 0,	Group St	at:0,Gro	up Descript	on : 0, Grou		ə: O										
⁻ Chann	nel Learned	Info i	Flow Stat	Flow Aggr	egated Stat	Port Stat	Vendor/E:	×perimenter	Stat Des	ription Stat	Table Sta	at Queue Confi	a Que	ue Stat	Port Fe	dures T	opology Learned	Info (Het	ter Stat	eter Configuration	Stat Mete	ter Featur
lect the	e rows to :	_						Negotiate	4	Erro	r Error		Meter	Flow					_		Num	hber of
	Local I			Data Path		ata Path ID I	` '	Version	Latency	(usec) Typ	e code	Reply State	ID	Count		In Count	Byte In C		ouration(Sec	· · · ·	ec) Band	d Stats
2				7,850,491,6 7,850,491,6				0x04 0x04	146 146			Reply Receive Reply Receive					9 18,446,744,0 9 18,446,744,0		1,125,714	0		1
								C1 1 1				F 1 0										
eter C sync C ⁷ Chan	Config Sta	at:0,S ed Info	witch Co Flow S	n fig:0,De	sc. Stat : 1,	. Table Sta	t : 1, Que	eue Confi	g: O, Queu	e Stat : 0, F	Port Featu	Feature : 0 ures : 5 Table Stat Qu	eue Con	fig Q	ueue Stat	Port Fe	atures Topolo	ogy Leam	ed Info Me	eter Stat	Configura	ration S
feter C .sync C F Chan	Config Sta	at:0,S ed Info	witch Co Flow S	n fig:0,De at Flow A at requests	sc. Stat : 1,	Table Sta at Port 8	t : 1, Que	eue Confi ndor/Experi	g: O, Queu	e Stat : 0, F	n Stat	ures : 5		fig Q Meter	ueue Stat Numb Band	erof	atures Topoli	ogy Leam	ed Info Me	eter Stat Meter	Configura	ration S
feter C .sync C F Chan	nnel Learne he rows to Loca	at:0,S ed Info osendt al IP Re 0.2 50	witch Co Flow S trigger/s ernote IP D.O.O.1	n fig:0,De at Flow A at requests	sc. Stat : 1, ggregated St Path ID 91,698,097	Table Sta at Port S Data 1 0x00010	t : 1, Que tat Ven Path ID (H	eue Confi idon/Experi Hex)	g:0,Queu menterStat legotiated	e Stat : 0, F Descriptio	Port Featurn Stat	ares : 5 Table Stat Qu Error Reply	State	Meter ID 1	Numb	er of Stats	atures Topolo	ogy Leam	ed Info 💧 Me	eter Stat Nieter	Configura	ration S
feter C sync C F Chan elect th 1 2	Config Sta mel Learne he rows to Loca 50.0. 50.0.	at : 0, S ed Info o send t al IP Re 0.2 50 0.2 50	witch Co Flow S mote IP 0.0.0.1 0.0.0.1	nfig:0,De at Flow A at requests Data I 497,850,4 497,850,4	sc. Stat : 1, ggregated St Path ID 91,698,097 91,698,097	Table Sta at Port S Data I 0x0001 C 0x0001 C	t : 1, Que tat Ven Path ID (H C4CAD9E	Hex Confi Hex)	: 0, Queu menter Stat legotiated Version 0x04 0x04	E Stat : 0, F Descriptio Latency (usec) 1600 1600	Port Featurn Stat	Ires : 5 Table Stat Qu Error Reply NA Reply Ro	State	Meter ID 1	Numb Band	er of Stats	atures Topoli	ogy Leam	ed Info Me	eter Stat	Configura	ration S
F Chan elect th	Config Sta nnel Learne he rows to Loca 50.0. 50.0.	at : 0, S ed Info o send t al IP Re 0.2 50 0.2 50 tocols	witch Co Flow S mote IP 0.0.0.1 0.0.0.1	nfig:0,De at Flow A at requests Data 1 497,850,4	sc. Stat : 1, ggregated St Path ID 91,698,097 91,698,097	Table Sta at Port S Data I 0x0001 C 0x0001 C	t : 1, Que tat Ven Path ID (H C4CAD9E	Hex Confi Hex)	: 0, Queu menter Stat legotiated Version 0x04 0x04	E Stat : 0, F Descriptio Latency (usec) 1600 1600	Port Featurn Stat	Ires : 5 Table Stat Qu Error Reply NA Reply Ro	State	Meter ID 1	Numb Band	er of Stats	atures Topolo	ogy Leam	ed Info Me	eter Stat	Configura	ration S
F Channer C F Channer C F Channer C F Channer C C C C C C C C C C C C C C C C C C C	Config State mel Learne he rows to Loca 50.0. 50.0. 9 Pro d Info Reco cnnel : 1, T Config Stat	at : 0, S ad Info o send t al IP Re 0.2 50 0.2 50 tocols tocols	witch Co rigger/s mote IP 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1	nfig:0,De at Flow A at requests Data I 497,850,4 497,850,4	sc. Stat : 1, ggregated St Path ID 91,698,097 91,698,097 91,698,097 91,698,097 91,698,097 91,698,097 91,698,097 91,698,097	Table Sta at Port S Data I 0x0001 C 0x0001 C t: 1, Port St es Stat : 0,	t: 1, Que tat Ven Path ID (H 24CAD9E 24CAD9E 24CAD9E sat: 4, Ven Group Sta	eue Confi Idor/Experi Idex) h 357881 357881 IControlle Indor/Exp at : 0, Grou	1: 0, Queu menter Stat legotiated Version 0x04 0x04 r Learned Ir Stat : 0, Met p Descriptic	e Stat : 0, F Descriptio Latency (usec) 1600 1600 1600 rformation er Stat : 2 n : 0, Group	Port Feature :	ares : 5	State	Meter ID 1	Numb Band	er of Stats	atures Topolo	ogy Leam	ed Info Me	eter Stat Meter	Configura	ration S
F Chani elect th 1 2 Learner Ci Async C 2 F Char	Loca Loca 50.0. 50.0. Pro d Info Rec nnel : 1, T Config Stat Config Stat	at : 0, S ed Info 0 send t IIIP Re 0.0.2 50 0.2 50 tocords : - opplogy :: 2, Met t : 0, Sw	witch Co Flow S mote IP 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.1 0.0.0.0.	nfig : 0, De at Flow A at requests Data 497,850,4 497,850,4 497,850,4 enFlow > Stat : 3, Flo es Stat : 1, 1 ig : 0, Desc. Flow Aggr	sc. Stat : 1, ggregated St Path ID 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,697,097 31,697,097 31,697,097 31,697,097 31,697,097,097,097,097,007,007,007,007,007,0	Table Stat	t: 1, Que tat Ven Path ID (H 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E	eue Confi Idor/Experi Idex) 1357BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1	: 0, Queu menter Stat legotiated Version 0x04 0x04 r Learned Ir Stat : 0, Met p Descriptio ueue Stat :	e Stat : 0, F Descriptio Latency (usec) 1600 1600 rormation er Stat : 2 n : 0, Group 0, Port Feat	Port Feature : Difference :	ares : 5	State acceived	Meter ID 1 2	Numb	er of Stats						
feter C C sync C F Chan elect th 1 2 2 JF Char Aeter C Sync C F Char F Charn	Config Statement Learner he rows to Loca 50.0. 50.0. 50.0. Pro- d Info Rec ronel 1, Statement Config Statement to '0F Ch.	at : 0, S ed Info 0 send t IIIP Re 0.0.2 50 0.2 50 tocords : - opplogy :: 2, Met t : 0, Sw	witch CC Flow S rigger/s rinote IP 0.0.0.1 0.0.0.1 0.0.0.1 v: 5, Flow v: c, Flow ter Featu tich Coni	nfig : 0, De at Flow A dat requests Data I 497,850,4 497,850,4 497,850,4 97,850,4 97,850,4 97,850,4 97,850,4 97,850,4 97,850,4 97,850,4 97,850,4 97,850,4 97,850,4 97,850,4 97,850,4 97,850,4 97,850,4 97,850,4 97,850,4 97,850,4 97,850,4 97,850,4 97,850,4 97,850,4 97,850,4 97,850,4 97,850,4 97,850,4 97,850,4 97,850,4 97,850,4 97,850,4 97,850,4 97,850,4 97,850,4 97,850,4 97,850,4 97,850,4 97,850,4 97,850,4 97,850,4 97,850,4 97,850,4 97,850,4 97,850,4 97,850,4 97,850,4 97,850,4 97,850,4 97,850,4 97,850,4 97,850,4 97,850,4 97,850,4 97,850,4 97,850,4 97,850,4 97,850,4 97,850,4 97,850,4 97,850,4 97,850,4 97,850,4 97,850,4 97,850,4 97,850,4 97,850,4 97,850,4 97,850,4 97,850,4 97,850,4 97,850,4 97,850,4 97,97,97,97,97,97,97,97,97,97,97,97,97,9	sc. Stat : 1, ggregated St Path ID 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,698,097 31,697,097 31,697,097 31,697,097 31,697,097 31,697,097,097,097,097,007,007,007,007,007,0	Table Sta at Port S Data I 0x0001C 0x0001C 0x0001C 0x0001C 0x0001C	t: 1, Que tat Ven Path ID (F 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 24CAD9E 2	Hex Configuration (Controlle Action (Controlle Ac	g : 0, Queu menter Stat legotiated Version 0x04 0x04 r Learned Ir Stat : 0, Met p Description p Description stat : 2, Met p Description	e Stat : 0, F Descriptio Latency (usec) 1600 1600 1600 er Stat : 2 n : 0, Group 0, Port Feat	Port Feature : Error E Type (NA NA NA P Feature : ures : 5 Table Stat	Ires : 5 Table Stat Qu Error Reply Code Reply R NA Reply R 0 Queue Config	State sceived	Meter ID 1 2	Port Feature	er of Stats						
feter C sync C F Chan sleet th 1 2 Carnet Aeter Cr Async C F Chan feter Cr Async C	Config States inel Learner he rows to 50.0. 50.0. 50.0. 50.0. config States config States config States config States inel Learner to 'OF Ch- Local IP	at : 0, S ed Info o send It IIP Re 0.2 50 0.2 50 0.0 2 5	witch Cc Flow S State Prove P Prove	n fig : 0, De at Flow A at requests Data 497,850,4 497,850,4 497,850,4 9 Stat : 3, Flo es Stat : 1, 1 ig : 0, Desc. Flow Agg trigger Data Path	sc. Stat : 1, ggregated St Path ID 91,698,097 91,698,097 91,698,097 11,698,097 11,698,097 11,698,097 11,698,097 11,698,097 11,698,097 11,698,097 11,698,097 11,698,097	Table Sta at Port S Data I 0x0001C 0x0001C 0x0001C 0x0001C 0x0001C 0x0001C	t: 1, Que tat I Ven Path ID (F (4CAD9E V4CAD9E at: 4, Ven Queue CC Vendor/Ex Vendor/Ex	eue Confi Idor/Experi Idex) 1357BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1 1557BB1	g : 0, Queu menter Stat legotiated Version 0x04 0x04 0x04 r Learned Ir Stat : 0, Met p Descriptio ueue Stat : Stat Descriptio	e Stat : 0, F Descriptio Latency (usec) 1600 1600 1600 1600 er Stat : 2 n : 0, Group 0, Port Feat iption Stat	Port Feature : Difference :	Ires : 5 Table Stat Qu Error Reply NA Reply R NA Reply R 0	State accived	Meter ID 1 2	Port Feature	er of Stats						

24. **Start data-plane traffic**, since traffic rate is below (or equal) to configured rate, no traffic loss should be observed

L2-3 Traffic		ffic *	dit Traffic Item	Edit Flow Group	Regenerate Edit	Delete	Traffic Options	Find Of		irid/Column Profiles iroup Rows By +	• 0%
٥١٥	Overview	< >			L2-3 Flow	/ Groups					
		_		nit State	Suspend		Tx Port		Rx Ports	Flow Grou	
■× <mark>=</mark>	Scenario		✓ (G)		raffic Item I		ligh_Priority		interleaved, Src/D	st Mesh: OneToOn	
0	_	1	G			Host-1		Host-2;		High_Priority-En	
- 🖯			✓ (G)		raffic Item I		.ow_Priority		nterleaved, Src/D:	st Mesh: OneToOne	
	Chassis	2 🕨	G			Host-1		Host-2;		Low_Priority-End	lpointSet-1 I
+ 😶 + +	Protocols Protocol Interfaces OpenFlow Host-1 Host-2 OFC Running	Summa	ary Flow	groups	Frame Setup	1	Q				
	Devices Controller Learne	•	Select	Views		w Contr	oller Aggregat	ed Statistics	L2-L3 Test Su	mmary Statistics	Flow Statistic
•	🕀 Static	Traffic	Item	Tx Frame	es 🛛 Rx Fram	nes Fr	rames Delta 🛛 L	.oss %	Tx Frame Rate	Rx Frame Rate Tx	L1 Rate (bps)
		High_P	riority		791	791	0	0.000	50.000	50.000	59,200.00
	Traffic	Low_P	riority	1	,582	1,582	0	0.000	100.000	100.000	118,400.00
•	L2-3 Traffic Items High_Priority Low_Priority										

25. Now, **double the traffic rate** on both streams. Since the rate is exceeding configured Meter rate, switch should drop 50% traffic

L2-3 Traffic • Traffic • Actions • Run		Grid/Column Profile Group Rows By ▼
Overview	< 📎 🚮 🔀 Traffic 🕨 🔀 L2-3 Flow Groups	
	Transmit State Suspend Tx Port Rx Ports	Flow Gro
■ Scenario	🗸 🕐 🕅 📕 Traffic Item Name: High_Priority 🛛 TX Mode: Interleaved, Src/	Ost Mesh: OneToO
~	1 🕝 🕨 🔲 🔲 Host-1 Host-2;	High_Priority-E
	Y 🐼 🕨 📕 Traffic Item Name: Low_Priority 🛛 TX Mode: Interleaved, Src/D	
Chassis	2	Low_Priority-Er
Protocols Protocol Interfaces OpenFlow Host-1		\searrow
Host-2	Summary Flow groups Frame Setup	
Devices Controller Le		ummary Statistics
🕨 🔂 Static	Tx Frames Rx Frames Frames Delta Loss % Tx Frame Rate	Rx Frame Rate 🔰
🚽 🔀 Traffic	High_Priority 7,080 3,569 3,511 49.590 100.000	50.000
	Low_Priority 14,160 7,137 7,023 49.597 200.000	100.000
 		

26. To further test Meter function, try to change band type as DSCP remark

>	🚮 Protocols > 🔁 OpenFlow > 🚺	OFC Running						
	w Tabs: controller O Switch O All ces Interfaces Controller OF Channels Fi	low Ranges Actions Controller Table:	s Contr	oller Table Flow Range	s Instruction Ir	nstruction Actions Groups Buckets	Bucket Actions Meters (Bands
		1						
	Meter Description	Band Description	Rate	Burst Size	Band Type	Precedence Level	Experimenter	
1		Band Description Band-1	Rate 50		Band Type DSCP Remark	Precedence Level	Experimenter	

27. Start data-plane traffic with **double rate** than configured Meter rate. Observe **Ingress/Egress** statistics.

	≽ 📿 • 🧿 💭 • [Drill down per Source/Dest End	point Pair	IxNetwork [C	PqD-Meter_Rate_imiting.ixn	cfg]			
File Home Autom	nation Results / Re	eports	Show All Filtered Flows		Design					
🔲 Aw 😽			Drill Down per Rx Port		0		. 📫 New		Data Col	llection 📝 Autoscroll
2 27 1			Ingress/Egress Statistics	•	Ethernet:IPv4 DS	CP (6 bits) at offset 120	• 🖋 Edit		CSV Log	ging 📝 Autoupdat
lear All Customize Dri atistics • Traffic View Dow	ill Ingress/Egress S vn • Statistics • F	stat Viev Profiles	Customize		Show All Egress		🔻 💘 Pin	Custom View Te Wizard P	Picker Data Sto	ore 🔲 Overview
atistics Traf	fic Cu	ustomiz	Edit Filter Selection			View Sets		New View	G.	Data
Overview	< > 🚮 🔀 Tra	affic 🔸	Edit Statistics Designer							
	Transmit	t State	Show/Hide Overview		Flow Groups	Tx Ports	Rx Po	rts En	ndpoint/Encapsulation Se	ets
Cenario	1 🔸 🕨 🔳		Display view as Chart		1		1	1		1
Ports	2		Hide view		1		1	1		1
A Chassis			Show	•						
Protocols										
			UnPin							
🕨 🤁 Protocol Interfaces			Undock.							
Protocol Interfaces GpenFlow				•						
🕨 🤁 Protocol Interfaces	Right Mouse		Undock	۰ ۱						
Protocol Interfaces OpenFlow Host-1 Host-2 OFC Running	Right Mouse click		Undock Insert Row	, ,						
	click)	Undock Insert Row Insert Column	> > >						
Protocol Interfaces OpenFlow Host-1 Host-2 OFC Running	click) Is Trai	Undock Insert Row Insert Column Insert Formula Column	> > >					4	
Protocol Interfaces OpenFlow Host-1 Host-2 OFC Running Bovices Controller Lear Static	click		Undock Insert Row Insert Column Insert Formula Column Edit Custom Cell(s)) 	L2-L3 Test Summary Sta	atistics Flow Statistics	Data Plane Port	Statistics User	r Defined Statistics	Traffic Item Statistic
Protocol Interfaces OpenFlow Henderland Host-1 Host-2 Horderland OFC Running Bovices Controller Lear Static	click me Summary Set og: Select Via		Undock Insert Row Insert Column Insert Formula Column Edit Custom Cell(s) Delete Row	•	L2-L3 Test Summary Str Frame Rate Rx Frame	tistics Flow Statistics	Data Plane Port		~	Traffic Item Statistic Tx Rate (bps) Rx R
Protocol Interfaces OpenFlow It Host-1 It Host-2 It Host-2 It OFC Running	click me Summary Set og: Select Via	ws	Undock Insert Row Insert Column Insert Formula Column Edit Custom Cell(s) Delete Row Delete Column	•	Frame Rate Rx Frame	tistics Flow Statistics		Bytes Tx Rate	~	Tx Rate (bps) Rx R

The switch should start performing **DSCP remark** on exceeded packets as shown in below snapshot

	Select Views	OpenFlow Controller Aggregated Statistics	L2-L3 Test S	Summary Statis	tics Flow		Data Plane Port S	tatistics Use	r Defined Statistic	Traffic Item :	Statistics
k	Back 🔻 👧 🗄	thernet: IPv4 DSCP (6 bits) at offset 120 Ethe	rnet:IPv4 DSC	P (6 bits) at off	set 120			_			
	Traffic Item	Egress Tracking	Tx Frames	Rx Frames	Frames Delta	Loss %	Tx Frame Rate	Rx Frame Rate	T× L1 Rate (bps)	R×L1 Rate (bps)	Rx Bytes
Ξ1	High_Priority	Ethernet:IPv4 DSCP (6 bits) at offset 120	15,613	15,613	0	0.000	100.000	100.000	118,400.000	118,400.000	1,998,46
▶2	2/2 Flow	24		7,775				50.000		59,200.000	995,20
3		48		7,838				50.000		59,200.000	1,003,26
Ξ4	Low_Priority	Ethernet:IPv4 DSCP (6 bits) at offset 120	31,226	15,677	15,549	49.795	200.000	100.000	236,800.000	118,400.000	2,006,650
▶5	1/1 Flow	0		15,677				100.000		118,400.000	2,006,656
						10					

Conclusion

ſ

This test case validates meter functionality. When the traffic rate for the associated flow entry stays below the configured rate, the switch should not apply meter/band and no packet loss should be observed. When the traffic goes above the specified rate, the switch should apply meter and should either drop the exceeded traffic or perform DSCP remark for exceeded traffic if the band type is set to DSCP remark.

Contact Ixia

Corporate Headquarters Ixia Worldwide Headquarters 26601 W. Agoura Rd. Calabasas, CA 91302 USA +1 877 FOR IXIA (877 367 4942) +1 818 871 1800 (International) (FAX) +1 818 871 1805 sales@ixiacom.com

EMEA

Ixia Technologies Europe Limited Clarion House, Norreys Drive Maiden Head SL6 4FL United Kingdom +44 1628 408750 FAX +44 1628 639916 VAT No. GB502006125 salesemea@ixiacom.com

Ixia Asia Pacific Headquarters 21 Serangoon North Avenue 5 #04-01 Singapore 5584864 +65.6332.0125 FAX +65.6332.0127 Support-Field-Asia-Pacific@ixiacom.com Web site: www.ixiacom.com General: info@ixiacom.com Investor Relations: ir@ixiacom.com Training: training@ixiacom.com Support: support@ixiacom.com +1 877 367 4942 +1 818 871 1800 Option 1 (outside USA) online support form: http://www.ixiacom.com/support/inquiry/

Renewals: renewals-emea@ixiacom.com Support: support-emea@ixiacom.com +44 1628 408750 online support form: http://www.ixiacom.com/support/inquiry/?location=em ea

Support: Support-Field-Asia-Pacific@ixiacom.com +1 818 871 1800 (Option 1) online support form: http://www.ixiacom.com/support/inquiry/