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Toward a resilient software defined infrastructure to support disaster management applications

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Abstract　A distributed visualization system which makes it easy to understand the information generated from analysis of retrieved large-scale datasets and keeps to provide them on multiple sites concurrently is required as one of disaster management applications which support to decide and perform an appropriate decision in a disaster. For such a distributed visualization system, we aim to realize an IT infrastructure that can tolerate partial failures of components and enables to adapt to rapidly changing environments caused and/or aggravated by disaster events. The goal of this project is to prototype a Software-Defined IT infrastructure to support the continuous distributed visualization.

1. Basic Information

(1) Collaborating JHPCN Centers

Osaka University

(2) Research Areas

- ☐ Very large-scale numerical computation
- ☐ Very large-scale data processing
- ☐ Very large capacity network technology
- ・ Very large-scale information systems

(3) Roles of Project Members

Yasuhiro Watashiba (Nara Institute of Science and Technology (NAIST)):
Representative, Resource management system

José A.B. Fortes (University of Florida):
Vice-Representative, Establishing international collaborations and acquiring international resources

Jason Haga (National Institute of Advanced Industrial Science and Technology (AIST)):
Vice-Representative, Multi-site visualization tool deployment

Kohei Ichikawa (Nara Institute of Science and Technology (NAIST)):
Vice-Representative, Integration of system with PRAGMA-ENT

Susumu Date (Osaka University):
Integration of system with PRAGMA-ENT

Hirotake Abe (University of Tsukuba):
Wide-area visualization testbed

Yoshiyuki Kido (Osaka University):
Wide-area visualization testbed

Hiroaki Yamanaka (National Institute of Information and Communications Technology (NICT)):
Integration of system with PRAGMA-ENT

Ryousei Takano (National Institute of Advanced Industrial Science and Technology (AIST)):
Wide-area visualization testbed

Ryusuke Egawa (Tohoku University):
Wide-area visualization testbed

2. Purpose and Significance of the Research

The concept of Information-as-a-Service (Infaas) is important for constructing an efficient and flexible disaster management environment. For an appropriate decision making process in the disaster management, the flow of information to authorities and the synchronization of retrieved and analyzed data between

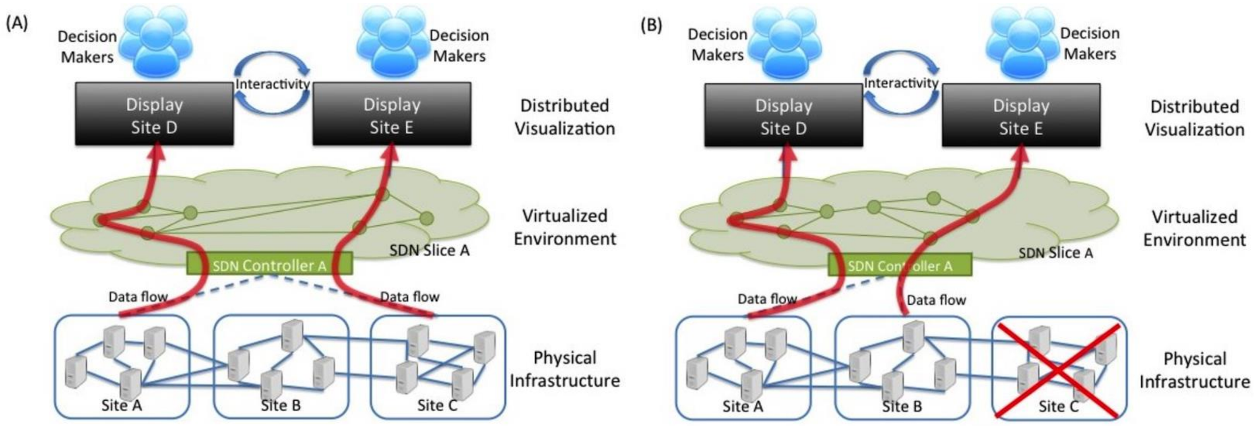

Figure 1 Conceptual diagram of the goal of the project.

different groups such as local governments and Non-Governmental Organizations (NGOs) must be maintained. Thus, a system which visualizes various types of data and synchronizes them between different groups is required for supporting their common understanding to make an appropriate decision in a disaster.

From the consideration above, a distributed visualization system which makes it easy to understand the information generated from analysis of retrieved large-scale datasets and keeps to provide them on multiple sites concurrently is necessary for considering an appropriate decision for the disaster. Moreover, in order for the decision makers to make an appropriate decision for the disaster, the information generated from retrieved data must be continually provided for them even when the disaster makes a part of IT infrastructure on which disaster management applications are running inoperable.

Since such distributed visualization system requires IT infrastructure that can tolerate partial failures of components and can adapt to rapidly changing environments caused and/or aggravated by the disaster events, we focus on the Software-Defined technology which has the potential to offer the needed flexibility and resilience to IT infrastructures. Therefore, we aim to realize a Software-Defined IT infrastructure to support the continuous distributed visualization for big data analysis during a disaster. This project is a first step in developing a large-scale crisis informatics system that is flexible and reconfigurable depending on the needs during a disaster.

In this project, the functionalities of the Software-Defined IT infrastructure are assumed as the scenario shown in Figure 1. Figure 1-(A) illustrates a normal situation of distributed visualization system. If a disaster makes Site C inoperable as shown in Figure 1- (B), then the resources assigned to the disaster management application are reconfigured by migrating application servers to Site B and reconstructing the assigned virtualized network slice.

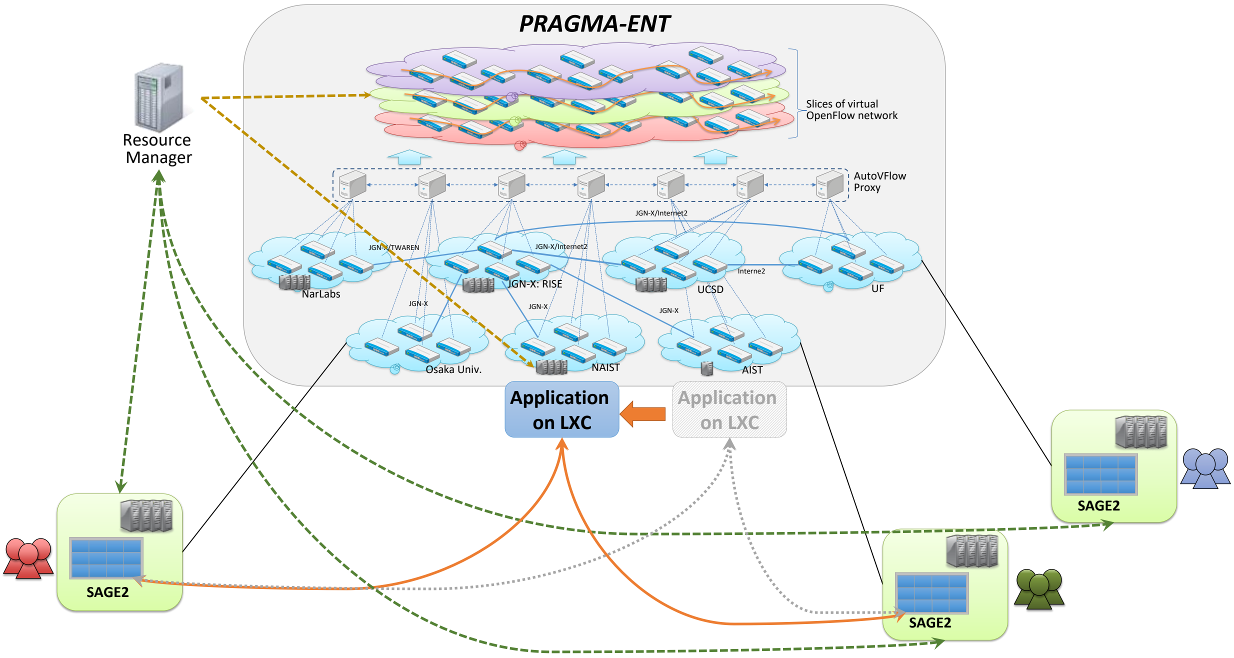

Figure 2　System structure of Software-Defined IT infrastructure

3. Significance as a JHPCN Joint Research Project

To construct and evaluate the prototype of Software-Defined IT Infrastructure, we assume that it utilizes computing resources, large-scale visualization system, and network between sites capable of Software-Defined Networking (SDN). Since Osaka University has the environment to provide them, we believe that this project can be achieved by leveraging the resources.

Moreover, the large-scale visualization system of Osaka University has the component technology of SDN-based distributed visualization system which is developed in the collaboration with National Institute of Information and Communications Technology (NICT). We believe that the knowledge and experience in the collaboration accelerate to achieve the Software-Defined IT infrastructure.

4. Outline of the Research Achievements up to FY 2015

(Omission. Because this project is starting FY2016.)

5. Details of FY 2016 Research Achievements

Our research plan to prototype a distributed visualization system on the Software-Defined IT infrastructure is divided into three stages:

(a) deployment of the multi-site visualization tool,
(b) creation of SDN-based infrastructure,
(c) testing the robustness of the tool with infrastructure congestion and/or failures.

In this section, the research achievement of each stage is described.

(1) Stage (a): multi-site visualization tool

In the stage (a), the multi-site visualization tool is implemented as a virtual whiteboard or workspace in which the same data is displayed to multiple visualization system in the distributed sites. In considering the guideline for the disaster, it is essential starting point to display the geographical maps. Thus, multi-site visualization tool is deployed as the collaborative environment centered on geographical maps among the multiple large-scale visualization environments. In this collaborative environment, the analytic information generated by retrieved data can be superimposed on the geographical maps for providing the same visualization images for all decision makers.

In this project, we suppose that the architecture of large-scale visualization system is a tiled display system which is composed of multiple monitors and display nodes. Thus, a large-scale visualization system is generally deployed a middleware to manage and support the visualization applications. In this project, to facilitate the composition and synchronization of visualized data, Scalable Amplified Group Environment（SAGE2）is adopted as a management middleware to control the behavior on the large-scale visualization system because the mechanism of SAGE2 is suitable for a distributed environment. In the SAGE2 system, the environment on the display nodes is Google Chrome web browser and the data transfer between visualization application and Chrome is performed by using WebSocket. Since the distributed visualization system is constructed by using the SAGE2, we implement the geographical maps and virtual whiteboard as a SAGE2 application.

(2) Stage (b): creation of SDN-based infrastructure

In the stage (b), the technology to migrate the application server and reconfigure the assigned virtual network slice for partial failures of environment coursed by the disaster is addressed. The large-scale visualization devices at different organizations and locations generally have different specification such as resolution, graphics capabilities, and network connectivity. Thus, it is important to allocate an appropriate set of resources based on the resource requirement of the visualization application for the synchronization of data.

We have been studying the resource management system (RMS) integrated the SDN technology. The RMS can manage not only computing resource such as CPU and memory but also network paths assigned to running applications as network resources. For the reconfiguration of virtual network slice, we utilize the network resource management mechanism.

On the other hand, it is difficult for the RMS to handle the migration of SAGE2 application server because the RMS is developed based on the traditional job scheduler. Thus, since the application allocated by the RMS is executed on physical computing resources, it is not suitable for migration process. Therefore, we utilize a virtual machine as the SAGE application server. In this project, we adopte the Docker, which provide light-weight computing environment, as virtual computer environment because the SAGE2 is also developed and validated on the Docker.

The migration mechanism of the prototype of the Software-Defined IT infrastructure is implemented by the checkpoint and restart method. In the scenario as shown in Figure 1, it is assumed that the computing environment which the SAGE2 application is running is stopped by the disaster. Therefore, it can achieve the cold migration. Even if the failure is only on the network, the trouble of communication between the tiled display and the SAGE2 application is not occurred because the assigned network slice is reconfigured.

(3) Stage (c): testing the robustness of the tool with infrastructure congestion and/or failures

In the stage (c), we deploy the distributed visualization system and the resource management system on PRAGMA-ENT. PRAGMA-ENT is a testbed which is designed for extensive network experiments and is especially suitable for testing the robustness of the multi-site visualization tool and underlying SDN technologies. In this project, since we construct the environment where the computing resources and large-scale visualization system is provided by Osaka Univesity, AIST, and NAIST, we establish the connection between every devices and PRAGMA-ENT. Moreover, the middleware of each visualization system is changed into SAGE2. After that, we deploy the multi-site visualization tool and the resource management system.

On the PRAGMA-ENT environment, we conduct the testing the robustness of the tool on the prototype of Software-Defined IT infrastructure. The failures of resources are performed by the shutdown of switch's port using the function of SDN.

6. Progress of FY 2016 and Future Prospects

In this project, we prototyped the distributed visualization system on the Software-Defined IT infrastructure to support the continuous distributed visualization for big data analysis during a disaster according to the scenario shown in Figure 1. The multi-site visualization tool which provides the basic collaborative environment centered on geographical maps among multiple large-scale visualization devices is developed as SAGE2 application. The SAGE2 application was deployed on the Docker for the server migration based on the checkpoint and restart. The resource management migrates the SAGE2 application server and reconfigures the assigned network slice when partial failures of infrastructure is happened. The distributed visualization system is deployed on the testbed provided from PRAGMA-ENT. In the testbed, computing resources and large-scale visualization systems are provided by Osaka University, AIST, and NAIST, and they are connected with PRAGMA-ENT.

In this project, though we could construct the prototype of Software-Defined IT infrastructure, the evaluation of the distributed visualization system and migration mechanism was not performed sufficiently because the deployment on the PRAGMA-ENT was behind schedule. One of the reason is the difficulty to change the middle ware for tiled display. Generally, different middleware is adopted on each large-scale visualization system according to the installed applications and the services. Since we adopted the SAGE2 for the prototype, the many times to change the tiled display middleware are spent. This is a problem to achieve the Software-Defined IT infrastructure with visualization system because many visualization applications for tiled display depends on the middleware. Therefore, we will address this problem in continuous JHPCN project.

7. List of Publications and Presentations

(1) Journal Papers

(2) Conference Papers

- Yasuhiro Watashiba, Susumu Date, Hirotake Abe, Kohei Ichikawa, Yoshiyuki Kido, Hiroaki Yamanaka, Eiji Kawai, and Shinji Shimojo, "Architecture of Virtualized Computational Resource Allocation on SDN-enhanced Job Management System Framework", Proceedings of the 39th IEEE International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO 2016), pp.257-262, 2016.

(3) Conference Presentations (Oral, Poster, etc.)

- Yasuhiro Watashiba, José Fortes, Jason Haga, Kohei Ichikawa, Susumu Date, Hirotake Abe, Yoshiyuki Kido, Hiroaki Yamanaka, Ryousei Takano, and Ryusuke Egawa, "Toward Construction of Resilient Software-Defined IT Infrastructure for Supporting Disaster Management Applications", International Symposium on Grids and Clouds 2017 (ISGC 2017), 2017 (Poster).

(4) Others (Patents, Press releases, books, etc.)