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Software-Defined Science DMZ Construction using SDN/Science DMZ/Edge Computing for High Performance Big Data Transformation

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Abstract

Background/Objectives: Recently, research using big data and AI has emerged as major issue in the ICT field.However, as size of big data grows exponentially, it brings up problemsthat is slow data transmission speed and is unable to accommodate various network structures when transferring data on existing legacy network. Accordingly, researchers demand new network technology that applies dynamic, flexible and high speed network technology.

Methods/Statistical analysis: It constructs network structure without network performance degradation by using ScienceDMZ technology that divide the network for research and the general Internet network and using security policy of high performance switch.In addition, KREONET-S infrastructure using SD-WAN technology for softwarization of KREONETis combined with ScienceDMZ to build flexible network that can be applied to various networks.When constructing network that combines the two technologies, the Software-defined SicenceDMZ (SD-SDMZ) is configured using Edge-Computing technology, which discards the centralized computing approach and configures system close to the user.SD-SDMZ technology combines ScienceDMZ and SDN technology to provide network suitable for user's needs through network programming andto transmit data at high speed.In addition, SD-SDMZ can solve the bottleneck problem caused by the large number of users by using Edge-Computing technology. Also Edge-Computing is effective in terms of user accessibility.

Findings: SD-SDMZ technology combines ScienceDMZ and SDN technology to provide network suitable for user's needs through network programming andto transmit data at high speed.In addition, SD-SDMZ can solve the bottleneck problem caused by the large number of users by using Edge-Computing technology. Also Edge-Computing is effective in terms of user accessibility.Edge-Computing technology configure by installing Data Transfer Node (DTN) in KREONET regional network center and installing Kubernetes which is container orchestration technology. Kubernetes uses container-based virtualization technology to provide container-based AI computing environment. A new Kubernetes Container Network Interface (CNI) has been developed for network linkage between Kubernetes and KREONET-S controllers. The newly developed CNI is used network for organizing containers on DTN server.

Improvements/Applications: In this paper, we measure performance of SD-SDMZ infrastructure using ScienceDMZ, SDN, and Edge-Computing. The first performance measurement measures performance of the newly developed CNI and compares it with other CNIs. The second performance measurement measures data transmission performance when data is transmitted using the established SD-SDMZ network. The second experiment confirms superiority of the SD-SDMZ infrastructure by comparing virtual machine, host machine and container environment.

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I. Introduction

All of our electronics and appliances are combined with networks and generate data. The data is then processed into big data.Big data is blending with AI technologies to develop applications and to create new technologies.Recently, the biggest issue in ICT field is research using big data and AI [1,2].But in fact, researchers studying big data and AI are dissatisfied with data transmission using network.The reason for this is that copying data using disk is faster than transferring using network.Recently, big data researchers want to transmit data in terabyte units.But when you are sending data using network, it can take as little as a week or more to a month.To solve this problem, ScienceDMZ technology [3] emerged.

ScienceDMZ is a model developed by the USA Energy Scienc Network (ESNet)[4] Energy Department.ScienceDMZ is network capable of high speed transmission installed in universities or research institutes for purpose of transmitting scientific data.ScienceDMZ is network architecture that can minimize packet loss by separating general Internet traffic and scientific data transmission traffic through network virtualization technology such as Software-defined Network (SDN).KREONET [5] is working on the KREONET-S project which is the project for softwarization of KREONET. KREONET-S [6] can solve the problem of flexibility and security through network programming of existing static network structure using Software-defined Wide Area Network (SD-WAN) technology.We combine KREONET-S and ScienceDMZ technology to separate general traffic and research traffic into network that can minimize packet loss.In addition, to configure ScienceDMZ, Data Transfer Node (DTN) must be configured. DTN is a Linux-based server with high-performance hardware such as 100Gbps Ethernet card and RAID storage. DTN refers to a server that is network tuned to provide high performance hardware as well as high performance data for ultra-fast data transmission.

Expert consulting firm Gartner has selected Edge Computing as one of its top 10 strategic technologies for 2019.The global edge computing market is expected to grow at an annual average compound growth rate (CARG) of 35.3%, reaching $ 49.4 billion by 2021[7].Edge-Computing is technology that collects and processes data close to user where the data is generated.Cloud computing technology, which has been widely used in the past, is built with a centralized computing structure. As the number of users increased, the bottleneck of the network became more severe.But if using the Edge-Computing, you can instantly respond to and process data from nearby servers without having to send it to a central server.This distributed structure improves the quality of service to users by reducing the excess cost and waiting time caused by the increase of users and the size of data.In addition, data is collected and processed using a local area network, so there is no burden of data being deprived. Therefore, Edge-Computing can guarantee real time and security.

Edge-Computing makes it easy to store and process data, but it does not solve the fundamental problems of network structure and performance. As data grows in size and complexity, it requires flexible and dynamic networking. According to the IT professional global media IT WORLD, existing legacy networks are difficult to handle cloud-centric applications and tasks, and most of all, they are a challenge for cloud deployment because they do not have end-to-end visibility into performance [8]. In order to solve such a problem, it can be applied in conjunction with Software-defined Network (SDN), which is an optimized network structure for big data transmission, and ScienceDMZ.

KREONET-S operates SDN wide area network by building and interworking domestic and international network network infrastructure, and consists of data plane, control plane, service and application part for SDN network operation, management and service. KREONET-S provides dynamic, on-demand based on virtual-dedicated network (VDN) technology to provide timely support for leading edge collaborative research that requires large-scale research data transfer and management by quickly provisioning high-performance networks that researchers need. Provide network slicing services. The main services of VDN include VDN-Slicing, VDN-Federation, vNAC, VDN-DHCP, and are composed based on Web UI for user-friendly configuration.

Currently, domestic and overseas research institutes are working on the construction of high performance transmission network for collaboration through sharing research data. In the United States, more than 50 research institutes and universities participate in the Pacific Research Platform (PRP) [9] project. More recently, it has expanded beyond the PRP and across the United States, based on the National Research Platform project. In the United States, ScienceDMZ is now used to form 100G of network backbones across the United States, with each organization becoming ScienceDMZ. In addition, projects using SDN and ScienceDMZ [10] are ongoing.

There are recent studies using SDN and Edge Computing together. The technology trends that are used in conjunction with SDN and Edge Computing can be divided into two services. The first technology is used in a network for IoT services to construct an infrastructure, and the second technology can be divided into a Vehicular Ad Hoc Network (VANET).

The SD-MEC architecture [11] increases network safety by reducing overload and signal transmission between access and core planes. In addition, the structure of SD-MEC increases the stability of the controller by using multiple SDN controllers. At the same time, users experience high quality service. In this paper, we propose a new architecture for IoT to overcome the problems of MEC configuration (such as management and traffic control). The most important component in this structure is the SDF-Gateway. Gateways ensure interoperability between different communication protocols and communication between heterogeneous network domains. Its main function is to compute forwarding rules through topology data collection, running some routing algorithms, implementing scheduling algorithms, and defining security rules. In addition, various functions depending on the information provided by the control layer can be implemented in the application layer and can be added dynamically.

[12] The paper is a paper that provides solutions for IoT based platform and SDN based IoT. In this paper, we investigated various platforms for IoT using fog computing and designed a network platform for SDN-based IoT. The IoT services using SDN-based fog computing were investigated and presented in a table, and the characteristics of the paper were compared. In this paper, we propose a hierarchical SDN-based routing scheme. Instrumental SDN controller is used, and it is divided into SDN controller for fog-computing and central SDN controller based on cloud. When configured in this way, it is possible to provide effective routing using a distributed logical SDN controller.

[13] proposes the Hierarchical SDN for Vehicular Fog (HSVF) architecture. HSVF is based on a hybrid SDN control plane that enhances centralized distributed management and includes a trajectory prediction module to compensate for frequent handover problems between the Roadside Unit (RSU) and the vehicle. In this paper, the SDN is used to compensate for frequent handover problems between vehicles, and the module for predicting this is to solve the prediction problem by performing an algorithm using edge computing. The structure of the HSVF configured at this time can be divided into data plane, control plane, application and service plane. The data plane is a network in which data originating from the vehicle that sends and receives data is transferred, and the control plane is divided into SDN-C and SDN-F. Many SDN-Fs receive the information of wireless networks distributed in each region to form a topology and manage them. NFVM creates and manages VMs to perform computing to predict handover problems in SDN-C. In this paper, the HSVF is actually configured to measure the performance change according to the use of SDN.

[14] proposed 5G next-generation VANET architecture, and proposed an architecture that can efficiently allocate resources by integrating with centralized and flexible 5G communication technology of SDN and Cloud Radio Access Network (C-RAN). . The Fog-Computing framework is proposed to avoid frequent handover between the vehicle and the RSU. This paper presents the results by analyzing the transmission delay, throughput, and control overhead of the SDN controller. Comparing with the paper [13], the computing cluster is configured at the edge stage, which enables fast computing.

In this paper, we construct SD-SDMZ using SDN,ScienceDMZand Edge-Computing. We build SD-SDMZ to perform performance tests. SD-SDMZ performs data transfer test in virtual machine, host and container environments and compares performance. We will compare and verify the superiority of our SD-SDMZ performance.

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II. SD-SDMZ Building Method

This chapter describes the overall structure of SD-SDMZ. Figure 1 shows the overall structure of the SD-SDMZ. This section describes the structure of ScienceDMZ construction and linkage with KREONET-S. It also shows the state of DTN and Kubernetes [15] established in each regional network center to configure Edge-Computing, and describes the structure of VDN-CNI that developed new Kubernetes CNI to use ScienceDMZ.

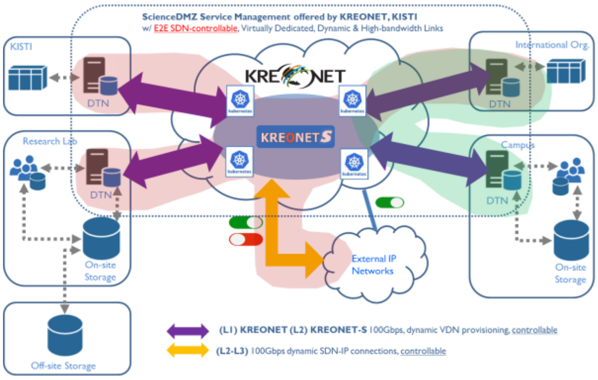

Figure 1. SD-SDMZ Architecture

In the structure of SD-SDMZ, some of KREONET's entire network connects KREONET-S to build SD-SDMZ network. When constructing KREONET-S, the network structure is composed of ScienceDMZ. To design the scienceDMZ network, 1) a network architecture with clear separation between science and general purpose networks, 2) the use of dedicated systems for data transmission, 3) security policies and hardening mechanisms tailored to the environment for transmitting high-performance scientific data, 4 Regular network performance measurement and network test systems are required. Use Data Transfer Node (DTN) as a dedicated system for data transfer. Figure 2 shows the ScienceDMZ schema deployed at each regional network center. In order to construct ScienceDMZ's data transmission system, PerfSonar [16] server and DTN and server serving as Kubernetes Node were used to measure network performance by using Management Switch before entering network. Once inside each agency, the security equipment built by the agency cannot provide high performance. In addition, since DTN has to play the role of Edge Computing, we build ScienceDMZ within the regional network center. In order to build SD-SDMZ, the control plane and data plane of KREONET-S are described in detail in Section 2-1, and in detail, the VDN-CNI developed to link Kubernetes and VDN is explained in detail.

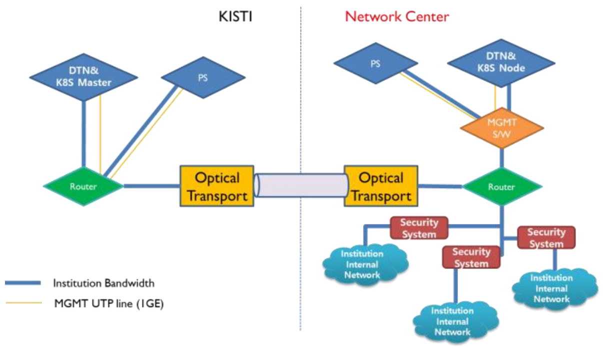

Figure 2. ScienceDMZ Schema

DTN Server Construction Status of *SD-SDMZ*

The infrastructure of KREONET-S is currently using the ONOS controller [17] by using Control Plane. In addition, five ONOS nodes are operated in one cluster in Busan, Daejeon. In Korea, Data Plane is currently installed in Seoul, Daejeon, Gwangju, Changwon and Busan regional network centers. Each regional network center has 10 1Gbps links and one 10Gbps link. The international network is located at the Chicago, Seattle, and Hong Kong international network centers. In Chicago, 10 1Gbps links and 1 10Gbps link are connected, and in Hong Kong and Seattle, 1 1Gbps link is connected. In order to connect KREONET-S and Edge Computing, I think it is most suitable to establish and operate DTN

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server in each regional network center and international network center. This is because the closest place to perform computing in each region is the regional network center. Building a DTN server in each regional network center will send data to researchers in other regions and the DTN server in the regional network center, and perform computations directly on that server so that users can only import the results into their institutional networks. When done according to this process, big data can be quickly transferred and the results only need to be brought to the internal network. Therefore, we performed the experiment by constructing DTN testbed server in Seoul, Daejeon, and Busan regional network center in Korea, and testbed server in Chicago international network center in Korea.

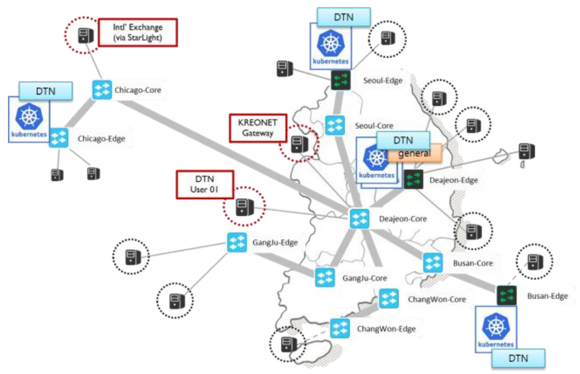

Figure 3. KREONET-S Testbed Building for ScienceDMZ

Figure 3 shows the construction of KRNNET-S's DTN server. Each DTN server configures hardware by installing a GPU to perform AI. The software installs Kubernetes on top of the DTN server to configure container orchestration for each region. Figure 3 shows Kubernetes deployment on our DTN server. In Figure 3, the Kubernetes configuration shows that each master node is configured as a VM for each DTN server, and each host server acts as a real worker node. The reason for this configuration is that the master and the node are configured separately because the distance between the master and each worker node affects the performance of the network. An orchestrator was developed in the ONOS controller to manage each Kubernetes Master. The orchestrator's structure is shown in Figure 3.The orchestrator communicates with the VDN via REST-AIP to instruct Kubernetes to create pods and to create pods by defining images, resources, etc. through the GUI. The generated pod visualizes the network connection through the ONOS controller, automatically detects that the VDN is created and creates a virtual dedicated network. The reason why VDN and Kubernetes can be linked is because they developed VDN-CNI. Details of VDN-CNI are explained in detail in Chapter 2-2.

VDN-CNI Development and Construction

The existing Kubernetes CNI has various plugins such as Calico [18], Flannel [19], OVS [20] and WeaveNet [21]. However, since most CNIs use virtualization methods, they do not consider performance, and when creating a container, they cannot configure a virtual network of 1Gbps or more, and have multiple NIC cards but cannot use multiple NICs. exist. Therefore, in this paper, we developed VDN-CNI. Since our system must be linked with KREONET-S, it must be linked with VDN, an application created by KREONET. The structure of the VDN-CNI is shown in Figure 4.

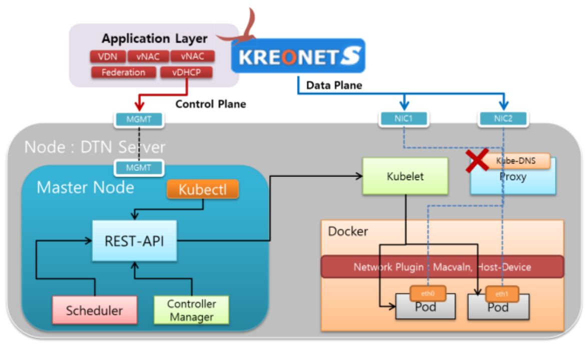

Figure 4. VDN-CNI Architecture

Two network plug-ins for VDN-CNI have

been developed. Figure 5 shows the structure of the two VDN-CNIs. The first is Host-Device. Host-Device is a CNI for ScienceDMZ / DTN users. When the Host-Device creates the pod, it gets the information from the actual NIC and allocates it, so the network bandwith configured by the NIC can be used as it is. Therefore, it is used for users who demand high performance, and one NIC cannot be assigned to multiple pods. In addition, if you define the NIC name in the configuration file when configuring the system so that multiple NICs are automatically assigned, the first NIC is automatically assigned. The second is Macvlan. Macvlan generates a virtual Mac address from one NIC and assigns it to a pod, and one NIC can be assigned to multiple pods. Macvlan is used to configure additional systems in Kubernetes and users of systems that don't need high performance. Macvlan is configured when there is no network specification when configuring a pod.

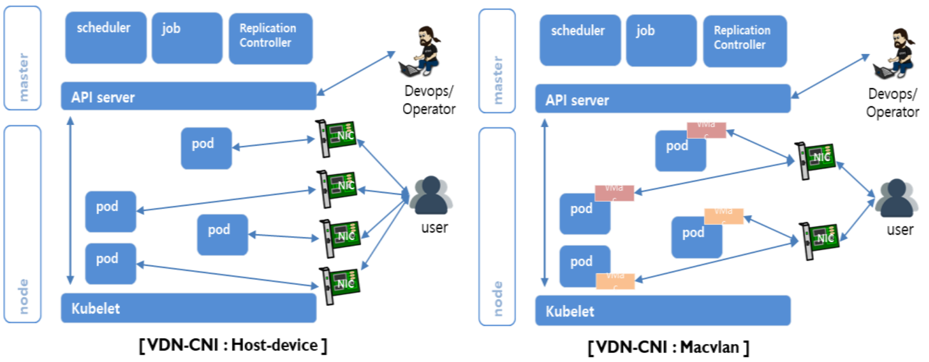

Figure 5. VDN-CNI Host-device, Macvlan Structure

VDN-CNI is composed of VDN. The reason is that existing Kubernetes is configured to be created by allocating IP from Network Plugin when creating a pod. However, VDN-CNI uses the VDN-vDHCP feature to orchestrate a visible and distributed Master in conjunction with the ONOS controller. If you use the vDHCP function, you can get information about the pod created by ONOS, so you can recognize the pod. Existing Kubernetes used Private IP when creating pod, but Public IP should be used to use VDN-vDHCP. When using public IP, the service is created and discarded the method of communicating with the outside using the host port, and is changed to direct IP communication using the actual NIC. This eliminates the need for Kube-DNS to connect the port for communicating with the outside and the IP inside the pod. Therefore, Kubernetes using VDN-CNI deletes kube-DNS.

III. Performance Measurement Result

Implement SD-SDMZ to perform performance measurements on DTN testbeds. There are two tools used to perform performance measurements. The first uses iperf3 to measure network performance. The second uses gridFTP [22] to measure disk to disk performance. To check the data transfer performance, you need to perform a Disk to Disk performance measurement. First, the performance measurement performs network performance measurement of the VDN-CNI. After that, perform Disk to Disk performance measurement using GridFTP in SD-SDMZ infrastructure. In this paper, we perform the performance measurement by using host, VM, and container. The tool used to create the VM was VirtualBox [23], and Kubernetes was used to create the container.

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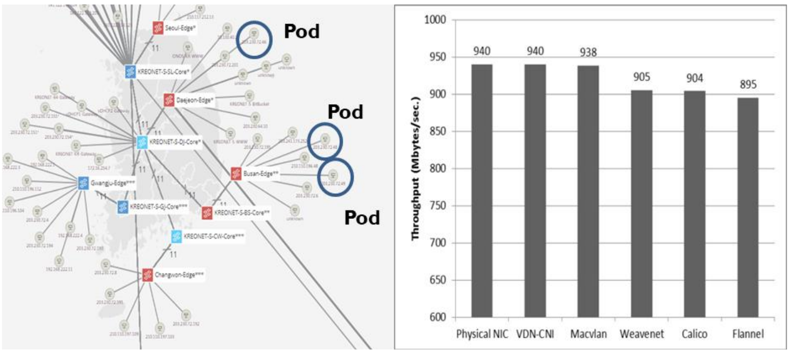
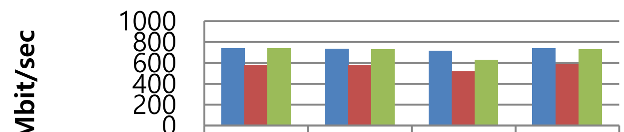


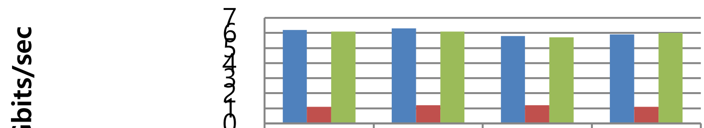
Figure 6. VDN-CNI performance measurement result

Perform performance measurements between DTNs installed at regional network centers and international network centers. First perform a performance measurement of the VDN-CNI. To perform the performance measurements, we compare the performance by measuring the performance of the two versions of Weavenet, Calico, Flannel, and VDN-CNI (Macvlan, Host-device), which were previously used in Kubernetes. Actually, performance measurement is performed between pod and pod, and performance measurement is performed between Seoul and Daejeon. Performance measurement results are shown in Figure 6. The performance measurements show that the pods actually created are visible to the ONOS controller. In addition, when the network performance is measured, the existing CNIs show about 900Mbps, but the VDN-CNI shows similar results to that of the physical machine.



	DJ→ SL	DL→ BS	DL→ CHI	DL→ GJ
Host Performance	740	736	713	738

Figure 7. 10Gbps link Disk to Disk performance measurement



	DJ→SL	DL→BS	DL→CHI	DL→GJ
Host Performance	6.2	6.3	5.8	5.9
VM Performance	1.1	1.2	1.2	1.1
Container Performance	6.1	6.1	5.7	6

Figure 8. 1Gbps link Disk to Disk performance measurement

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Next, perform Disk to Disk performance measurement using GridFTP in SD-SDMZ infrastructure. Starting from Daejeon, Daejeon-Seoul, Daejeon-Busan, Daejeon-Chicago, Daejeon-Gwangju performance measurements are performed and the results are shown. Performance measurement results for each section are shown using 1Gbps link, and the performance measurement results are shown in Figure 7. In the network performance measurement results, the host showed 740Mbits / sec in the Daejeon-Seoul section, 580Mbits / sec in the VM, and 738Mbits / sec in the Container. In the Daejeon-Busan section, the host showed 736 Mbits / sec, the VM 578 Mbits / sec, and the Container 730 Mbits / sec. In the Daejeon-Chicago section, the host showed 713Mbits / sec, the VM 521Mbits / sec, and the Container 630Mbits / sec. In the Daejeon-Gwangju section, the host showed 738 Mbits / sec, the VM 586 Mbits / sec, and the Container 730 Mbis / sec. Figure 8 shows the transmission test result connecting 10Gbps link. When transmitting data by connecting 10Gbps link, the result of measuring disk to disk performance was 6.2Gbits / sec for host and 1.1Gbits / sec for VM in Daejeon-Seoul. The result showed 6.1Gbits / sec. In the Daejeon-Busan section, the host showed 6.3 Gbits / sec, the VM showed 1.2Gbits / sec, and the Container showed 6.1Gbits / sec. In the Daejeon-Chicago section, the host showed 5.8Gbits / sec, the VM showed 1.2Gbits / sec, and the Container showed 5.7Gbits / sec. In the Daejeon-Gwangju section, the host showed 5.9 Gbits / sec, the VM 1.1 Gbits / sec, and the Container 730 Mbis / sec.

According to the performance measurement result of each section using SD-SDMZ, VM does not support network virtualization of more than 1Gbps. If you look at the performance measurement results of the container, you can see that the performance measurement results of the disk to disk as well as the network show little difference in performance from the host test results. In case of SD-SDMZ using VDN-CNI developed in this paper, it can be confirmed that the data loss is little different from the actual host when data is transmitted in Container environment. Through this, we demonstrate the superiority of the performance of the SD-SDMZ.

IV. CONCLUSION

In this paper, SD-SDMZ was established by linking ScienceDMZ, SDN, and Edge Computing. We have constructed an infrastructure that enables AI researchers to transfer big data at high speed.We developed a new CNI, VDN-CNI, in conjunction with KREONET-S's application VDN using container orchestration Kubernetes on top of this infrastructure. We have developed an application to orchestrate a working distributed Kubernetes Master. Kubernetes provides AI researchers with a container-based computing environment.

In the container-based research environment, network and disk to disk performance measurements are performed to verify performance. Performance comparison is performed on the same server on the same server to compare with the VM environment and the host server environment. The results of this performance test show that the container environment is similar to the actual host server, the VM environment does not provide network performance of more than 1Gbps, and the performance is lower than that of the container. This proved that high performance can be achieved even if AI is performed in container-based virtualization environment. This enables the use of SD-SDMZ infrastructure to increase AI researchers' research productivity and

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create a multidisciplinary shared environment for artificial intelligence.

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REFERENCES

[1]. Statista, "Artificial intelligence software market revenue worldwide 2018-2025", Sep. 24. 2019

[2] IDC, "Worldwide Big Data and Analytics Software 2017 Market Shares: Healthy Growth Across the Board", Sep. 24. 2019

[3] E. Dart, L. Rotman, B. Tierney, M. Hester, and J. Zurawski, "The ScienceDMZ: A network design pattern for data-intensive science," Scientific Programming, vol. 22, no. 2, pp. 173-185, 2014.

[4] ESNET web site, Retrieved Sep., 22, 2019, from https://fasterdata.es.

[5] KREONET web site, Retrieved Sep., 22, 2019, from http://www.kreonet.net/

[6] KREONET-S web site, Retrieved Sep., 22, 2019, from http://www.kreonet-s.net/

[7] Gartner, "Top 10 Strategic Technology Trends for 2019", Oct, 15, 2018

[8] PRP web site , Retrieved Sep., 22, 2019, https://prp.ucsd.edu

[9] Pho, Nam, D. Magri, F. Redigolo, B. Kim, Timothy Feeney, H. Morgan, C. Patel, Chris Botka, and T. Carvalho"Data transfer in a science DMZ using SDN with applications for precision medicine in cloud and high-performance computing.", Proceedings of the SC 15 ,2015.

[10] Salman, Ola, et al. "Edge computing enabling the Internet of Things." 2015 IEEE 2nd World Forum on Internet of Things (WF-IoT). IEEE, 2015, pp.603-608.

[11] Okay, FeyzaYildirim, SuatOzdemir. "Routing in Fog-Enabled IoT Platforms: A Survey and an SDN-Based Solution." IEEE Internet of Things Journal, vol. 5, no. 6, 2018, pp.4871-4889.

[12] Chekired, DjabirAbdeldjalil, Mohammed Amine Togou, and LyesKhoukhi. "Hierarchical Wireless Vehicular Fog Architecture: A Case Study of Scheduling Electric Vehicle Energy Demands." ieee vehicular technology magazine, vol. 13, no. 4, 2018, pp.116-126.

[13] Khan, AmmaraAnjum, MehranAbolhasan, and Wei Ni. "5G next generation VANETs using SDN and fog computing framework." 2018 15th IEEE Annual Consumer Communications & Networking Conference (CCNC). IEEE, 2018, pp.1-6.

[14] Kubernetes web site, Retrieved Sep., 23, 2019, from http:// https://kubernetes.io//

[15] PerfSONAR web site, Retrieved Sep., 23, 2019, from https://www.perfsonar.net/

[16] P. Berde et al., "ONOS: towards and open, distributed network OS," in Proc. the third workshop on Host topics in software defined networking, 2014, p. 1-6.

[17] Calicoweb site, Retrieved Sep., 23, 2019, from https://www.projectcalico.org/

[18] Flannel web site, Retrieved Sep., 23, 2019, from https://coreos.com/flannel/

[19] Open Virtual Switch web site, Retrieved Sep., 23, 2019, fromhttp://www.openvswitch.org/

[20] Weavenet web site, Retrieved Sep., 23, 2019, fromhttps://www.weave.works/

[21] GridFTPweb site, Retrieved Sep., 23, 2019, fromhttp://toolkit.globus.org/ toolkit

[22] Virtualboxweb site, Retrieved Sep., 23, 2019, from https://www.virtualbox.org/