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K-GENI testbed deployment and federated meta operations experiment over GENI and KREONET

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ABSTRACT

The classical Internet has confronted many drawbacks in terms of network security, scalability, and performance, although it has strongly influenced the development and evolution of diverse network technologies, applications, and services. Therefore, new innovative research on the Future Internet has been performed to resolve the inherent weaknesses of the traditional Internet, which, in turn, requires new at-scale network testbeds and research infrastructure for large-scale experiments. In this context, K-GENI has been developed as an international programmable Future Internet testbed in the GENI spiral-2 program, and it has been operational between the USA (GENI) and Korea (KREONET) since 2010. The K-GENI testbed and the related collaborative efforts will be introduced with two major topics in this paper: (1) the design and deployment of the K-GENI testbed and (2) the federated meta operations between the K-GENI and GENI testbeds. Regarding the second topic in particular, we will describe how meta operations are federated across K-GENI between GMOC (GENI Meta Operations Center) and DvNOC (Distributed virtual Network Operations Center on KREONET/K-GENI), which is the first trial of an international experiment on the federated network operations over GENI.

1. Introduction

To date, current Internet architecture has strongly influenced the evolution of diverse network technologies, applications, and services. This evolution has, however, inherently created many problems, such as network security, scalability, and performance, which are mainly due to the explosive growth in the number of Internet users and the variety of new services and their demands. Therefore, revolutionary Future Internet technologies have been developed to resolve the inherent weaknesses of the classical Internet, which results in the fast-growing demands of large-scale Future Internet testbeds and relevant research; these advances allow researchers and experimenters to work on innovative network development.

The new technologies and services in the Future Internet are mainly related to network virtualization, programmability, and federation [1]. There have been a variety of Future Internet initiatives in the USA, Europe, Japan and many other countries. For example, GENI (Global Environment for Network Innovation), FIRE (Future Internet Research and Experimentation) and CORE (Collaborative Overlay Research Environment) are the leading projects for Future Internet research and development. Additionally, KREONET/KISTI (Korea Research Environment Open Network/Korea Institute of Science and Technology Information) [2] started to collaborate with GENI in 2009 to deploy a dedicated programmable Future Internet testbed between the USA and Korea, which supports international experiments over GENI, such as ProtoGENI-based federations by the University of Utah and ETRI (Electrics and Telecommunications Research Institute) and federated

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meta operations by Indiana University and KISTI. A few more Korean researchers joined the GENI collaboration as well, to perform international joint experiments, e.g., a NetOpen networking experimentation between GIST (Gwangju Institute of Science and Technology) and RENCI (Renaissance Computing Institute) over K-GENI.

Among the GENI-based experiments on the K-GENI testbed, the federated meta operations effort is a unique international trial in the GENI spiral-2 program between GMOC (GENI Meta Operations Center) [3] and DvNOC (Distributed virtual Network Operations Center on KREONET) [4,5]. This experiment has two motivations. First, operational datasets (such as network topology, status, and performance) are critical for administrators and operators to monitor and manage the sustainability of each individual network testbed. Second, operational datasets are demanded for experimenters and researchers to monitor end-to-end network resources that were allocated for collaborative experiments over multi-domain network testbeds across national boundaries. The meta operations in this paper represent a standard and centralized method of operations in a single-domain network testbed (e.g., GENI/GMOC), and the federated meta operations specify the gathering, sharing, federating, and provisioning of operational datasets exchanged among individual centralized meta operations entities (e.g., GMOC and DvNOC).

The remainder of this paper is organized as follows. The K-GENI design principle and deployment issues are explained in Section 2, and several collaborative experiments over K-GENI are introduced in Section 3. Section 4 describes the federated meta operations experiment between GMOC and DvNOC, focusing on the development results presented at the previous GENI Engineering Conferences (GECs). Section 5 presents the conclusions to this paper.

2. K-GENI design and deployment

The K-GENI testbed is designed to support international experiments that require programmable long-distance core networks with guaranteed deterministic QoS (up to 1 Gbps). The dedicated bandwidth guarantee of K-GENI makes it possible to run and test very high performance applications and experiments (e.g., 3D/HD science visualization resulting from nanotechnology, astronomy, or e-Science). Programmable core networks of K-GENI are supported by OpenFlow protocol and ProtoGENI-compatible control frameworks [6], while the dedicated network performance guarantee is obtained by lower-layer network technologies such as SONET/SDH. K-GENI provides a single 1 Gbps physical path now, but the path can be divided into multiple logical or virtual paths with specific bandwidth allocated for each application, research, and experiments, based on the VCAT (Virtual Concatenation) standard [21]. Furthermore, each virtual path carries specific experimental network flows for more than 5000 miles, enabling experimenters to test delay/jitter-sensitive simulation or applications that have multiple flows generated simultaneously. The K-GENI testbed is designed to extend its programmable high performance network infrastructure to GENI backbone networks in the USA (Internet2 and NLR), to enable experimenters in both countries to use K-GENI for their end-to-end GENI-based research across national boundaries.

Fig. 1 shows the overall network configuration of the K-GENI testbed in detail. An OpenFlow core node (HP Procurve 5412 switch) is colocated in PNWGP (Pacific NorthWest GigaPoP) in Seattle, USA, while a FIRST (Future Internet Research for Sustainable Testbed Platform) node developed by ETRI [6] is deployed on the KRLight facility in Daejeon, Korea. The FIRST node is OpenFlow-enabled; therefore, both the HP Procurve and FIRST nodes can be manipulated by an OpenFlow/SDN (Software Defined Network) controller(s). The two core nodes are connected through a dedicated lightpath that is enabled by SONET/SDH with a VCAT capability on layer 1 and VLAN on layer 2. The VLANs configured between Seattle and Daejeon have been extended to two major GENI backbone networks in the USA, Internet2 and NLR.

The FIRST node was developed to provide a programmable virtual network testbed. Each FIRST node has an ATCA-based hardware substrate that is equipped with a XEN software extension as well as ProtoGENI-compatible control frameworks [6]. Several NetFPGA-oriented OpenFlow nodes are additionally offered for end-user access and controls over K-GENI. A set of PacketShaders will be another testbed environment for network experiments over K-GENI. The PacketShader [7] is a GPU-based 10 Gbps programmable router developed by KAIST (Korea Advanced Institute of Science and Technology), which is not yet deployed on K-GENI but is planned to be installed in the future for extended experimentation. Future Internet researchers in the US and Korea will ultimately be able to exploit the K-GENI testbed for their network experiments and research, which require the programmable and QoS-guarantee network testbed between GENI and KREONET. For example, GENI-side researchers are going to use RSPECs to search for any available network aggregates in Korea, which is supported by the ProtoGENI-compatible control framework (being developed at ETRI), while Korean experimenters will work on their international efforts on the GENI testbed using RPECs as well.

Fig. 2 shows that the K-GENI testbed consists of two core nodes: an OpenFlow-capable HP Procurve 5412 switch and a FIRST node (called NP5000) in one single VLAN domain. NetFPGA OpenFlow nodes and PacketShaders will be located in the same VLAN domain to enable controllers and experimenters to efficiently access all of the K-GENI experimental nodes to install and run their code. It is shown in Fig. 2 that K-GENI nodes are interconnected via national research backbone networks such as KREONET in Korea and Internet2/NLR in the USA. Figs. 3 and 4 elaborate the actual deployment of K-GENI nodes: a FIRST node that is NP5000, NetFPGA servers, an HP Procurve 5412 node, and other required hardware such as a DC/AC inverter and monitoring servers. Based on all of the components above, the K-GENI testbed is designed to support at least two types of network experiments: (1) small-scale and low-performance experiments and (2) large-scale and high-performance experiments. In other words, researchers can choose appropriate network resources according to their