

SDN Test Cases Development and Implementation

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Abstract—The evolution of information technology and the explosive growth in Internet data have rendered traditional ways of providing information services and their infrastructure no longer appropriate. Data storage, computing and Internet services are moving toward virtualization and cloud computing. However, the performance of this network architecture needs to be examined to improve network bandwidth utilization. Google's success in using the Software-Defined Networking (SDN) to achieve a system utilization rate as high as 90% stimulated widespread development of SDN. This work conducts SDN research and develops a test platform for conformance and interoperability analysis.

Keywords—Software-Defined Networking (SDN), Test Cases, Open Networking Foundation (ONF), Device Under Test (DUT), RYU

I. INTRODUCTION

As internet technology develops, service types have rapidly changed, and network technology has become highly competitive in the information and communication technology industries. To enhance the quality of network application services, new network technologies are needed. Internet service providers, telecommunications service providers, network technology research and development (R&D) units, and network management defenders are expected to construct a new generation of network infrastructure to meet the diverse needs of the network services today.

In SDN layered architectures, the control mode differs from that in the conventional network, and the network is divided into control plane and data plane. The controller uses a centralized approach to network management in the control plane. Network administrators can change settings directly on the controller and do not need to log on to each local respective network device, in addition to saving costs also reduces the possibility of human negligence of the deployment occurred.

II. BACKGROUND KNOWLEDGE

Table 1 below shows several examples of the successful application of SDN technology, making it one of the mainstream of the future development of the Internet's in the world. SDN is also the future of the core functionality beyond 4G (B4G) / 5G networks. The network communication industry has gradually developed products that use SDN

technology and urgently need a fully functional platform for SDN test and verification. This study builds a test case environment for developing SDN and for strengthening the breadth and depth of the surface of SDN.

TABLE 1. EXAMPLES OF DEVELOPMENTS IN THE GLOBAL SDN SYSTEM

SDN system	SDN application and technical characteristics
Google TE Server[5]	Google deployed its Data Center network through SDN and used traffic engineering technology to upgrade its network utilization.
Cisco onePK [6]	Cisco onePK is an SDN-based open network environment that provides an SDN programming development platform.
HP FlexNetwork Architecture [7]	HP FlexNetwork architecture based on SDN provides the network infrastructure for the data center and enables optimization of virtualization and cloud computing.
NEC MasterScope [8]	The NEC Master Scope based on SDN uses an automated virtual data center to provide the effective management to achieve cloud platform in large and complex environment.
VMware NSX[9]	The VMware NSX based on SDN provides virtual environments in internet data centers. The virtual environments can be used for optimization and virtualization in a cloud computing environment.
Microsoft Hyper-v 3.0 [10]	Microsoft Hyper-v 3.0 provides SDN network environment and network virtualization capabilities that allow multiple virtual network infrastructures to operate in the same physical network.
OpenDayLight Hydrogen [11]	OpenDayLight is an SDN development organization that provides the optimal platform.
Radware DefenseFlow [12]	Radware DefenseFlow is responsible for flow attack detection and defense mechanisms.
A10 SoftAX Series [13]	A10 SoftAX Series based on SDN provides the Load Balance needed to optimize the network server for service purposes.
BigSwitch Big Tap [14]	BigSwitch Big Tap based on SDN is an application for monitoring and analyzing network traffic.
Ryu SDN Framework [15]	Ryu is an SDN framework for control plane support of BGP, OF-Config 1.2, OpenFlow 1.4.
A Study of Requirements for SDN Switch Platform [16]	The SDN Switch Platform proposed by NTT allows users to develop SDN Software and Service.

III. RESEARCH METHODS

The SDN network provides conventional network deployment and effectively provides dynamic bandwidth allocation and resource management. It improves network quality so that internet service providers can offer next-generation networks that can support their core functionality. After importing the SDN architecture, cloud and mobile networks provide sufficient elasticity to meet user needs. Dividing the physical network into multiple virtual networks substantially increases flexibility. Network operators can deploy network resources planning based on service applications, reduce operating network management costs.

The objective of this study is to build an SDN platform validation testing environment to meet international standards of OpenFlow 1.3 test specifications, as show in Figure 1. Conformance testing is performed to ensure that the equipment meets the conditions required for testing and verification. Interoperability testing is performed to test whether equipment from different vendors can be connected to each other. Network verification platform is no longer confined along label equipment manufacturers. The interoperability testing program developed in this study can be used by many manufacturers to solve problems with equipment specifications and interoperability protocols and to help manufacturers develop products tend to improve and optimize, in addition to verified enforceability and integrity. In this study proposed that SDN test platforms, mainly including Device Under Test (DUT), Uni-Command, Testing Framework, Unit Testing Module, User Profile and Results Report. The DUT module is responsible for real-time monitoring and recording the results of the test cases, its includes network sniffer, performance monitor, bug/report/test automation utilities. The Uni-Command is responsible for instruction conversion between DUT and Testing Framework. The Testing Framework is responsible for test analysis for DUT. The Unit Testing Module is responsible for combination of test case. The User Profile is responsible for user information. The Results Report is responsible for DUT test results analysis report.

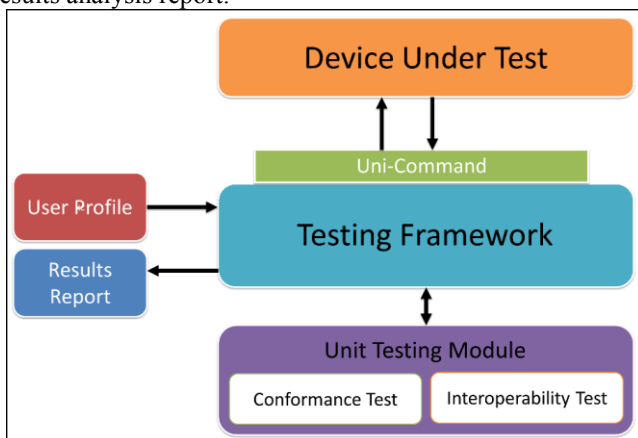


Figure 1. SDN Test Environment Platform

The test objectives and definitions are given below:

- **Traffic Generator:** The traffic generator is responsible for generating and transmitting network traffic to the SDN Controller and Switch and for transmitting traffic flow through the control to test process efficiency, delay, and input and output messages.
- **Network Emulator:** The Network Emulator is responsible for using network equipment to simulate the network environment. Through this simulated network environment for cases testing.
- **Attack Message Generator:** Attack Message Generator is responsible for sending network attack messages (Such as: DoS, TCP SYN, DDoS and Service Attack, etc.) to the SDN Controller and Switch in different test scenarios and for confirming the security mechanisms in Controller and Switch.
- **Network Sniffer:** Network Sniffer is responsible for monitoring the overall test Network, real-time capture and transmission of the SDN Controller and Switch packet delivery status, and packet information.
- **Performance Monitor:** Performance Monitor is responsible for monitoring the overall network performance and for providing network performance information to users.

3.1 Test case coverage

Testing is divided into conformance testing and interoperability testing for SDN Controller and Switch for test analysis. (1) The conformance test addresses the basic operational functions for building a test environment. The test category comprises the control channel, controller-to-switch messages, flow table, group table, meter, counters, meter modification messages and protocol messages. (2) The interoperability test focuses on packet exchange, table updating or deleting, and message exchange as a basis for development, which includes multiple tables and metadata, 1 on 1 testing, small topology testing, compliance test cases, L3 forwarding and firewall, L2 and L3 forwarding, failure recovery, L2 and L3 multi-path, basic interoperability, discovery, and topology mapping. Test case coverage as shown in Table 2.

TABLE 2. TEST CASE COVERAGE

Conformance Test	Interoperability Test
➤ Control Channel	➤ Multiple tables and meta data
➤ Controller-To-Switch messages	➤ 1 on 1 Testing
➤ Flow table	➤ Small topology testing
	• L2 Data Plane Traffic
	• L3 Data Plane Traffic
➤ Group table	➤ L3-Forwarding and firewall
➤ Meter	➤ L2 and L3 forwarding
➤ Counters	➤ Failure recovery
➤ Meter Modification Messages	➤ L2 and L3 Multi-path
➤ Protocol Messages	➤ Basic Interoperability
	➤ Discovery and Topology Mapping

3.2 Test environment and category

This work test environment consists of three main modules: Controller, Switch and Device Under Test, as shown in the Figure 2. The Controller module is responsible for simulating controller channel functions for establishing, transmitting and receiving messages. The Switch module is responsible for generating traffic and attack message and sending them to the Device Under Test module. The Device Under Test module is responsible for real-time monitoring and recording the results of the test cases, its includes network sniffer, performance monitor, bug/report/test automation utilities.

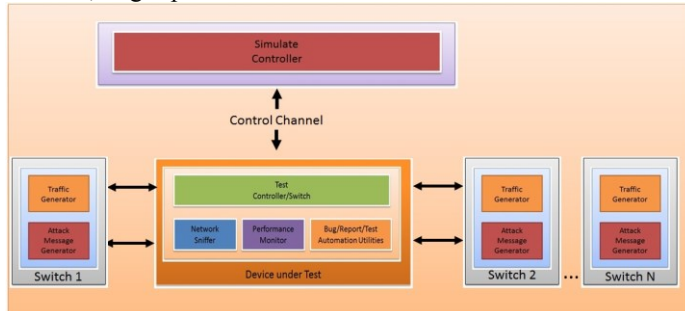


Figure 2. Function Module and Test Environment

Next, the test environment and test items for Conformance Test and Interoperability Test in each category are explained.

3.2.1 Conformance Test

This work focuses on basic procedures for using the Controller and Switch to develop test cases, confirm their production, modify and transmit packets, start, install, failure and other basic functional testing, test its various categories as follows:

1. Control Channel : This category focuses on the SDN Controller and Switch basic functions in Control Channel, development switch startup, installation, failure, multiple controllers and other operational functions of the division of roles,
2. Controller-To-Switch Messages : This category focuses on SDN Controller and Switch in transmission message, include information gathering, confirmation process of send and receive.
3. Flow Table : This category focuses on the SDN Controller and Switch in Flow Table occur modify, add and delete, includes Table Miss, Matching, Matching Optional, Masking, Pre-requisites, Special Values, Actions, Instructions, Action List and Modification Messages.
4. Group Table : This category focuses on the SDN Controller and Switch in Group Table for Field modify..
5. Meter: Meter is mainly used to control the transmission rate between Flow Table and packet, test case includes Meter Table, Meter Entry and Meter Bands.
6. Counters : This category focuses on the SDN Controller and Switch function in Counter Port, Queue and Field, test case includes Per Flow Table, Per Flow Entry, Per

Port, Per Queue, Per Group, Per Group Bucket, Per Meter, Per Meter Band and Global.

7. Meter Modification Messages : This category focuses on the SDN Controller and Switch in modify state of Meter Modification Messages.
8. Protocol Messages : This category focuses on the test SDN Controller and Switch function in send and receive OpenFlow Messages, test case includes Symmetric Message, Async Message Controller/Switch Message, Port Structures, Queue Structures, Action header, OFPT_METER_MOD, Multipart Messages, OFPT_MULTIPART_REQUEST and OFPT_MULTIPART_REPLY.

3.2.2 Interoperability Test

Interoperability Test focuses on the Controller and Switch their packet switching, protocol exchange, table update or delete, message exchange and data plane traffic. The various categories are tested as follows:

1. Multiple Tables and Metadata : This category focuses on the Controller and Switch function between the Multiple Table and Metadata on how to communicate, transmit, receive, update, delete, and add.
2. 1 on 1 Testing: This category focuses on the Controller and Switch function under 1 on 1 Testing, tested Control Channel against its functional operation, confirm operation status of the whole network through real-time monitoring situation.
3. Small Topology Testing : This category focuses on whether the Controller Control Channel is functioning correctly, and Confirm indicates the status change in one Controller to multiple Switch situation.
4. L2 Data Plane Traffic : This category focuses on the change in Controller and Switch traffic status in different states, port and set at Layer 2 Data Plane.
5. L3 Data Plane Traffic : This category focuses on the change in Controller and Switch traffic status in different states, port and set at Layer 3 Data Plane.
6. L3-Forwarding and Firewall : This category focuses on whether the Controller and Switch security mechanism is functioning properly, test case include L3-Forwarding with Firewall ACL and Multicast Traffic with Group Object Functionality.
7. L2 and L3 Forwarding : This category focuses on whether the test SDN Controller and Switch are properly sending and receiving control messages.
8. Failure Recovery : This category focus on whether the Controller and Switch is functioning properly in automated troubleshooting features.
9. L2 and L3 Multi-path : This category focuses on the Controller and Switch operation state in Equal-Cost-Multi-Path mechanism.
10. Basic Interoperability : This category focuses on whether the Controller and Switch comply with the OpenFlow1.3 specification, test case includes Push Flows to single and Multi-Table, Stats Request, Auxiliary, Controller Flow

Idle Timeout and TLS Connection.

11. Discovery and Topology Mapping : This category focuses on the Controller and Switch in transmission Message in add, delete and modify mode, test case include Multicast Traffic with Group Object Functionality.

IV. CONCLUSIONS

The Open Networking Foundation (ONF) and Okinawa Open Laboratory (OOL) test specifications were used to build the test environment and cases. The overall test environment architecture, which included Traffic Generator, Network Emulator, Attack Message Generator, Network Sniffer, Performance Monitor, Bug/Report/Test Automation Utilities, SDN Controller, SDN Switch, and SDN Northbound/Southbound API. After conformance testing and interoperability testing of the two spindles, this study built complete test case SDN groups. The objective was to shorten the SDN test verification platform building schedule.

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