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Preliminary Study on Continuous Diagnosis for Wireless Sensing for Secondary Systems in Operating Nuclear Power Plants

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1. Introduction

Safe operation of nuclear power plants (NPPs) is one of the most important considerations in the field of nuclear energy in Korea. Recently, the concerns and demands for the safety of NPPs are greatly increased even at the non-expert's level. Thus, to ensure the scientific and technological safety margin at the expert's perspective and to satisfy the safety at the public's one, the new and applicable technologies relevant to sensing, monitoring, and diagnosing any possible leakages at operating NPPs are of great interest [1].

Wireless sensing is emerging as one of the effective and applicable technologies to apply the wide-area monitoring and diagnosing for the secondary systems in operating NPPs. That is, the wireless sensing can resolve the problems result from applying huge numbers of cables and operations when applying lots of additional sensors to NPP pipelines of several hundred kilometers. However, to apply wireless sensing to operating NPPs, the continuous diagnosis must be realized at a proper level, otherwise too much burden is loaded to the NPPs operation. Here, we present a strategy towards a continuous diagnosis system based on ICT technology, namely Kubernetes, and provide a preliminary study on the system.

2. Continuous diagnosis for wireless sensing

When the sensors are installed for the secondary system in operating NPPs, they will collect the data with respect to any possible leakages. From a safety perspective, the early detection of any abnormal case is of great importance. Thus, not only the monitoring, but also the diagnosis of the data collected is of crucial importance. Furthermore, the diagnosis must be continuous and automatic. To realize this diagnosis for the secondary system in operating NPPs, we propose a method utilizing Kubernetes. Kubernetes, a cloud software, is a container orchestration tool in computing that allows portability and monitoring automation [2].

Maintaining a continuous diagnosis and monitoring requires a tremendous amount of memory and resources, so a single PC will not be able to withhold the overload. Thus, to achieve continuous diagnosis, *i.e.*, a zero-downtime deployment of diagnosis and monitoring services, a cloud software which enables distribution of loads is needed. Kubernetes distributes applications by inspecting the memory and resource usages of each server. Provided that server A, for example, is at its max capacity, the next incoming data will be allocated to server B. In the course of load balancing, the performance may lower, however, its effect is only temporary and recoverable. Most importantly, the diagnosis system will still be maintained.

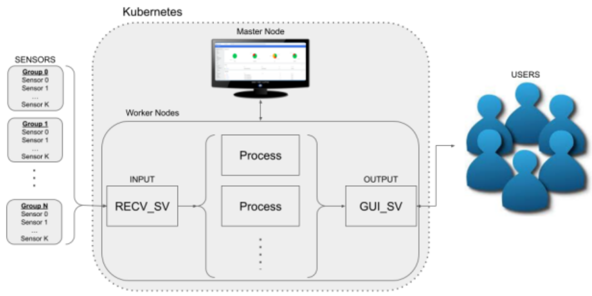

Fig. 1. Proposed continuous and automatic diagnosis system for secondary systems in operating NPPs.

Figure 1 illustrates the concept of our system proposed. The system is a cluster consisting of one master node and multiple worker nodes. Master node automates and manages service, scaling, and failure, whereas worker nodes collect and process the raw data (input), and deliver the output to users. Nodes are composed of pods containing applications. The number of pods, replicas, functions as a key to the continuous diagnosis. When a pod fails, the master node commands Kubelet, a mediator responsible for all communications within the cluster, to terminate the existing failed pod and create a new pod with identical functionality. These applications are based on Python programs that collect, process, analyze, and visualize sensor data from various location points in the secondary system in NPPs.

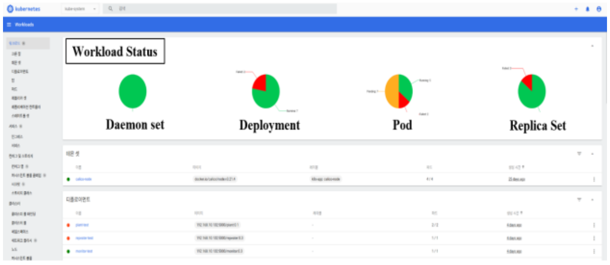

Fig. 2. Kubernetes Graphical User Interface (GUI).

Figure 2 shows an example of Kubernetes GUI visualizing our master node. By default, the master node presents a daemon set, deployment, pod, and replica set, as a form of pie chart. In each pie chart, red area denotes failure of the applications, yellow denotes stagnant cases, and green implies functioning applications. Thus, current Kubernetes GUI indicates 20% failure and 80% functioning applications in deployment, 10% failure, 50% stagnant, and 40% functioning in pods, and 10% failure and 90% functioning in replica set.

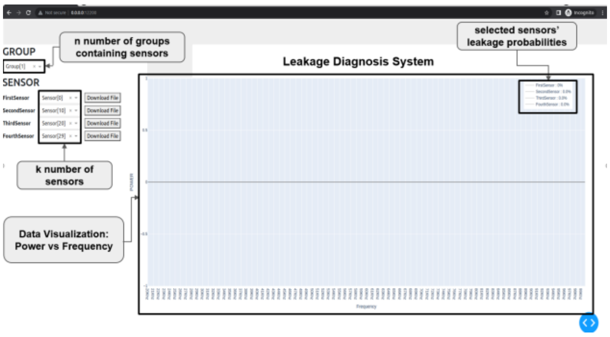

Fig. 3. Graphical User Interface (GUI) for users.

The Figure 3 shows a leakage diagnosis system (OUTPUT GUI in Figure 1) in Kubernetes. The user can choose a group and sensors of interest, then the graph of the corresponding data will be drawn as a graph. The top right box on the graph displays the leakage probabilities of the selected sensors. The user can also download the data as a CSV file.

3. Conclusion

We proposed a continuous diagnosis system for any possible leakage from the secondary systems in NPPs, based on the ICT technology, namely Kubernetes. We architect the cluster in computing including master and worker nodes. The programming that enables the function of each component (*e.g.*, receiver (RECV), process, and graphic user interface (GUI)) in the cluster needs further development.

REFERENCES

[1] Korea Institute of S&T Evaluation and Planning (KISTEP), KISTEP Report, 11-1721000-000597-01 (2021).
[2] Kubernetes site. August 2022. Available from: http://www.kubernetes.io.

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