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Opportunities and Challenges of Online Monitoring Systems for Sodium Leak Detection with Internet of Things

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1. Introduction

In recent years, Internet of Things (IoT) has attracted a large amount of research interest due to the remarkable development of Information Communication Technologies (ICT) [1,2]. The IoT allows users to integrate the communication network into various things such as sensors, actuators blend with the environment around us and new services and applications, such as a smart power grid [3], smart building energy management [4], and connected vehicles [5] etc., are enabled by sharing a lot of information.

One of the promising application domains of IoT is online monitoring system for leak detection. From a small size thermal-hydraulic experimental facility to huge size pipeline networks (gas, oil, steam, and water etc.), leakage might occur during its lifetime and it is significant to detect such leakage. Especially, leak detection and corrective action are indispensable to Sodium-cooled Fast Reactor (SFR) or sodium thermal-hydraulic test facility using sodium as a coolant, since accurate leak detection is necessary to guarantee safe operation of the systems.

In this paper we have focused on design issues considering integration of IoT into online monitoring system for sodium leak detection. This paper is organized as follows. In Section 2, some preliminaries about IoT and leak detection systems are provided. Issues on online monitoring systems with IoT are provided in Section 3 and the conclusion is given in Section 4.

2. Preliminaries

2.1 Internet of Things (IoT)

Internet of Things (IoT) is a novel paradigm which connects humans, computers, and things each other. Sensors deployed everywhere convert physical data into digital signals and transmits them to its control center in the cloud through sensor networks. The signals are converted into meaningful information in the control center by additional analysis and the information could be shared through internet as shown in Fig 1. By this way a variety of things or objects such as sensors, actuators, and mobile phones, etc. interact with each other and cooperate with their neighbors to reach common goals. Also, environmental changes can be remotely monitored from any part of the world via internet.

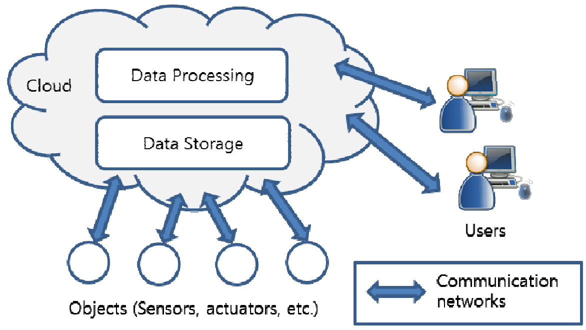

Fig. 1. A general model of Internet of Things (IoT)

Sensor networks for data acquisition and transmission could be configured by wired or wireless communication. Although wireless sensor network is more preferable to wired sensor network due to its scalability and flexibility, available power and resource for each node for sensing and communication consisting of sensor networks should be considered.

2.2 Overview of Sodium Leak Detection Techniques

Since sodium has good electrical conductivity, wire type leak detector has been widely used [6]. The wire type leak detector consists of metallic wire insulated with ceramic beads, which is equipped on the surface of the pipe or vessel. Any sodium leaks bridges the small gap between the wire and the pipe surface and grounds the signal, and thus sodium leaks can be detected. Spark plug type leak detector which has an electrode making a short circuit when sodium leaks has been also used for detecting accumulated sodium at a place such as bellows sealed valves [7].

Various ionization type detectors have been used for detecting sodium aerosol. Sodium Ionization Detector (SID) detects ionization current from ionized sodium by filament with high power supply [8]. In Laser Resonance Ionization Mass Spectrometry (RIMS) technique, time-of-flight mass spectrometer detects ionized sodium atoms by laser irradiation [9].

Furthermore, Distributed Temperature Sensor (DTS) using optical fiber also has been developed for leak detection based on Raman scattering, Rayleigh scattering, or Brillouin scattering. Since environmental changes affect backscattered signals, temperature variation at leak point can be obtained by relative optical phase difference and enables leak detection [10].

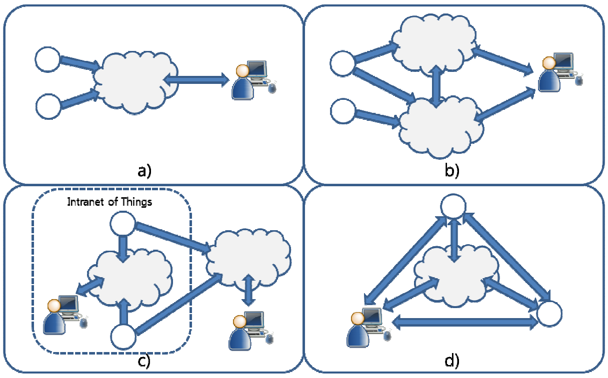

Fig. 2. Approaches in IoT-based online monitoring systems; a) Centralized IoT based approach, b) Collaborative IoT based approach, c) Connected intranet of things based approach, d) Distributed IoT based approach

3. Issues for Online Monitoring Systems for Sodium Leak Detection with IoT

3.1 Applicability of IoT into Online Monitoring Systems for Sodium Leak Detection

IoT-based online monitoring system regarding its approach characteristics can be classified into four categories as shown in Fig. 2. The system consists of sensor nodes, control center nodes, and user nodes. In the centralized IoT approach, all the data from sensor node is retrieved by a single control center and information from data processing in it can be provided to users. In the collaborative IoT approach, there are several control centers which can exchange information each other and thus new or valuable information could be obtained. In the connected intranets of things approach, intranet of things can process local information and provide it to control center. Thus, remote users as well as local users can access to information, however the information mainly flows from intranets to control center. In the distributed IoT approach, all the nodes are able to retrieve, process, and provide information to other node even if it does not pass through control center.

Online monitoring system for sodium leak detection consists of a lot of sensors. Data from these sensors is retrieved to control center through sensor network. Information obtained from data processing in the control center could be monitored by remote users as well as local users. Also, security issues should be considered for designing the online monitoring system. Thus, among the previously mentioned IoT-based approaches, the connected intranet of things based approach could be more appropriate solution for online monitoring system for sodium leak detection as shown in Fig. 3. Previously mentioned sensors such as wire type leak detector, sodium ionization detector, and distributed temperature sensor with optical fiber can be used in online monitoring system for sodium leak

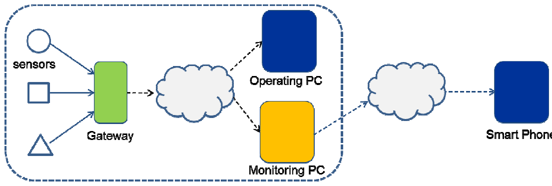

Fig. 3. Connected intranet of things based online monitoring systems

detection. Since there are a lot of sensing points for leak detection, communication network could be wired or wireless sensor network according to type of sensors. Data storage and processing can be operated in the intranet and furthermore, condition monitoring and diagnosis can be remotely operated via the internet as in [11] if security issues have been resolved.

3.2 Challenging issues of Online Monitoring Systems for Sodium Leak Detection with IoT

There are various challenging issues of IoT based online monitoring systems for sodium leak detection. First, appropriate selection or development of sensors which is compatible with IoT environment is required since the existing sensors for sodium leak detection could be inappropriate for IoT based system configuration. Second, finding scalable security solutions for integrating IoT into online monitoring systems with a lot of multiple sensors since the IoT environment has some security issues itself [1], and there is a tradeoff between security and availability. Third, fault tolerance is required for stable operation of the systems. Thus, Fault Detection and Isolation (FDI) [12] of sensors or other things should be considered to obtain reliable data or operation. Furthermore, sensor fusion [13] finding optimum fusion rule from multiple heterogeneous sensors for decision to improve accuracy of sodium leak detection is one of challenging issues.

4. Conclusions

In this paper, we have provided the design issues considering integration of Internet of Things (IoT) into online monitoring system for sodium leak detection. Some preliminaries about IoT and sodium leak detection systems are provided. Also, applicability of IoT into online monitoring systems for sodium leak detection and some challenging issues are provided. Although the paper has focused on design issues and concepts for online monitoring system for sodium leak detection, we believe that it would be meaningful to develop newly improved systems as a next stage.

ACKNOWLEDGEMENT

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