

Edge-IoT Architecture-Based Visualization Service Platform for RTO Real-Time Monitoring

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Abstract – In this study, we present the Edge IoT Architecture (Architecture) for analyzing the real-time state information of the regenerative thermal oxidizer (RTO) and implement a visualization method. The Edge-IoT architecture system interfaces with the programmable logic control (PLC) that controls the monitoring of RTO operations and transmits real-time data to a remote server, analyzes the channel data received through the IoT to build a database, and visualizes the characteristics of database (DB) analysis. IoT architecture implementation for fault diagnosis and maintenance of RTO designs IoT circuits on PLC control panels that control monitoring. Compatibility and information security are considered to facilitate remote maintenance. The received data is segmented by each channel and analyzed by a visualization algorithm to detect anomalies in the segmented data. At this time, the visualized data is judged to be normal, insufficient, or warning, depending on the threshold.

Keywords – RTO, real time monitoring, edge-IoT, PLC, visualization

I. INTRODUCTION

The Internet of Things (IoT) is becoming the paradigm of the Internet of the future, providing a network that can easily build information flows between different kinds of products, devices, users, and information systems [1].

Many IoT applications manage data collection at the edge and provide data storage and analysis capabilities in the cloud. Although sufficient network bandwidth is available for nodes with edge-to-edge connections in the data stream to generate alarms, computing capabilities at the edge alone may not be sufficient. In this case, some processing steps may be transferred from the edge to the cloud. These computational placement decisions depend on many problems and require optimal placement decisions at runtime [2].

The processing phase of IoT applications can be divided into two parts: edge implementation and cloud implementation. Traditional IoT systems require (i) a common software stack for computing, portability, and manageability to move data processing between edges and clouds. (ii) When edge nodes interact with a particular cloud backend, the available network bandwidth between edges and clouds becomes a bottleneck for large-scale data transfer. This requires computing at edge nodes to minimize physical distance delay and consume less bandwidth [3].

In systems where many nodes with data transfer between

the edge and the cloud are clustered, data can be lost forever due to malfunctions of a single edge node, and in the case of node failures or intermittent long-distance network connection problems, local fault tolerance must be implemented to preserve system state locally at the edge. Thus, we propose CEF-IoT, a new fault-tolerance architecture for IoT applications [4]. The CEF-IoT architecture consists of three layers: (i) application isolation, (ii) data transfer, and (iii) a multi-cluster management layer. Based on this layer design, the architecture allows computing deployment at the edge or cloud without source code modification. This is possible by using the same lightweight docker container-based software stack at the cloud and edge, which deploying embedded Linux devices at the edge. Figure 1 shows the service concepts for remote monitoring.

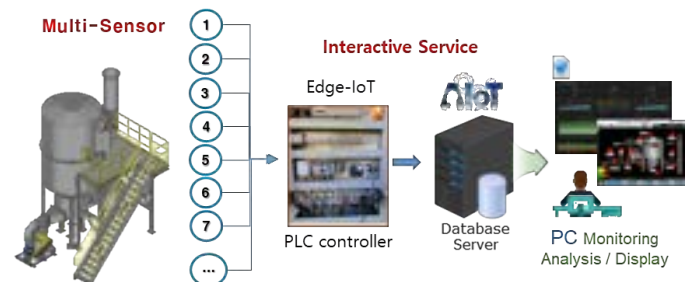


Figure 1. The service concepts for remote monitoring.

In this paper, we design an edge IoT system for remote maintenance of RTO facilities. Implement a system for collecting and storing real-time state data through the Edge-IoT terminal. Device abnormality detection and temperature control stability are important factors in operation and maintenance through the RTO's PLC control panel. In particular, an IoT data collection system is essential for the management of remote equipment. Figure 1 shows the configuration of the IoT system required for research. It can reduce the physical cost for MRO and provide an experience that can escape the constraints of time and space.

II. IMPLEMENTATION OF EDGE-IOT SYSTEM

2.1 RTO monitoring

As shown in Figure 2, the RTO equipment is monitored through the HMI installed in the RTO facility, and various

sensor and actuator states are collected and controlled through the programmable logic controller (PLC). When a problem occurs at the system site by checking the status at a remote location, the same information as the site should be identified and the history can be monitored remotely. Through real-time monitoring, abnormal symptoms should be recognized in advance and predictive preservation should be possible before an accident occurs.

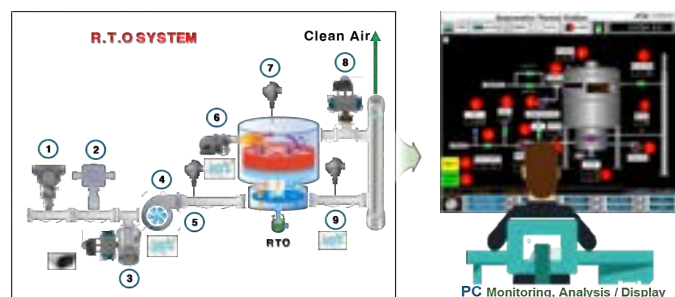


Figure 2. The connection between sensor-IoT and RTO equipment

In the case of IoT node failure or intermittent long-distance network connection problems, it is necessary to implement local fault tolerance to preserve system state locally at the edge. To address this issue, we propose CEF-IoT, a new fault-tolerant architecture for IoT applications using edge computing based on cloud technology. The Edge-IoT architecture consists of three layers: (i) Application Isolation, (ii) Data Transport, and (iii) Multi-Cluster Management layer. Based on this layered design, the architecture allows computing deployment at the edge or cloud without source code modification.

The CEF-IoT architecture is designed to provide fault tolerance to both edge and cloud-side clusters, and to provide integrated multi-cluster management that enables failover in large interconnected networks. In addition, CEF-IoT's separate clusters for edge and cloud allow edge devices to operate independently even when they are separated from the cloud backend. Thus, this architecture operates in degraded mode even when cloud connectivity is lost. This architecture is logically constructed from underlying techniques with three abstraction layers [4].

Figure 3 shows an application with application separation, data transfer and multi-cluster management layer, and four PC.1, PC.2, PC.3, and PC.4 have processing steps. Here, PC processing container, ET edge topic, CT cloud topic, EN edge node, and CN cloud node are described.

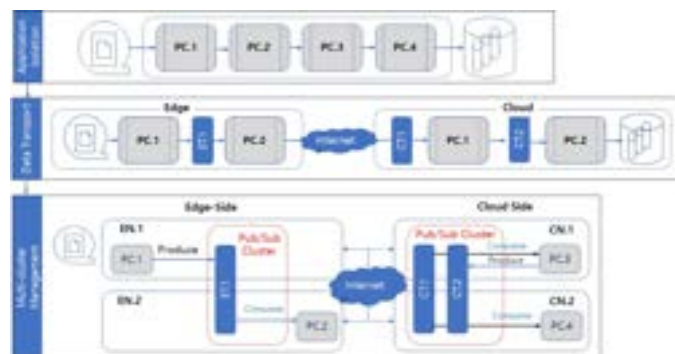


Figure 3. Edge-IoT layer-type architecture.

Edge-IoT's Application Isolation layer wraps individual processes into separate, independent blocks, and configures them to act as a single isolated application for transferring data from source to destination. This wrapping is achieved by adopting a Linux container that provides application isolation for convenient software deployment and allows processing of data streams regardless of physical hardware. For machines with different architecture types, the container executes the same application-level code without modifying the source code to ensure software portability. Docker is chosen for the following. As it is the most mature and adopted development tool that creates distributed applications and organizes them to interact with the outside world, this purpose can be achieved. It also separates multiple IoT applications and cloud nodes from each other running on the same edge. As shown in Figure 4, the Edge-IoT system should be able to collect RTO PLC data, analysis value data for diagnosis, and VOC data for facility efficiency measurement and transmit them to a remote data collection server [5].

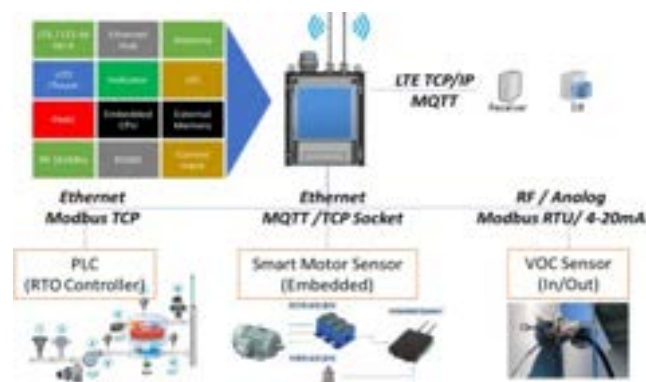


Figure 4. The Edge-IoT system with communication network.

Table 1 shows trip information indicating an abnormal operation of the RTO in a PLC control operation. When this trip occurs, it becomes an index for confirming a problem of the RTO through the occurrence information.

TABLE 1. TRIP INFORMATION THE RTO IN A PLC PANEL.

Tag Name	Trip type
TRIP information	FD fan trip
	Rotary trip
	Purge fan trip
	Combustion fan trip
	Fresh damper trip
	Hot Fresh damper trip
	Overheated combustion chamber
	Combustion chamber of high temperature
	Low temperature of combustion chamber
	Incoming temperature high

	high exhaust temperature
	Inlet GAS Trip
	high-temperature inlet temperature
	high exhaust temperature
	Burner trip

Figure 5 designs the entire DB configuration from Edge-IoT to remote maintenance services based on Figure 3 and Figure 4. MQTT is a data pipeline of message queue method and delivers information collected from edge-IoT terminals to the collector in message queue method [7].

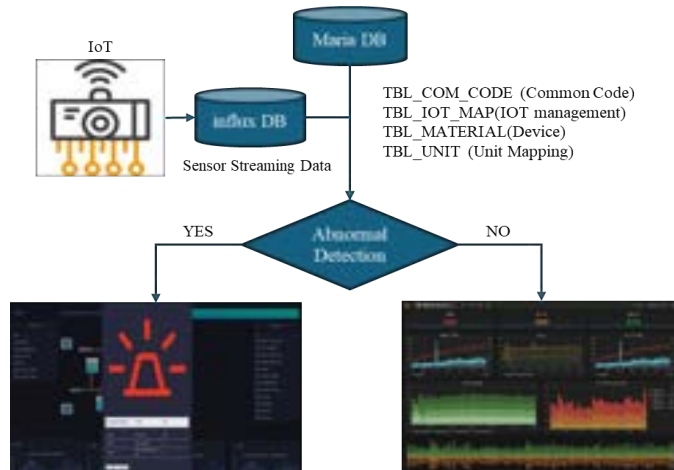


Figure 5. The entire system configuration from Edge-IoT

III. DATA VISUALIZE FOR RTO ANALYSIS

Figure 6 shows the data dashboard collected from the edge IoT. It shows visualization information for providing analyzed data to field workers or managers. When a menu bar is selected at the top of the figure, heat, amount of gas, temperature change, etc. appear according to the selection items, and printing and mail transmission are made to provide the analyzed data[6].



Figure 6. The data dashboard collected from the edge IoT.

Figure 7 is an implementation of a visualization method through simultaneous analysis of multi-channel data points. The determination of the presence or absence of an

abnormality in RTO through the trip information in Table 1 represents a visualization method for simultaneously expressing related operations because the presence or absence of an abnormality by different operation modules is considered.



Figure 7. Visualization of multi-channel data points.

Figure 8 shows the visualization method of registering the abnormal alarm pattern required when determining the stop, alarm, and continuous operation of the RTO according to the various abnormal signs shown in Figure 7. Here, an example of a change when the RTO burner temperature increases is shown.



Figure 8. The visualization method.

Figure 9 shows that sensor data from nine channels build a sensor database on a server. The right shows the database to be observed.



Figure 9. Sensor database on a server

The data obtained from the sensor are data generated by physical sensors such as temperature, flow rate, and pressure of the RTO. By combining them, the concept of virtual sensors is applied to software calculate new indicator values such as the status of RTO emissions. As real-time data collection of field operations becomes possible, various artificial intelligence machine learning techniques can be applied to preserve the system's prediction. A prediction algorithm may be applied using the acquired data. Table 2 shows the configuration diagram of the monitoring operation program [8, 9].

TABLE 2. CONFIGURATION OF THE MONITORING SERVICE

Description	Observation Information management	Sensor measurement management
Status	Measure risk	Data analysis Tools
Analysis	Setting	Information management
Facility Management	Equipment management	Customization
Setting	Customizable	

Figure 10 shows the visualization of temperature, gas and pressure and humidity.



Figure 10. View of temperature, gas and pressure and humidity

After the RTO reaches a stable operating state, the test results obtained by continuously measuring for 30 minutes were as shown in Table 3. Here, the nitrogen oxide is an actual value not corrected by the standard oxygen concentration.

TABLE 3. TEST RESULTS

Sortation	Unit	Inlet	Outlet
Total hydrocarbon	ppm	6,221.27	155.55
nitrogen oxide	ppm	-	2.49
Exhaust gas temperature	℃	-	70.13

IV. CONCLUSIONS

In this study, an Edge-IoT architecture (Architecture) for collecting and determining real-time state information for remote maintenance of heat storage combustion arsenic acid devices (RTOs) was presented and visualization methods were implemented. The Edge-IoT architecture system interfaces with the PLC that controls RTO operation monitoring and transmits real-time data to a remote server, and the channel data received through IoT is analyzed to establish a database and visualize the characteristics of the RTO device. Dataset collection was performed three times per second to collect real-time data from a remote server. In the case of high-speed data at the Edge and Smart Sensor Corps, it was configured to enable remote transmission of the result after signal processing, which reduced the load on the Edge-IoT side and the Cloud side network, which enabled efficient operation of the system.

ACKNOWLEDGMENT

This study is a knowledge service industry technology development project supported by the Korea Evaluation Institute of Industrial Technology (KEIT), Ministry of Trade, Industry and Energy (No. 20023721). This study was jointly conducted by the Industry-Academic Collaboration Group.

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