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OF@TEIN: A Community Effort towards Open/Shared SDN-Cloud Virtual Playground

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***Abstract* — After its launch in 2012, OF@TEIN project has faced several changes in both resource configuration and usage procedure for OF@TEIN infrastructure. In order to maintain and verify the functionality of this open/shared virtual playground, there were many difficulties for managing multi-national distributed infrastructure as a collaborative community effort. In this paper, we discuss the past and on-going experience on OF@TEIN collaborative operation and enhancements. Based on this collaborative experience on OF@TEIN virtual playground, we could build our understanding on the emerging SDN-Cloud paradigm.**

***Index Terms* — Software-defined networking, Cloud computing, Future Internet Testbed, and distributed cloud.**

I. INTRODUCTION

OF@TEIN project, launched in July 2012 as one of e-TEIN projects sponsored by Korean Government, was initially targeted to gradually build and operate an OpenFlow-enabled SDN testbed over TEIN (Trans-Eurasia Information Network). This OF@TEIN collaboration project is being carried out by a consortium of multiple international collaboration sites. The main target of OF@TEIN project was to deploy and develop an OpenFlow-based SDN (Software-Defined Networking) testbed for Korean and South-East Asian (SEA) collaborators over TEIN4 [1]. By leveraging TEIN4 international network connection, as shown in Fig. 1, OF@TEIN now connects 12 sites spreading over 7 countries (Korea, Indonesia, Malaysia, Thailand, Vietnam, Philippines, and Pakistan) [2].

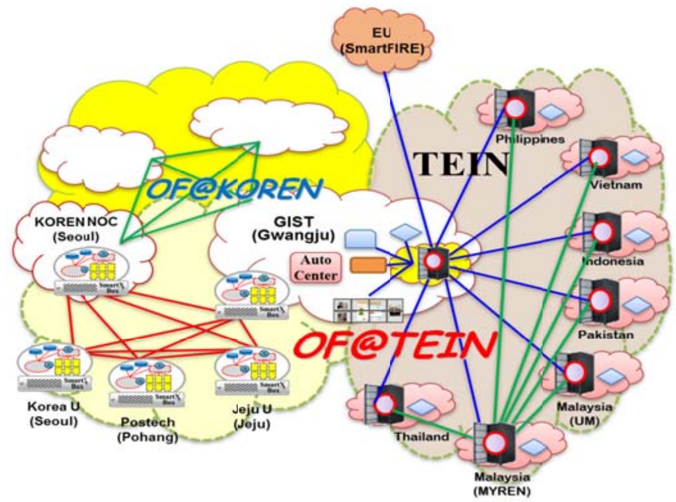

Figure 1: OF@TEIN resource infrastructure (2015).

As part of OF@TEIN, we have designed a unique resource, denoted as SmartX Rack (later renamed as SmartX Box), with OpenFlow switching and remote management functionalities. Also, we have installed SmartX Racks at participating sites and connected them to enable OpenFlow-based SDN experiments

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[1]. Among them, SmartX Rack Type B consists of four devices, i.e., Management & Worker node, Capsulator node, OpenFlow switch and Remote power device. In early 2014, a simplified design of SmartX Rack (denoted as SmartX Box Type B+) was introduced to merge multiple devices into one unified and virtualized box with integrated remote management. SmartX Box minimized the number of nodes for each rack by logically replacing separate computing and networking devices with virtualized ones. Also, the configuration upgrade to SmartX Box is automated (except for minimal wiring changes) via Chef DevOps (Developments and Operations) automation tool, which utilizes the installation and configuration modules supported by remote power management [2] [3]. Separate from SmartX Box Type B+, from middle of 2013, another effort to build OpenStack-leveraged virtualized playground is conducted and resulted in SmartX Box Type C (located in several Korean sites). Thus, in early 2015, to enable SDN-Cloud experiments over OF@TEIN infrastructure, we started another upgrade to SmartX Box Type B* by incorporating OpenStack. Again, all upgrades are executed remotely by the DevOps automation tool for SmartX Boxes. Note that, in Fig. 2, most of SmartX Boxes are depicted for comparison purpose.

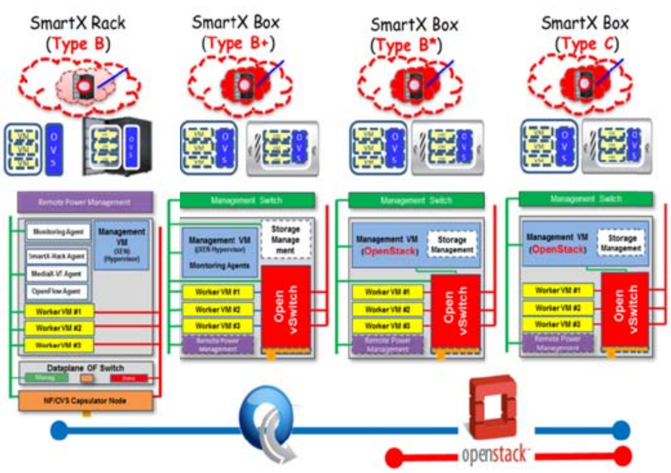

Figure 2: SmartX Box types and their comparison.

Recently, we opened OF@TEIN Community Portal (http://oftein.net), to facilitate communications among OF@TEIN collaborators. The portal, based on Redmine open-source management web application, contains project documents, annual workshop schedule and materials, and open discussion bulletins.

II. OF@TEIN Operation and Enhancement

A. (Overlay) Network Management and Troubleshooting

In order to automate the multi-point L2 (i.e., Ethernet) inter-connection of OpenFlow islands in OF@TEIN infrastructure, we design and implement an administrator tool to configure the required NVGRE (Network Virtualization using Generic Routing Encapsulation) tunneling by leveraging the OVSDB (Open vSwitch Database) configuration interface for OpenFlow switches. With the implemented operator tool and appropriate operators/developers privilege management, we can quickly inter-connect the multi-point international OpenFlow islands with NVGRE tunnels. Also, the administrator can manage the inter-connections among multiple OpenFlow islands while letting the developers freely control (i.e., tag/steer/map) their own traffic flows for their own experimentation, eventually enabling the formation of overlaid virtual tenant networks [4].

However, although we applied automated tunnel configuration, it is prone to unexpected changes in underlying networks, as illustrated in Fig. 3. Quite frequently, we should delete and re-initiate tunnel configurations to recover. To mitigate this, we realized a centralized overlay networking management tool, called as OvN (Overlay vNetworking) Manager. OvN Manager attempts to maintain the consistent virtual switches and tunnels by following the given templates. When problems are occurred, OvN Manager detects them and reports them to the operators. It also attempts to solve them, depending on the problem level.

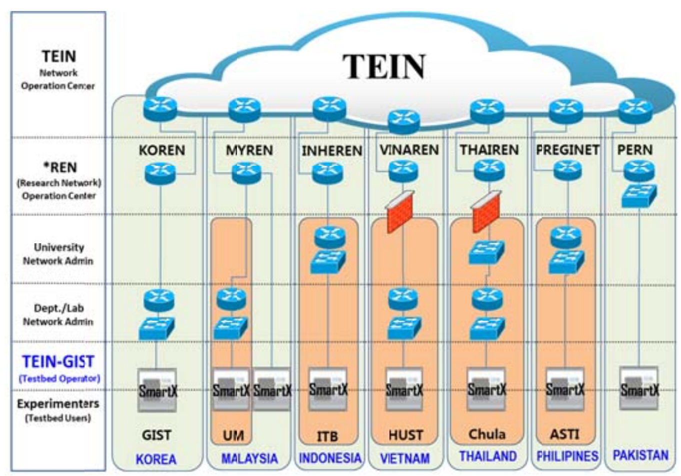

Figure 3: OF@TEIN infrastructure and underlay networks.

B. SmartX Operation Center including Visibility Challenges

In order to smoothly operate OF@TEIN infrastructure, we are building SmartX Operation Tower facility by leveraging SAGE (Scalable Adaptive Graphics Environment) visualization framework with SAGE Controller, NetWall NeTDs (networked tiled displays), and other networking devices [5]. Also, to address visibility challenge, we are working on SmartX Visibility Center as a component solution of SmartX Operation Tower, by integrating visibility tools with specific focuses on performance data collection, distributed resource monitoring and event-alert generation. Fig. 4 shows the preliminary design of SmartX Operation Tower and its component solution SmartX Visibility Center to monitor and visualize OF@TEIN infrastructure.

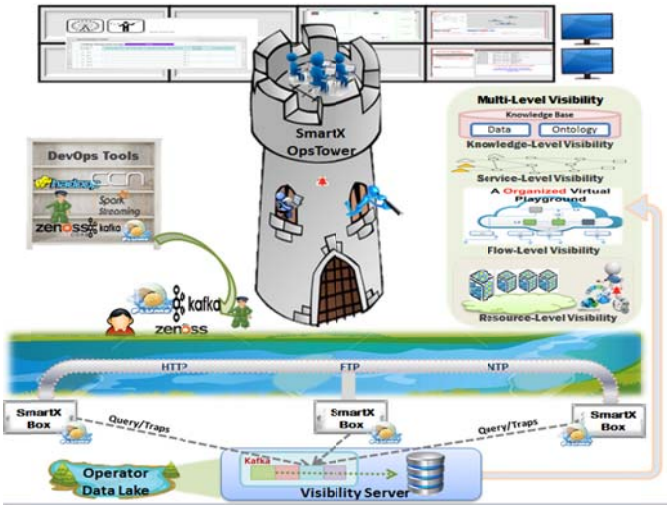

Figure 4: SmartX Operation Tower

In OF@TEIN SDN-enabled infrastructure, resource-level visibility is extremely critical to assist high availability solution of physical resources. Lack of visibility causes resource management problems and gives a hard job for operators, who need to check, monitor and recover resources on a regular basis in order to ensure the infrastructure sustainability and to satisfy the resource demands from developers. Another visibility challenge is how to monitor virtualized functions and the inter-connections over NVGRE-tunneled overlay networking. Indeed each SmartX Box contains multiple Open vSwitches to provide SDN networking capability, which makes the visibility more difficult. Without having complete visibility of underlying physical resources, high resource availability cannot be guaranteed. Thus, one key challenge is to fully monitor and control OF@TEIN resources from SmartX Operation Tower.

Also, it is required to support the service-level visibility that closely captures application-related monitoring to track the application performance of service-driven experiments. In fact, between resource and service visibilities, flow-level visibility is required to monitor the flow-centric networking. For example, we need to verify packets flowing through the virtualized overlay networking and inspect detailed packet payloads for further troubleshooting. By extracting the information from incoming packets payload, the type and number of flows can be identified and measured to distinguish the "desired" or "undesired" flows [6].

C. SDN-enabled Testbed into SDN-Cloud Integrated Testbed

OF@TEIN is motivated to address all the requirement of distributed SDN-Cloud infrastructure. Multi-tenant virtual networks are adopted to provide cloud networking that is aligned with network slicing requirement in Future Internet testbeds. Small modifications are required to provide fully programmable virtual tenant networks, where all slices are based on FlowSpace information in the SDN-enabled infrastructure. Also, OF@TEIN is motivated to build multi-region distributed cloud deployment by leveraging that OF@TEIN infrastructure is spread over several separately-administered RENs (research and education networks). Thus, by utilizing a single hyper-convergent SmartX Box for each SmartX site and gradually expanding towards federated cloud models, the currently deployed and to-be-expanded OF@TEIN infrastructure is nicely aligned with the open/shared vision for virtualized playground.

III. OF@TEIN ON-GOING COMMUNITY COLLABORATIONS

A. Automated Media Distribution Experiment

This example lifecycle experiment has been conducted by GIST (Gwangju Institute of Science & Technology, Korea) collaborators. In this experiment, we smoothly collect content video streams from multiple locations (i.e., VM-based video servers). A content player (i.e., VM-based video client) needs to visualize multiple media streams and perform the periodic quality checking for content adaptation. This media distribution experiment is initially handled by an experiment preparation script. It first checks IP subnet and FlowSpace resource allocation, registers networking resources to FlowVisor, and creates computing resources. The experiment execution script then starts ping tests among all VM pairs, which can verify the resource availability. Next, an output on top of SDN experimenter UI (Java-based GUI) will be generated to explain the results of automated resource checking, which automatically shows the allocated resources and active traffic flows. Finally, the media distribution experiment is executed to verify the media distribution of HTTP-based streaming from two different origins. At both sides, specific VLC-based VMs are employed to support the required media streaming. At the receiving side, both streams are played, as shown in Fig. 5.

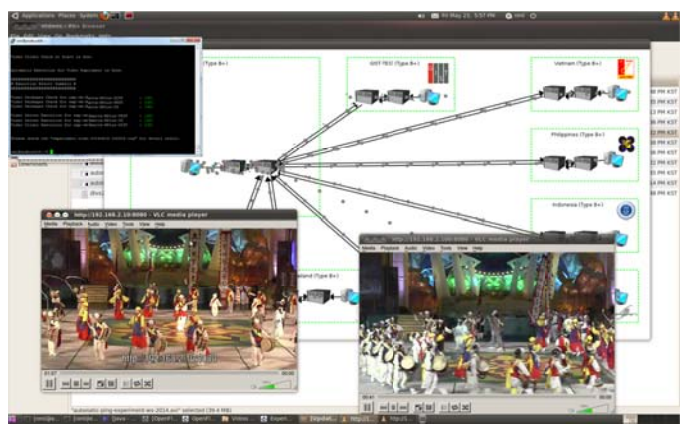

Figure 5: Automated media distribution experiment.

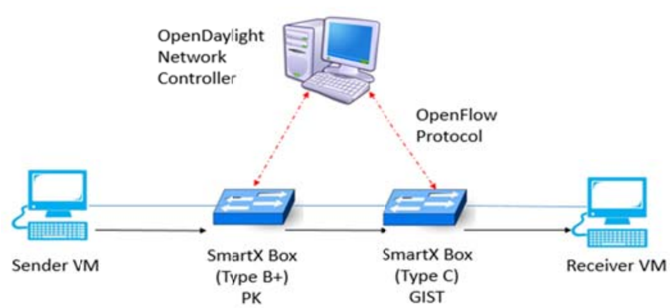

Figure 6: End-to-end delay measurement over OF@TEIN.

B. Stochastic Modeling of Packet Delay in OpenFlow-enabled Networks

It well known that OpenFlow enables direct communication between SDN centralized controllers and SDN distributed switches. NUST (National University of Science and Technology, Pakistan) is developing a stochastic model for network delay in networks built using OpenFlow-enabled SDN switches. Such a model will help to understand the characteristic of the next-generation OpenFlow-enabled Internet. The stochastic model developed based on measurements and simulations will help the operators to measure the end-to-end delay in an OpenFlow-enabled network to ensure certain grade of service to end users. In addition, we are taking similar measurements in the Mininet emulator to assess how accurately it models packet delays.

This stochastic modeling is also extended into a variety of testbed environment that includes a lab-scale testbed of inexpensive switches, the GENI testbed [7] and the OF@TEIN testbed [1]. As part of OF@TEIN collaboration, OF@TEIN testbed is utilized for end-to-end delay measurement as it provides a unique SDN infrastructure spanning over seven Asian countries. Experimentation on widely distributed resources will help explore the behavior of OpenFlow switches at scale. For measurements we are using the Distributed Internet Traffic Generator (D-ITG) that is installed on VMs hosted on OF@TEIN SmartX Boxes. Experimental setup for delay measurement on OF@TEIN testbed infrastructure is depicted in Fig. 6.

The experiments were conducted by measuring round trip time of a packet on a single OpenFlow switch or end-to-end between experimentation VMs. 1,000,000 packets were sent with a constant rate of 10,000 packets per second using D-ITG traffic generator and the size of each packet was 1500 bytes. So far, only TCP protocol was used for the experimentation.

C. Multi-path Video Experiment

Upon the global challenge in designing CDN (Content Delivery Network) service platform, one of the potential researches deployed over the large-scale OF@TEIN infrastructure is experimentation of multi-path video streaming. Chulalongkorn University at Thailand has joined with GIST and other OF@TEIN partners in developing and testing necessary middlebox enablers. The goal is to introduce an OVS-based splitting functionality to divide each incoming video stream into chunks of packets. The packet chunks can then be switched concurrently towards multiple bandwidth-constrained paths towards the intended streaming destination. And just before reaching the destination, a middlebox has been implemented to intercept incoming video streaming packets from all utilized concurrent paths, classify into proper buffers, then schedule appropriately to resolve all mis-ordered packet arrivals and deal with the optimal streaming rate parameters to match with the receiving video clients.

In addition to the local PC-cluster testbed [8] or Mininet-emulated testing environment [9][10], important insights for such streaming experiments can be obtained directly by extending the tests into the OF@TEIN testbed spanning different time zones for the network congestion and latency are geographically time varying and unavoidably significant. In addition, since international link bandwidths are often limited by each nation, the multi-path video streaming technology being developed can help aggregate higher path bandwidths than those achievable by relying only on a single restrictive-bandwidth path. In that regard, much can thus be gained by OF@TEIN-based experimentations.

D. VM Live Migration Experiment

One of the collaborators from University of Malaya (Malaysia) has visited GIST Korea and conducted experiment for moving VMs between servers in the Datacenter, as shown in Fig. 7. This experiment utilizes SmartX Box Type B+ with Xen as VM hypervisor. The goal of the experiment is to verify VM live migration for intra-site and inter-site at OF@TEIN infrastructure. Keep in mind that VM data need to be "online" copied from one hypervisor to another hypervisor before VM live migration is executed in order to minimize the VM downtime during migration. The intra-site experiment result shows there are no significant connection problem for migrated VM, because we only have increased delay from the ping for only 6 sequences of ICMP packets. This is expected as Xen provides memory-page copy from one hypervisor to another before the VM can be taken over. Unfortunately, current XEN hypervisor only supports live migration for the same subnet, so the inter-site experiment cannot be conducted as there is no available layer of two connections between both the hypervisors.

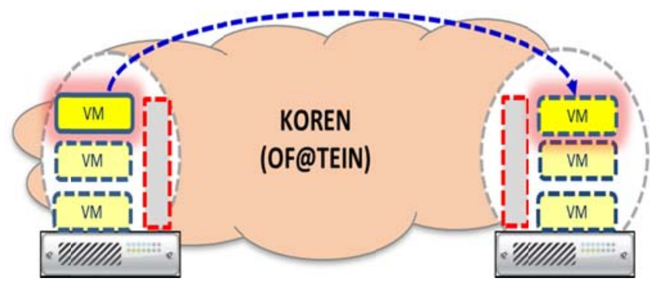

Figure 7: Xen VM live migration experiment.

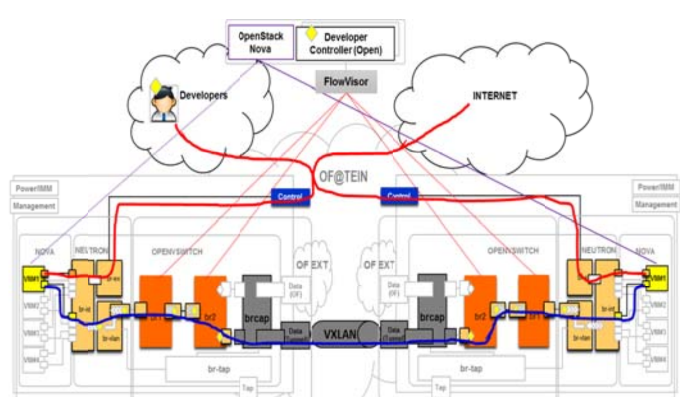

Figure 8: OF@TEIN SDN-Cloud preliminary experiment.

E. Preliminary SDN-Cloud Integrated Experiment

The experiment scenario as shown in Fig. 8, is a part of the SDN-Cloud integration verification to deploy VLAN-based multi-tenant traffic control by integrating cloud management and SDN control platform to inter-connect multi-regional OpenStack clouds through SDN networking. The first step of the experiment is placing the VMs in two different sites (or regions) and then preparing the connectivity for those VMs. Those VMs will be tagged by OpenStack Nova project with a specific VLAN ID. Thus, the VMs will be tagged automatically by OpenStack Neutron project with VLAN ID match with SDN slice, in order to allow VM flows to be steered by the developers via OpenFlow SDN controller (under the FlowVisor supervision). The steering will insert flow entries based on corresponding input and outgoing ports in user SDN switches with several ports mapped to remote sites or regions. Finally, the region or site remote destination will be mapped to specific pre-configured tunnel interface and flow entries by the OpenFlow controller of operators. The end-to-end connection test between the VMs is required to verify the consistency of flow tag-steer-mapping between OpenStack cloud management and SDN control platform for that specific testing flow.

IV. Conclusion and Future Works

The current effort of OF@TEIN project is to establish OF@TEIN Open Consortium based on existing project collaborators and new potential project members. The next step is to develop a reference model for OF@TEIN community in building and operating an SDN-Cloud-leveraged open/shared infrastructure (resembling the convergence of compute/storage clusters) by all the community members. All partners need to get together to share information about application cases, deployment scenarios, technical limitations, and troubleshooting efforts. In fact, they can facilitate and partially support community mobility programs (e.g., exchanging students, researchers, and professors) between project partners and collaborators.

In long-term vision, OF@TEIN community would like to establish OF@TEIN+ as a cloud-leveraged open community project in further promoting SDN-Cloud R&D collaboration among TEIN partners. The next first step is to establish shared OF@TEIN+ SDN-Cloud and DataFarm facility (consisting of distributed compute/storage clusters) to provide TEIN community with the opportunity to have hands-on experiences with SDN (software-defined networking) and Cloud computing resource and platform. Then, the second step is to establish a virtual OF@TEIN support center to provide technical guidance and training for project partners to utilize the shared OF@TEIN+ SDN-Cloud and DataFarm facility in supporting their SDN-Cloud R&D tasks.

Acknowledgement

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