KREONET-S: Software-Defined Wide Area Network Design and Deployment on KREONET

Dongkyun Kim, Yong-Hwan Kim, Chanjin Park, and Kyu-Il Kim

***Abstract*—Software-defined networking (SDN) has emerged to achieve open, programmable, virtualized and dynamic network environment for innovative applications and services which are totally apart from traditional hardware-oriented, fixed, closed network infrastructure. This paper indicates development and deployment of KREONET-S infrastructure which is designed to realize software-defined wide area network (SD-WAN) in Korea. The principal components of KREONET-S include SDN data plane networks (core and edge network devices), distributed control platform for SD-WAN based on Open Network Operating System (ONOS), and ONOS-based applications/ services. Each control instance is geographically distributed in distant locations in Korea to gain SDN scalability, sustainability, performance in particular. New SD-WAN service scenarios and use-cases are developed based on the KREONET-S design, development, and deployment in this paper. Three service scenarios are uniquely categorized as pure SDN services, SDN-IP services and federated SDN services where virtual network provisioning and SDN-to-Internet extended connectivity are considered principal use cases. In addition, we setup a network performance evaluation environment in conjunction with the distributed control platform of KREONET-S which is a 7-node ONOS cluster centering on international data paths between Korea and USA. Since the data plane network of KREONET-S provides multiple bi-directional links between distant locations, required flow rules or intents have been installed at the SDN core and edge network devices to situate end-to-end (host-to-host) paths in place for each network performance evaluation. In this test, we gained the desired network throughput, minimal delay and constant jitter which are massively demanded by advanced data-intensive science researchers and experimenters. The performance is measured and presented through a-first-of-its-kind international deployment of SD-WAN infrastructure in Korea and USA under geographically distributed control platform. KREONET-S has been advanced to provide end-to-end production SD-WAN environment for those demanding time-to-research and time-to-collaboration in high-end research areas such as Supercomputing, Data-intensive Science, and Big Data/IoT.**

***Index Terms*—SDN, SD-WAN, Distributed Control, KREONET-S, ONOS**

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I. INTRODUCTION

The Korea Research Environment Open Network (KREONET) is a national research network in Korea[1]. So far, KREONET has been playing a key role in enhancing national Science & Technology competitiveness by providing advanced network infrastructure for global and domestic science and research collaborations. However, there are big barriers for KREONET to move forward to the next paradigm of networking, which are mostly inherited from traditional legacy network infrastructure on KREONET. So to speak, the barriers are hardware-oriented, fixed, and closed network environment on which no researchers and/or technologists are able to deploy and experiment their newly developed network software and products. Therefore, one of the biggest motivation of network softwarization on KREONET (KREONET-S) is to develop software and user driven, virtualized, dynamic, and flexible network environment.

Second motivation of KREONET-S comes from what KREONET users are demanding for their advanced science applications research and experiments which include supercomputing, data intensive science (e.g., high energy physics, weather & climate, astronomy), and Cloud[2,3], Big Data/IoT[4]. The KREONET user requirements[5] are as follows:

1) Deterministic network performance and Quality of Service (QoS) guarantee for up to 100Gbps high-speed and high-throughput data transfer for data-intensive science applications

2) Time-to-research and time-to-collaboration based on user-centric dynamic, programmable, virtualized, and flexible network environment

3) Highly reliable and security-guaranteed logical or virtual network infrastructure for global and domestic collaborative research and experiments

In this background, KREONET-S has been designed as very-reliable, carrier-grade, and public Software-Defined Wide Area Network (SD-WAN) infrastructure. In order to guarantee the network reliability and stability, KREONET-S adopts distributed control architecture and 24x7 network operations. This paper primarily describes the design issues and service scenarios of KREONET-S, while the pivotal building blocks of KREONET-S are depicted as Software-Defined Network (SDN) hardware and software network infrastructure (southbound), distributed control platform (east-westbound), and SDN applications & services (northbound). It is elaborated in this research work that the service scenarios of

KREONET-S are composed of pure SDN services, SDN-IP services, and federated SDN services. In turn, this paper shows why the service scenarios are crucial and how KREONET-S is deployed according to the design issues and service scenarios based on the specific use cases. Another main contribution of this paper is that the data plane network performance of KREONET-S is measured and presented through the production deployment of KREONET-S in internationally distributed locations, which has been carried out for the first time as a carrier-grade public SD-WAN network in Korea and USA.

II. Design and Deployment of KREONET-S

KREONET-S has been designed mainly based on three principal building blocks according to SD-WAN objectives and diverse user requirements introduced in the previous section. In this section, principal building blocks of KREONET-S is described more in detail, and the design and deployment issues of KREONET-S are followed.

A. Principal Building Blocks of KREONET-S

There are three major building blocks for KREONET-S as shown in Figure 1, i.e., 1) SDN network infrastructure that consists of multi-layer and multi-vendor environment, 2) open source based control platform incorporated for distributed controls, 3) SDN applications and services for new user experiences. The suggested building blocks match to three basic interfaces of SDN control platform, which are southbound, east-westbound, and northbound interfaces[6].

The KREONET-S data plane network infrastructure in association with hardware and software network devices is designed to incorporate core network devices and edge/access network devices, enabled with programmable and virtual network functionalities. The core network devices are required to connect geographically distributed network centers (e.g., Daejeon in Korea and Chicago in USA) in order to provide softwarized backbone network infrastructure. Likewise, the edge/access network devices need to make connections with the core network devices co-located in each of distant network centers, granting the edge/access network devices to be the interconnection gateway for end-user sites on KREONET-S. In addition, multi-vendor and multi-layer network infrastructure should be designed, based on the above two types of network devices, primarily leading to CapEX and OpEX savings in terms of integrated and automated network operations as well as cost-effective multi-vendor selections.

On top of the data plane network infrastructure is the software-driven control platform adopting an open source SDN network OS that is Open Network Operating System (ONOS)[7] as a next principal building block. ONOS is developed to provide high availability, scale-out, and high performance targeted for service provider networks and carrier-grade networks, originated in distributed core, northbound and southbound abstractions/APIs, and modular software architecture. By adopting ONOS as its logically-centralized and distributed control platform, the control layer design of KREONET-S is suited to gain very high reliability, stability, and scalability

The third building block of KREONET-S exists on the applications and services layer which is considered the most important part of KREONET-S design principles, since this layer interacts with end-users directly so that they can experience the new SD-WAN's benefits. Currently, KREONET-S focuses on virtual dedicate network and user-oriented visibility applications in particular, where users are able to generate, update, and delete their own virtual network slices on demand that can be monitored and managed via user-specific virtual network topologies and dedicate work spaces.

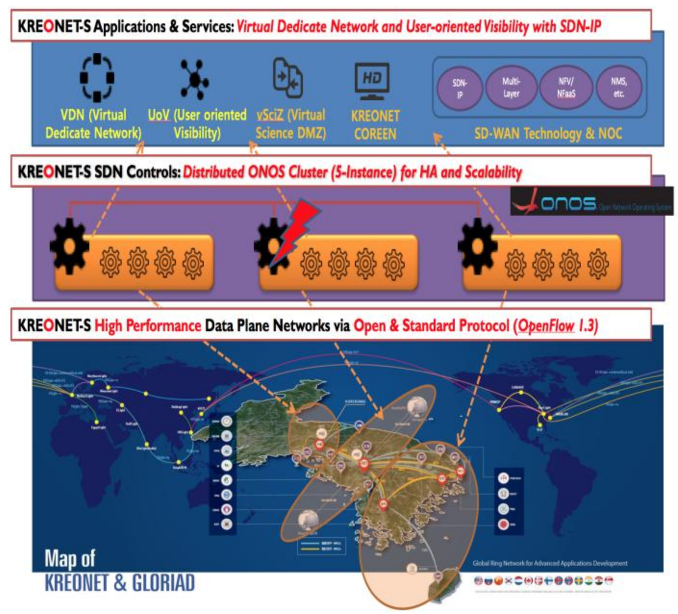

Fig. 1. The Principal Building Blocks and Their Impacts of KREONET-S

B. KREONET-S Designs and Deployment

Derived from the principal building blocks in 2.1, KREONET-S data plane network infrastructure is designed as following Figure 2. As shown here, KREONET-S is composed of core and edge/access network devices being connected with multiple 1Gbps and 10Gbps links between two distant cities in Daejeon, Korea and Chicago, IL, USA. Furthermore, there are several Open Virtual Switches (OVSes) and server machines configured in the new network in order to bring forth various network experiments, general operations & management, and performance measurement. In the upper layer of this network environment, ONOS controller instances are installed and being operated to serve as reliable and scalable distributed control platform on KREONET-S.

In this way, KREONET-S is deployed through controller and OVS/experiment servers as well as the designed network hardware and software network devices in two remote locations in Korea and USA. Following Figure shows the detailed configurations of the network infrastructure and control/OVS/experiment servers in Daejeon network center.

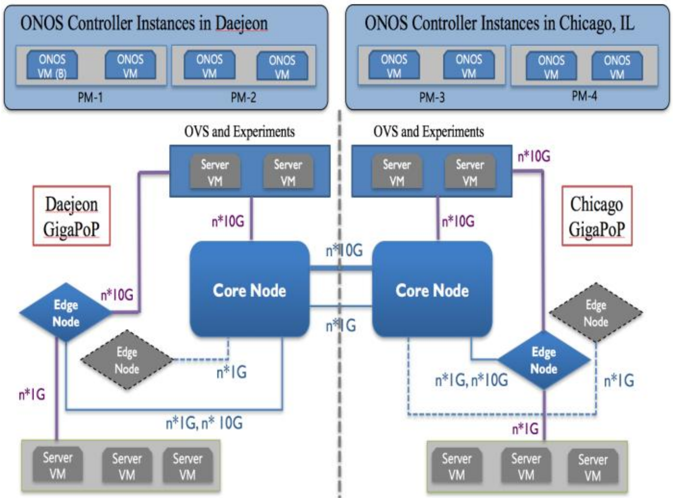

Fig. 2. Overall Design of KREONET-S Control Plane/Data Plane Architecture

As for detailed KREONET-S data plane network configurations, the deployed network devices are associated through multi-layer network architecture. While the edge/access network devices are extended from the core network devices, there are optical transport network devices connected between core network devices in Daejeon and Chicago as indicated in the following Figure 3. This network setup insinuates that two layers of (packet-optical) network are operating complementary to each other on KREONET-S which should be tightly integrated for efficient network operations in the cost-saving manner.

Figure 4 points to the deployment status of KREONET-S sitting on distributed controller infrastructure and the default master-standby designation of ONOS instances. At this moment, KREONET-S is softwarized with a 7-node ONOS distributed control cluster and underlying SDN data plane networks, where at least two instances elected as master instances to make KREONET-S highly sustainable, stable, and scalable.

Fig. 3. Detailed Configurations of Network Devices and Corresponding Server Equipment

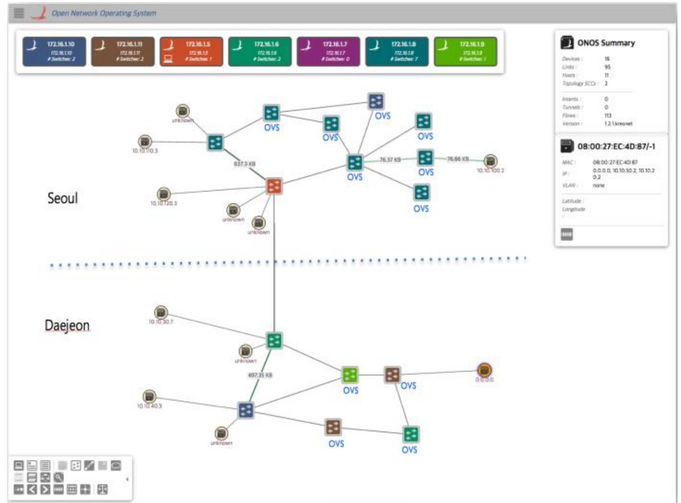

Fig. 1. KREONET-S Distributed Control Platform Based on ONOS 7-node Cluster

III. Service Scenarios and Performance Evaluation

Generally, SD-WAN services are required for new network services and user experiences such as deterministic quality of network service and advanced security guarantees[8,9] that are hardly achieved under traditional and legacy network environment. Besides, it should be reimagined and utilized for SD-WAN service providers to provision dynamic, flexible, and open network environment which can hardly be achieved by the existing closed and fixed networks of today.

The new service scenarios of KREONET-S have been proposed in Table 1, under the above background. New SD-WAN environment should be able to meet both essential prerequisites including new functionalities and network openness for KREONET-S end users. From this perspective, three service scenarios are presented as pure SDN services, SDN-IP services, and federated SDN services[10-12] as follows.

Among the three service types on KREONET-S, the first one, pure SDN service, is considered most basic and essential in order to satisfy various advanced application users' requirements related to deterministic network QoS, high performance, and advanced security. The pure SDN services meet those requirements by provisioning virtual, logical and strictly isolated user-driven networks that can be dynamically and automatically generated on users' demands. Hence, one of the key enablers for the pure SDN services is the virtual dedicate network and user-oriented visibility applications/services which are being developed and applied to KREONET-S.

In turn, our performance measurement results on the data plane networks (1Gbps and 10Gbps end-to-end SD-WAN networks in Daejeon and USA) show that the newly deployed KREONET-S network guarantees the demanding network performance in terms of TCP and UDP throughput, jitter, and delay.

TABLE I
CORE USE CASES FOR EACH PRINCIPAL SERVICE SCENARIOS

Types	Functionality
Pure SDN Services	• Deterministic QoS & Performance • Virtually Isolated User Group Networks • Enhanced Security & New User Experiences • User-centric Open Networking Environment
SDN-IP Services	• SDN-to-Internet Extended Connectivity • Traffic-engineered AS Transit (DC to DC) • Partial Guarantee of QoS & Performance • Partial Security, but still New User Experiences
Federated SDN Services	• Inter-SDN Connectivity & Federated Resources • Virtually Isolated Networks on Inter-Cluster SDN • Deterministic Guarantee of QoS & Performance • Enhanced Security & New User Experiences • Extended Connectivity with SDN-IP

The distance between Daejeon and Chicago network centers is approximately 10,500km, while the minimal round trip time (RTT) calculated at two locations is around 157ms. The following Figure 5-7 indicates the measured performance metrics where the outcomes are in the criteria of high performance network environment providing up to 10Gbps high throughput and bandwidths for user sites.

IV. CONCLUSIONS AND FUTURE WORK

KREONET-S has been designed and deployed as the new carrier-grade and reliable public SD-WAN environment on KREONET.

For summary, this paper makes three contributions: 1) design of KREONET-S as the deployment model of public SD-WAN, 2) development of advanced service scenarios and use cases of KREONET-S/SD-WAN, 3) presenting a first-of-its-kind performance measurement result of the KREONET-S data plane networks deployed between Korea and USA as international SD-WAN environment.

Our further work includes the research and experiments focusing on distributed controls as well as more reliable SD-WAN network operations. Plus, SDN data plane network performance up to 100Gbps on KREONET-S will be tested and measured for the purpose of satisfying upcoming advanced application users' requirements. Finally, the developments of virtual dedicate network and user-oriented visibility applications will be conducted to deliver time-to-research and time-to-collaboration environment to KREONET-S users in the near future.

REFERENCES

[1] The KREONET official website. http://www.kreonet.net/kreonet/index.jsp.
[2] Xian Zhong et al. "Clustering and Correlation based Collaborative Filtering Algorithm for Cloud Platform", IAENG International Journal of Computer Science. 2016, 43 (1), pp. 108-114.
[3] Supriya M et al., Trustworthy Cloud Service Provider Selection using Multi Criteria Decision Making Methods.", Engineering Letters, 2016, 24 (1), pp. 1-10.
[4] S.M. Mirdehghan, "Relations Among Technical, Cost and Revenue Efficiencies in Data Envelopment Analysis.", IAENG International Journal of Applied Mathematics, 2016, 45 (4), pp. 249-258.
[5] M. Jeung et al. "The Data Processing of e-Science for High Energy Physics.", The Korean Physical Society. 2009, 55 (52), pp. 607-2071.
[6] M. Shin et al. "Software-defined Networking (SDN): A reference architecture and open APIs. Proceedings of ICT Convergence (ICTC), South Korea", 2012, pp. 360-362.
[7] P. Berde et al. "ONOS: towards and open, distributed network OS. Proceedings of 3rd workshop on Hot Topics in Software-defined Networking,", USA, pp. 1-6.
[8] D. Kim et al. "K-GENI deployment and federated meta operations experiment over GENI and KREONET", Computer Networks. 2014 March, 61, pp. 39-50.
[9] M. Berman et al. "GENI: A federated testbed for innovative network experiments. Computer Networks.", 2014 March, 61, pp. 5-23.
[10] M. Gerola et al. "ICONA: Inter Cluster ONOS Network Application. Proceedings of 1st IEEE Conference on Network Softwarization.", UK, pp. 1-2.
[11] Sravan Yadav Eadala et al. "A Review on Deployment Architecture of Path Computation Element using Software Defined Networking Paradigm.", Indian Journal of Science & Technology. 2016 March, 9 (10), pp. 1-10.
[12] Ankita Vinod Mandekar et al. "Centralization of Network Using Openflow Protocol.", Indian Journal of Science & Technology. 2015 January, 8 (2), pp. 165-170.

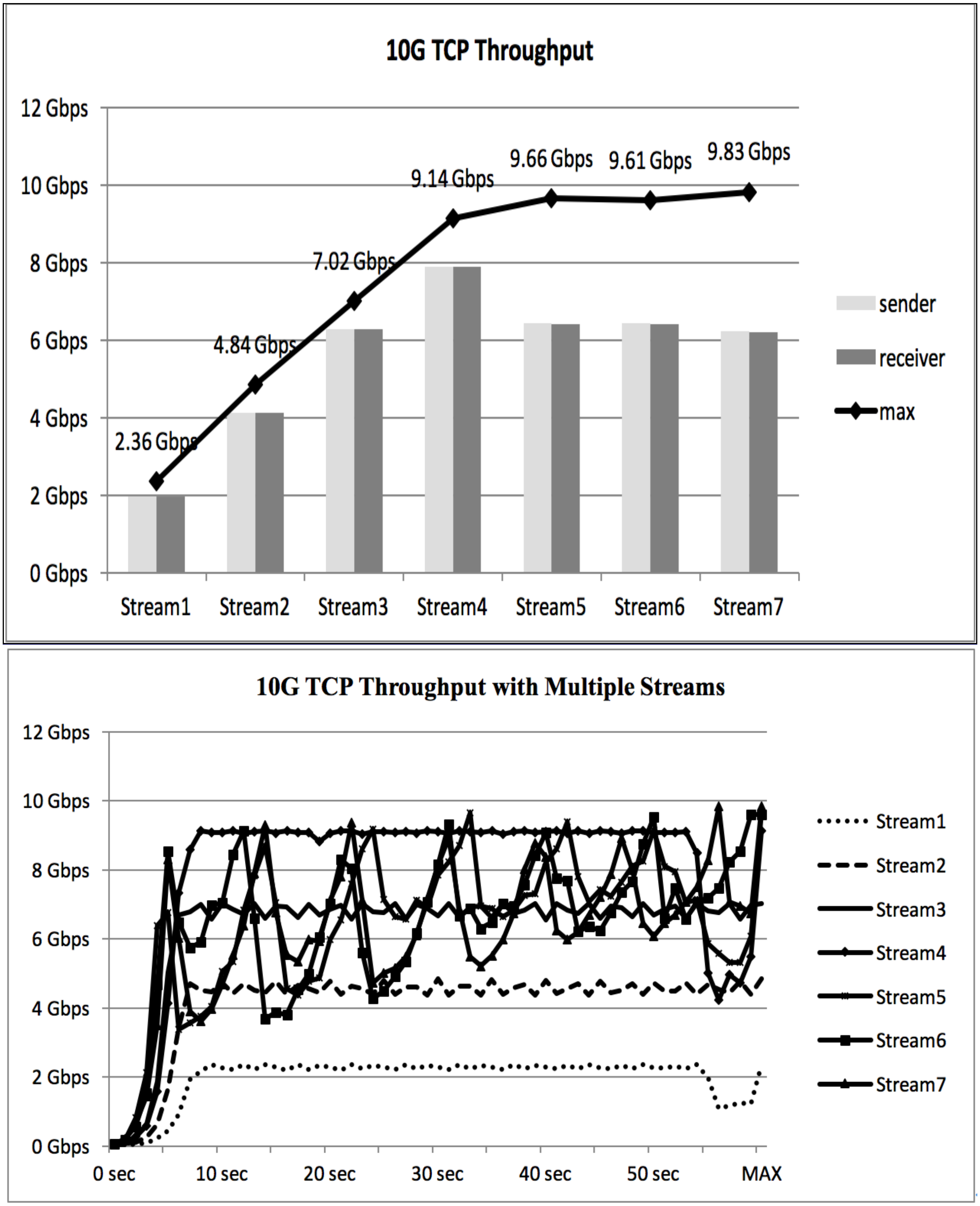

Fig. 5. 10Gbps Performance Measurement: TCP Throughput with Multiple Streams

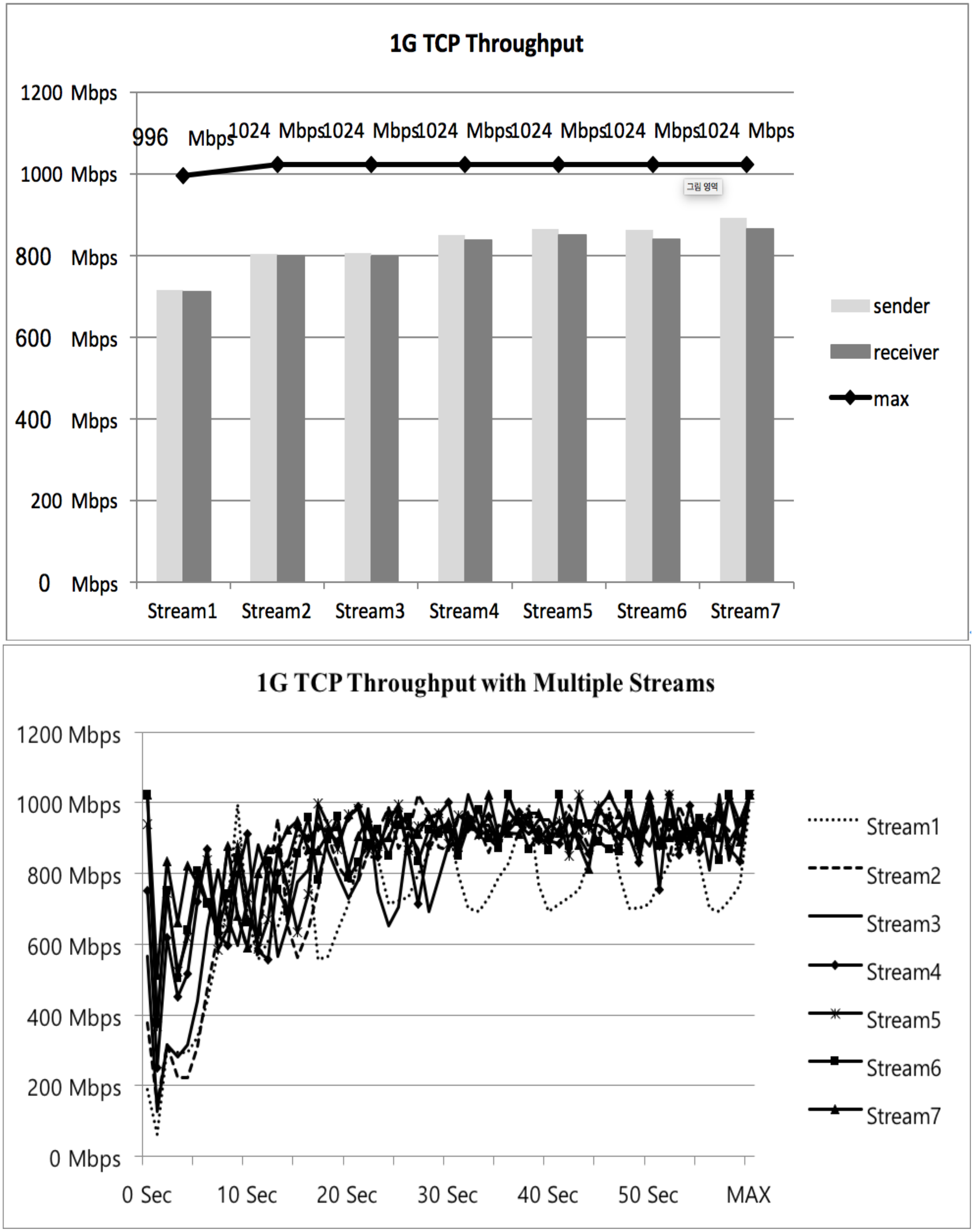

Fig. 6. 10Gbps Performance Measurement: TCP Throughput with Multiple Streams

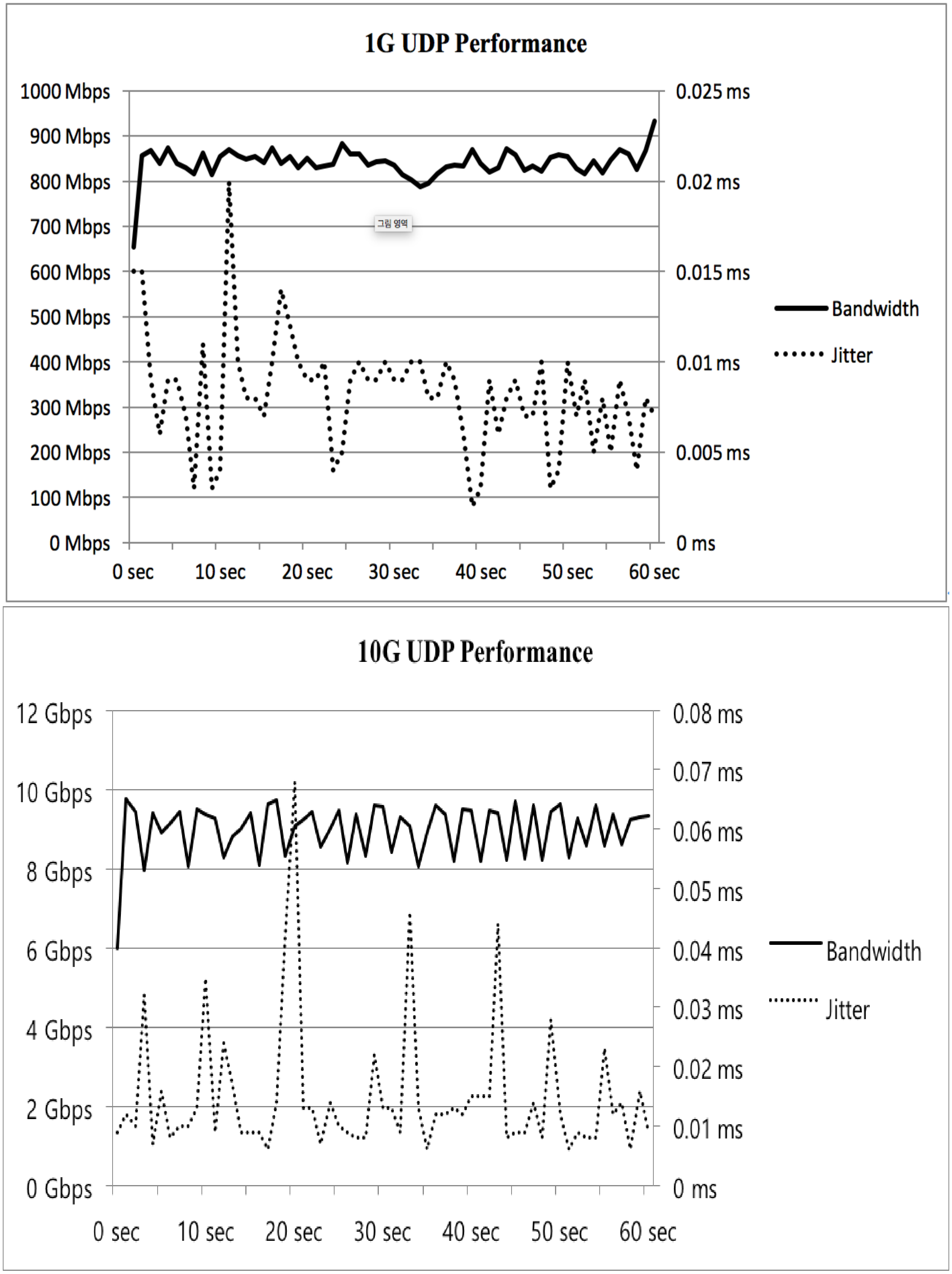

Fig. 7. 1Gbps and 10Gbps UDP Performance Measurement Results