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Toward Inter-Connection on OpenFlow Research Networks

Pang-Wei Tsai [1], Pei-Wen Cheng [1], Hou-Yi Chou [1], Mon-Yen Luo [2] and Chu-Sing Yang [1,*]

1 Institute of Computer and Communication Engineering, Department of Electrical Engineering, National Cheng Kung University / No.1, University Rd., East Dist. Tainan City, Taiwan
2 Department of Computer Science & Information Engineering, National Kaohsiung University of Applied Sciences / No.415, Chien Kung Rd., Sanmin District, Kaohsiung City, Taiwan

E-Mails: pwtsai@ee.ncku.edu.tw; pwncheng@ee.ncku.edu.tw; hychou@ee.ncku.edu.tw; myluo@cc.kuas.edu.tw; csyang@ee.ncku.edu.tw

* 92633R, EE Department Building, Tze-Chiang Campus, National Cheng Kung University, No.1, University Rd., East Dist. Tainan City, Taiwan 701, Taiwan; Tel.: +886-6-2757575-62357; Fax: +886-6-234-5482

Abstract: With the advance of Future Internet technologies, many research issues and ideas are growing fast in recent years. In the field of network virtualization, software defined network becomes a common topic on network research. In Taiwan, many institutes and laboratories of universities already built their bench-scale testbed for research and educational use with OpenFlow protocol. As time goes by, stitching experimental networks is a growing trend to fulfill requirements for large scale emulation. Hence, this paper revealed a progressing deployment which connects different experimental networks with centralized control policy. The objective is to build an integrated research network with a proposed solution which utilizes OpenFlow protocol to deal with the inter-connections. With a centralized controller and implemented architecture, the deployment not only solves the limitation of VLAN tag number in network but also improves the flexibility of configuration. This design could be a solution for the realistic constraints of network environment in Taiwan, and it also supports the possibility of stitching regional experimental networks for networking research.

Keywords: inter-connection; network stitching; OpenFlow; software defined network.

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1. Introduction

The Future Internet research has been carried for a period of time. There are many researchers making efforts on constructing experimental testbeds. For testbed deployment, several methods were raised to achieve integration of distributed network resources and to cross the geographic limitation toward collaborated researches. Hence, how to integrate networking resources across regions and the issue of network stitching are the main challenges. Moreover, an experiment network with high-speed and high-quality data path is indispensable for gradually prevalent applications such as high performance digital media transmission, big data mining or other applied research.

In Taiwan, many institutes and laboratories already built their bench-scale testbeds for research and educational use like National Center for High-performance Computing [1], Chung-Hua Telecom [2] and many universities. Most of them use OpenFlow protocol [3] to deploy their experimental network. Also, most inter-connection requirements between testbeds rely on IP tunneling techniques. In the infancy stage, this might be feasible and suitable for small-scale and light-traffic usage. Proposing a formulation with advanced connecting environment for stitching these separated testbed-islands is a growing trend to fulfill research requirements. In the beginning, only few units have layer 2 connection with NCHC's OpenFlow testbed. Others still rely on existed network techniques to stitch experimental network across regions. For example, inter-connection across different universities and their local Internet Service Providers (ISPs) in Taiwan utilize the layer 3 tunneling (Capsulator [4]) technique. This is sufficient for simple usage, however, this is not stable enough to sustain, not to mention the effectiveness of transmission is lowered down because of encapsulation/de-capsulation procedures. Hence, migrating current architecture to an integrated layer 2 OpenFlow network on Taiwan Advanced Research and Education Network (TWAREN, [5]) is a desired solution for growing usage. Now with the support from NCHC, several institutes are able to use dark fiber for connecting their experimental network to TWAREN. However, all research groups are sharing with one VLAN[6] which is carried on TWAREN. Therefore, a new issue occurred: transmission required single VLAN tag on all stitched layer 2 networks making it hard to accommodate traffic from geographically dispersed institutes. Therefore, this paper plans a stitching principle which solved the circumstances mentioned above to fulfill the requirements for connection issues in Taiwan.

The following articles in this paper are arranged as bellow. Section 2 introduces different methods used in testbed to handle the stitching problem. Some comparisons are made and to reveal the advantages of the method used in deployment. The detail of planning and deployment of inter-connection issue in Taiwan is depicted in Section 3. Section 4 demonstrates the testing result of this deployment. Section 5 will conclude implementation and contribution in this work.

2. Related Work

2.1 Global Environment for Network Innovation

As one of the greatest network testbed in the world, the Global Environment for Network Innovation (GENI, [7]) provides network resources for wild-area users. GENI welcomed any campus network to join the testbed by registering them with a GENI aggregate manager [8]. GENI provided five inter-campus connectivity options [9]: single VLAN, VLAN translation, layer 2 tunneling, direct fiber connections, and higher layer tunneling. As mentioned in section 1 that tunneling methods and direct fiber connections are often used but with its limitations. The option of VLAN translation mentioned in GENI document indicated that it is a port-based physical VLAN translation or an OpenFlow-based VLAN translation. The former one is a method that utilizes multiple ports to effectively translate VLANs. While the later one allows the experimenter to configure the OpenFlow-enabled switch according to their own needs. Either way of translation requires the administrators or experimenters to pre-install the configuration.

2.2 Research Infrastructure for large-Scale network Experiments on JGN-X

Research Infrastructure for large-Scale network Experiments (RISE, [10]) is a large-scale OpenFlow testbed on JGN-X [11]. Last year, RISE are actively to inter-connect with other OpenFlow testbed such as "Network Development and Deployment Initiative (NDDI [12])" in United States and "OpenFlow in Europe: Linking Infrastructure and Application (OFELIA, [13])" in Europe. With OFELIA, the inter-connecting method is OpenVPN [14] which is a layer 2 tunneling. With NDDI, Open Exchange Software Suite (OESS, [15]) developed by Internet2 [16] and Indianan University are integrated into RISE controller to configure and control dynamic VLAN networks through OpenFlow protocol. Although the OESS developed complete with modules of interface and modules of communicating with other domains, it supported only provisioning without packet-in driven event.

Concludes above, methods related to the stitching solution for VLAN often involved complicated applications and configurations to the cross-layer network. As most research or experimental networks are supported by OpenFlow protocol, this paper proposes an OpenFlow solution based on VLAN translation in order to handle the problem of layer 2 inter-connection in Taiwan. Moreover, this technique supported dynamic flow installation driven by packet-in event and multiple VLAN IDs in control method. Different from many OpenFlow solutions that require users to register their own stitching in experimental data plane, this deployment in this paper focuses on centralized controller with automated VLAN translation mechanism which would be introduced in next section.

3. Design and Deployment

In following segments, this section will introduce the networking environment, stitching options, and planning of inter-connections over experimental networks among testbeds.

3.1. Network Stitching

Taiwan Advanced Research and Education Network is operated by National Center for High-performance Computing. There are three branch establishments distributed in north, middle and south of Taiwan. Also, there are twelve Giga POPs which directly connected to backbone network. Most colleges away from fiber convergent of Giga POPs may need to lease transition service from local ISPs. Due to mentioned network environment above, it is indispensable to propose a stitching formulation in order to connect each experimental network to OpenFlow backbone. Most network testbeds are built in bench-scale, which scattered in different campuses. Regional OpenFlow networks [17] are deployed based on OpenFlow protocol implemented on NetFPGA [18]. Therefore, stitching methods can be classified and applied into two circumstances: Layer 3 and Layer 2 Stitching. The former method is used for testbeds which are under developing status or without urgent need to stitch to OpenFlow backbone on TWAREN. The other method is used through directly local area network attachment, VPLS VPN or other layer 2 tunnel techniques. Current layer 2 stitched units are shown as Figure 1. Also, a centralized controller for OpenFlow Network is needed, so this deployment changes control plane from de-centralized to centralized status for experimental networks.

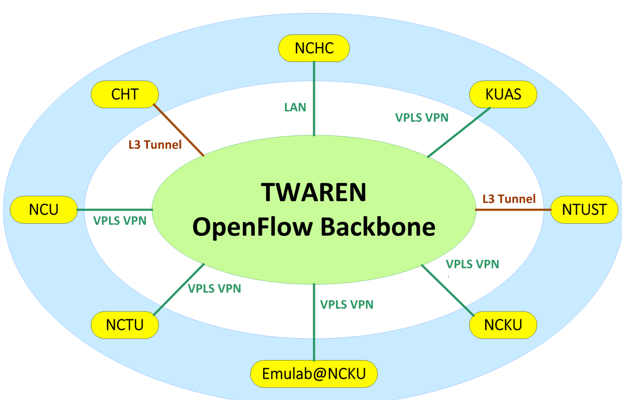

Figure 1. TWAREN OpenFlow Backbone.

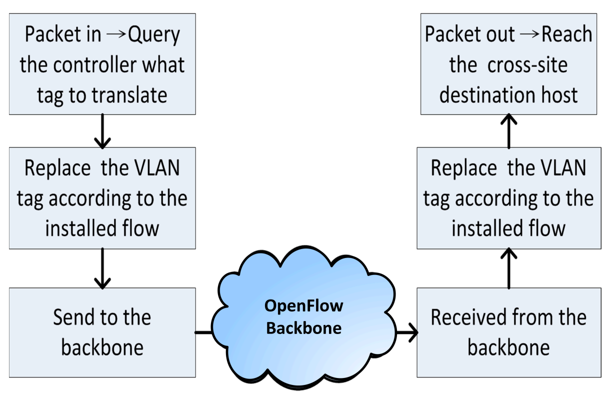

Figure 2. The process of tag-translation.

3.2. Tag-Translation

To inter-connect different OpenFlow testbeds which carry multiple VLAN tags, the proposed solution of VLAN Tag Translation [19] tried utilizing the OpenFlow controller to maintain a tag table. The translation processes in data plane are shown as Figure 2. Each first packet comes in the edge OpenFlow switch queries the table maintained in the centralized controller, VLAN tag re-written process would then be executed according to the flow installed by the controller.

During the transmission in backbone, the packets are processed with assigned VLAN tag. When packets arrive at the receiving side, packet header would be re-written back again with its original VLAN tag and then be switched in local area network. The same procedure in the opposite direction, and the detail depictions of the VLAN translation procedure were omitted here. The main advantage of this tag-translation mechanism is that it utilizing the OpenFlow solution with a centralized controller to flexibly configure the stitching environment among geographically distributed testbeds. With the discussions in section 3.1, the deployed architecture enables the regional OpenFlow testbed to carry multiple VLAN tags and be translated into the requisite VLAN tag on backbone. Therefore, the large-scale real deployment not only proves the breakthrough of the limit number of VLAN tag but also build up the inter-connections across distributed experiment networks with this mechanism.

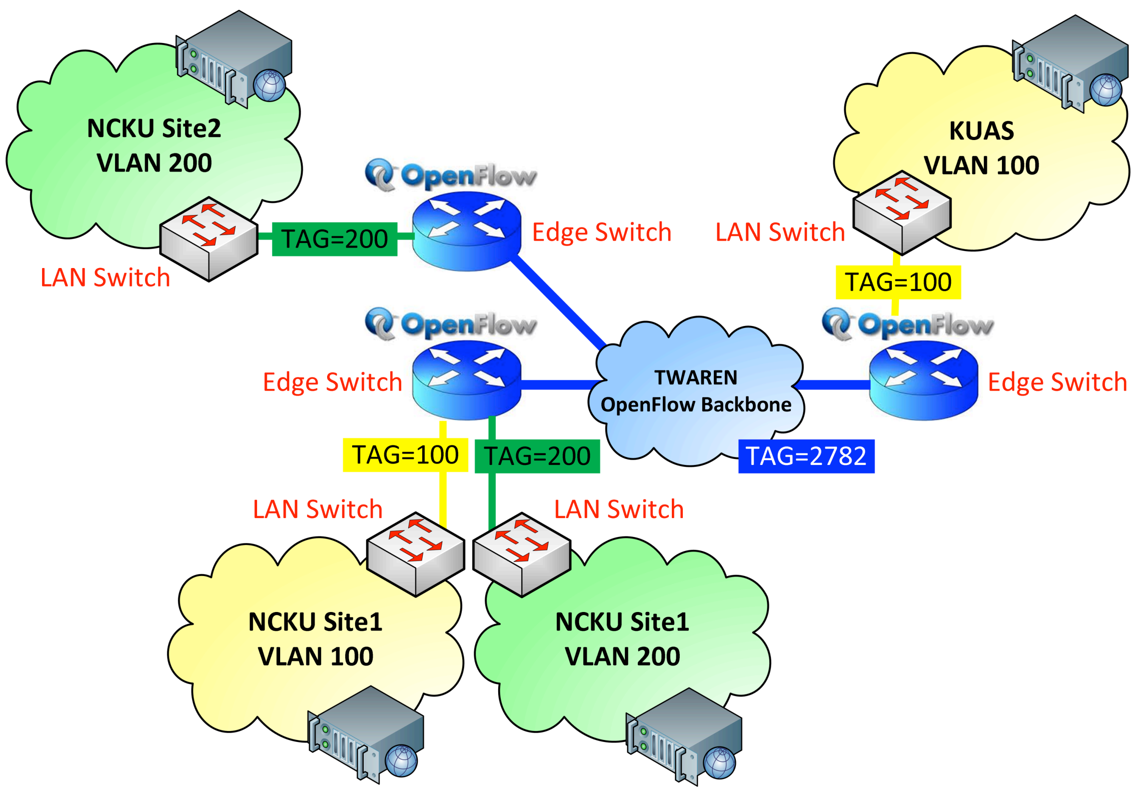

Figure 3. The deployment of inter-connections between two universities.

4. Deployments and Verifications

Based on the mentioned above, we deployed an experimental implementation between National Cheng Kung University [20] and National Kaohsiung University of Applied Sciences [21], as shown in Figure 3. There are three OpenFlow switches on edge side connect to TWAREN. We expected that tag-translation enabled the inter-connection be realized through briefly utilizing OpenFlow protocol to solve the problem of limited VLAN tag number in network. In future, distributed testbed can also support multiple experimental networks by migrating to an integrated architecture.

4.1. Latency Measurement

We used the ICMP Ping [RFC0792] to measure the round trip time across sites. The comparisons with other mechanisms such as QinQ tunneling had been revealed in [19]. Here, the testing results with real deployment are shown in Table 1. The average time between two geographically distributed testbeds in NCKU is 0.228 milliseconds which is the average of 600 Ping packet counts. Compare to the simple topology that we test between two end-hosts connected through one OpenFlow switch with layer 2 learning operation; it takes only 0.075 milliseconds due to more traveled devices. The other measure between two campuses (Site 1 of NCKU and KUAS) which cross two cities is 5.78 milliseconds in average but with a bigger maximum value occurred because of the first Address Resolution Protocol (ARP) query packet. The results revealed that the mechanism increase few load during the stitching of tag-translation in real deployments.

4.2. Throughput Measurement

TCP throughputs were measured with the iperf [22] as table 2 shows. Since the maximum LAN speed in NCKU is 1Gbps but 100 Mbps in KUAS, the throughput could only reach 92.4 Mbit/sec between NCKU and KUAS. The performance could still reach 937 Mbps with the deployment between two sites of NCKU. Also the test with layer 2 learning operation proves that the tag-translation mechanism does not affect the transmission rate apparently.

Table 1. The statistics of round trip time across sites

Round Trip Time (ICMP)	min (ms)	avg (ms)	max (ms)	mdev (ms)
NCKU Site 1 ←→NCKU Site 2	0.182	0.228	0.320	0.020
NCKU Site 1 ←→KUAS Site	4.097	5.780	53.941	4.390
*NCKU sites without translation	0.070	0.153	0.248	0.038

*Using classic OpenFlow Switch (ver. 1.1.0) on NetFPGA platform

Table 2. The TCP throughput results

TCP Throughput	Time (sec)	Transfer (Byte)	Throughput (Mbit/sec)
NCKU Site 1 ←→NCKU Site 2	0.0-60.0	6.55G	937.0
NCKU Site 1 ←→KUAS Site	0.0-60.0	661M	92.4 (FastEthernet)
*NCKU sites without tag translation	0.0-60.0	6.55G	937.0

* Using classic OpenFlow Switch (ver. 1.1.0) on NetFPGA platform

5. Conclusions

This paper proposed an experimental design for stitching research networks across campuses. Other solutions such as QinQ tunneling and any other administrative methods not only require complicated configurations but also limit itself with finite VLAN IDs. With a centralized controller and implemented architecture, the deployment not only solves the limitation of VLAN tag number in network but also improves the flexibility on network stitching. Moreover, for building geographically distributed institutes, the implementation can provide an inter-connection over layer 2 architecture across diverse infrastructure. This design could be able to solve the realistic constraints of mentioned environment in Taiwan, and provide the possibility of stitching different research networks to form an inter-connected architecture for networking research. Since only three OpenFlow switches in two different campuses are involved into this architecture currently, there are still some migrating issues need to be improved. After processing a series of verifications, the proposed design in this paper would be enhanced with more use cases in near future.

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