Resource Monitoring and Visualization for OF@TEIN SDN-enabled Multi-site Cloud

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***Abstract*—Resource-level monitoring and visualization are important operation activities for OF@TEIN (OpenFlow @ Trans-Eurasian Information Network) SDN-enabled multi-site cloud. The SDN/Cloud integrated environment demands considerably different resource-level visibility solution from traditional ones. A distinctive, component-based, data-oriented approach is required for resource-level visibility of OF@TEIN p+v (physical & virtual) resources. To address the resource-level visibility challenges, we setup 'SmartX Visibility Center' as a module of SmartX Operation Tower. By integrating open-source tools, in this paper, we present a unique resource-level visibility solution, which is focusing on operation data collection and large-scale visualization.**

I. Introduction

OF@TEIN (OpenFlow @ Trans-Eurasian Information Network) is a multi-site SDN-Cloud playground, which connects 10 international sites spread over 9 countries (Korea, India, Indonesia, Malaysia, Pakistan, Philippines, Taiwan, Thailand and Vietnam), as shown in Figure 1 [1]. Several types of SmartX Boxes are deployed for OF@TEIN to support heterogeneous computing and networking resources. Among them, the latest (Type B*) SmartX Box consists of four virtualized nodes for management/worker, capsulator, OpenFlow switch, and remote power control. Also, network inter-connections among SmartX Boxes are divided into two separate planes: One for management/control and the other for datapath (i.e., forwarding). The former uses L3 IP connections while the latter employs special L2-GRE tunnels created by virtualized capsulators [2].

This SDN/Cloud integration for SmartX Boxes provides diverse resource combinations for developers while at the same time brings new complexities for operators. Monitoring and visualization are important operation activities, to be carried out by the operators in order to ensure the smooth operation of OF@TEIN playground. The OF@TEIN playground, providing SDN-enabled multi-site Cloud, requires considerably different operations from localized datacenter ones. At the end of the day, we should provide so-called multi-level (i.e., resource-level, flow-level, service-level, and semantic-level) visibility to operate and orchestrate OF@TEIN playground. Thus, we need specially designed visibility support, coupled with intelligent analytical operation and management. However, to the best of our knowledge, existing open-source solutions are limited in providing integrated monitoring and visualization support.

Currently, we are building so-called SmartX Operation Tower, which is a centralized location for operators to fully monitor and control the operation of OF@TEIN playground [3]. In order to develop multi-level visibility framework for OF@TEIN playground eventually, we are starting with a resource-level visibility solution. A distinctive, component-based, data-oriented approach is required for resource-level visibility of OF@TEIN p+v (physical & virtual) resources. Thus, to address the resource-level visibility challenges, we setup 'SmartX Visibility Center' as a module of SmartX Operation Tower. By integrating open-source tools, in this paper, we present a unique resource-level visibility solution, which is focusing on operation data collection and large-scale visualization.

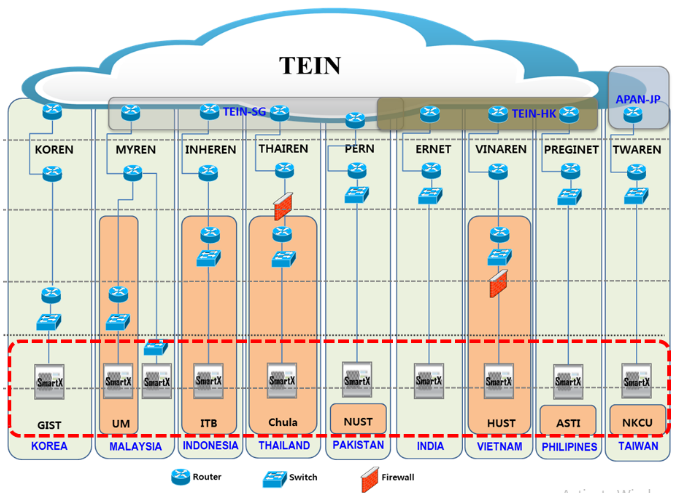

Figure 1: OF@TEIN SDN-enabled multi-site Cloud: Physical infrastructure.

The rest of this paper is organized as follows. In Section II, we discuss the visibility challenges and identify key performance parameters. In Section III, we present our approach for visibility measurement/collection. In Section IV, we focus on SmartX Operation Data Lake and visualization. In Section V, we conclude the paper with final remarks.

II. OF@TEIN Resource–level Visibility: Issues

A. *Resource-level visibility challenges and requirements*

The resource-level visibility for OF@TEIN playground is quite challenging due to multiple international sites with diverse networks (under separate administrative domains), and heterogeneous hardware/software compositions [5]. The diverse composition (i.e., chaining) of SDN-/Cloud-based functions, without appropriate visibility support, can increase the complexity of resource management. Thus, without having the complete picture of both physical and virtual resources, the smooth operation of OF@TEIN playground is not guaranteed. For example, the developers may face resource unavailability (e.g., tunnel down error, system access limitation, and VM instance creation error). Thus, for OF@TEIN operators, the regular monitoring and recovery of OF@TEIN resources is essential to ensure trouble-free operation and satisfy resource demands from the developers.

B. p+v Resources and associated performance parameters

To smoothly operate OF@TEIN playground, we need to monitor the resource-level operation data. OF@TEIN resources can be divided into two categories namely physical and virtual resources. Physical resources consist of switches, routers, SmartX Boxes and physical network links. The virtual resources consist of VM instances, vRouters, and vSwitches, which are residing inside SmartX Boxes.

Next we need to check key performance parameters that play critical role in identifying performance bottlenecks. The identified key parameters are listed in Table 1. We capture CPU loads for 1/5/15 minute intervals, user/system CPU time, total/used/free memory, total/used/free disk space, I/O sent/received, network interface status and bytes sent/received, system/application logs for physical boxes. For virtual resources, we monitor VM power status, the number and utilization of vCPUs assigned to VM, assigned/utilized virtual memory, and MAC and IP details of vNICs.

Table 1: Performance Parameters for p+v Resources.

Resource Component	Parameters / Metrics / Status
Physical Resources	
System Information	Power Status Up/Down, OS Details, Uptime
CPU	Count, Type, Utilization, Load
Memory	Size, Utilization
I/O	Bytes/sec
Disk Usage	Total Space, Used, Free, utilization
Interfaces	No. of Interfaces, Throughput, packets, errors
Virtual Resources	
VM Power Status	Up/Down
vCPU	Count, Utilization
vMemory	Size, Utilization
Disk Usage	Total Size, repository, utilization
vNIC	Bytes received/sec, Bytes sent/sec
vSwitch/vRouter	Reachability, Bytes received/sec, Bytes sent/sec

C. Existing tools for resource-level monitoring

There are many tools available specifically for resource-level monitoring. Although limited solutions are targeting SDN/Cloud integrated environments, Nagios, Zabbix, Zenoss and Icinga are the most well-known open-source tools [6] [7]. Nagios and Icinga have wide range of plugins. However, they have scalability limitations and did not evolve much over the years. Zabbix is another lightweight monitoring tool aimed to beat Nagios and can be customized through GUI. However, Zabbix is very limited in auto discovery, cumbersome in configuration, and weak in escalation policy. Finally, Zenoss is a highly scalable monitoring system that possesses layered architecture and provides interactive GUI. Our deployment trial at OF@TEIN revealed that Zenoss is resource extensive and visibility data is spread across MySQL, internal ZOPE database, and RRD files on disks, which makes it difficult to extract data from multiple sources without standardized API.

D. Software framework for OF@TEIN resource visibility

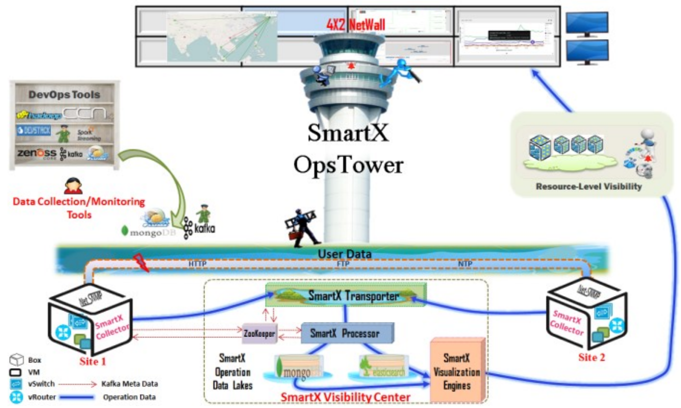

Figure 2: SmartX Operation Tower overall Design

Figure 2 shows the visibility software framework for OF@TEIN SDN-enabled multi-site Cloud. SmartX Operation Tower employs SmartX Visibility Center to cover the job of developing and integrating resource-level visibility tools for the smooth operation of OF@TEIN playground. The proposed resource-level visibility solution at SmartX Visibility Center has major components such as SmartX Visibility Plugins, SmartX Operation Data Lake, and SmartX Visualization. One important focus is reliable data delivery from SmartX Boxes to SmartX Visibility Center and collection of performance data into SmartX Operation Data Lake. For example, collected raw operation data is transported, processed by analytics tools, and visualized over networked tiled displays.

III. OF@TEIN Resource-level visibility: measurement and collection

A. Measurement and collection for physical resources

This section explains the details of monitoring OF@TEIN physical resources. By deploying SmartX Visibility Plugins into SmartX Boxes, we collect SNMP (Simple Network Management Protocol)-based performance data, captured system logs, and path connectivity status.

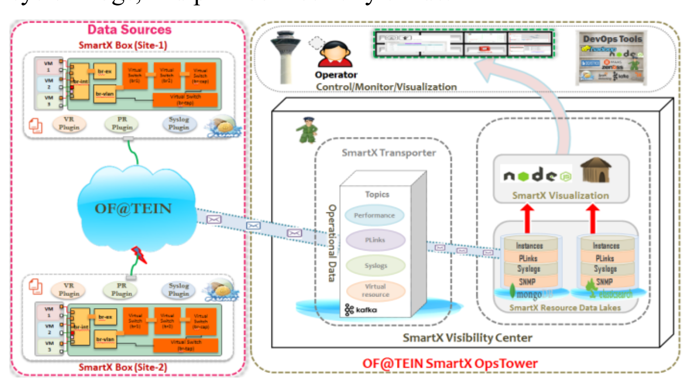

Figure 3: Resource Measurement & Data Collection Flow

Figure 3 illustrates measurement and data collection for OF@TEIN resource-level visibility. To capture visibility data from SmartX Boxes, we deploy Net-SNMP agents. Java-based SmartX Collector Plugin uses Apache Flume for data collection at SmartX Boxes via Net-SNMP agents. The visibility data is delivered from multi-site SmartX Boxes to the centralized SmartX Visibility Center by using SmartX Transporter Plugin. SmartX Transporter Plugin is based on Apache Kafka, which is distributed, partitioned, replicated commit log service. Finally, after reformatting, the visibility data is stored in SmartX Operation Data Lake. To manage reliable and persistent transport of visibility data, we are using Apache ZooKeeper, which is a centralized service for maintaining configuration information and providing distributed synchronization.

Currently 30-second query interval is set for collecting the visibility data. A single message contains 24 key-value pairs and the size of single message is approximately 1 Kbit. Each message has five components: identification information (e.g., collection timestamp and box identifier), system information (e.g., OS details, system uptime), CPU (% load, user/system time), memory (utilization in GB), disk (capacity in GB). Also, we use Rsyslog to collect detailed event messages for SmartX Boxes. Rsyslog is known for fast log processing capability. In addition, since OF@TEIN SmartX Boxes are geographically distributed, we need to verify network path (i.e., collection of links) from SmartX Visibility Server to all SmartX Boxes. For this, we employ Nmap and MTR tools to monitor path/link status.

B. *Measurement and Collection for Virtual Resources*

The multi-regional deployment of OpenStack Cloud is deployed for SmartX Boxes of OF@TEIN playground. The OpenStack Nova covers the role of VM creation, supported by KVM hypervisor. Thus, we are collecting the status (e.g., configuration data) of virtual resources (i.e., mostly VMs) by using OpenStack Nova Libvirt restful APIs, which is a toolkit to interact with VM instances

IV. OF@TEIN RESOURCE-LEVEL VISIBILITY: DATA LAKE AND VISUALIZATION

A. *SmartX Operation Data Lake for Visibility Data*

To store collected visibility data, we develop SmartX Operation Data Lake. Data lake refers a storage repository that holds a vast amount of raw/processed data in its native format until it is needed (e.g., to be used for analysis purposes). We may use the aggregation of HDFS, MongoDB, and Elasticsearch. Currently we use MongoDB to archive resource-level visibility data into specific collections while Elasticsearch is used for real-time visualization of operation data. Note that Elasticsearch is a distributed, open-source search and analytic engine using index-based approach for data storage and retrieval.

B. *OF@TEIN Resource-level Visualization*

For OF@TEIN resource visualization, we currently use ELK (Elasticsearch – Logstash - Kibana) stack and Node.js web application. The resource-level visibility data is visualized through web interfaces over large-scale networked tiled displays, driven by SAGE (Scalable Adaptive Graphics Environment) visualization framework [4]. SmartX Operation Tower manages the large-size visualization of p+v resources involved in operating OF@TEIN playground [5]. Figure 4 shows the large-scale visualization of resource-level visibility. It can depict the past and current resource status of OF@TEIN playground over NetWall networked tiled display.

Figure 4: Visualization of OF@TEIN Resources over 4 X 2 NetWall

V. CONCLUSION AND FUTURE WORK

In this paper, by integrating open-source tools, we presented a unique resource-level visibility solution, which is focusing on operation data collection and large-scale visualization. In future, we are planning to integrate it with flow-level visibility solution.

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