Development of IoT-Based Sensor Tag for Smart Factory

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***Abstract*— To reduce the rate of defective products and ensure the health of employees, it has become increasingly necessary to improve air quality in factories. To do so, it is important to accurately determine the air quality in the factory first. However, currently available industry-grade sensors require complex and often separate construction processes, making them difficult to use in complicated industrial sites. In order to solve such an issue, this study developed an IoT-based sensor that can collect data such as factory temperature, humidity, CO2 levels, dust, and stench. This study has also developed software to manage the IoT-based sensors, which can transmit the data via RF communication. Sensor tags were tested for basic environmental durability, including waterproof, dustproof, and vibration standards. The sensors can be connected via USB to a computer to configure its settings and access the stored data within the sensors. Unlike other existing environmental sensors, these can be easily installed anywhere as they transmit data via wireless communication. These sensors can also be installed in the factory to check the factory's internal pollution level in real time. The application of this sensor will enable the real-time monitoring of air pollution in factories. By locating the polluted areas accurately, it will be possible to exercise distributed control over ventilation devices to prevent further spread of pollutants, while also pushing out the polluted air to maintain an optimal working environment. Future studies should develop a simulation model for determining the ideal installation location for the sensors. There also needs to be further studies in developing a distributed-controlled air-conditioning system to run empirical tests.**

***Index Terms*—IoT, Sensor Tag, Smart Factory, Air-Conditioning System, Distributed control**

I. INTRODUCTION

Recently, there have been various studies on realizing smart factories. In addition, there has been an increasing need for an automated ventilation system that can minimize and remove pollutants to reduce the rate of defective products and ensure the health of factory workers [1]. However, most less-profitable factories rely on natural ventilation to dilute and remove their pollutants. This can spread the pollutant from its origin to the rest of the factory.

To prevent this from happening, it is necessary that Internet of Things (IoT)-based sensors be installed on the expected points of origin. It is also necessary for polluted air to be forcibly extracted out of the factory, and at the same time minimize its spread throughout [2]. At this time, distributed control of only the ventilation system nearest to the origin will help reduce power consumption and prevent the possible spread of pollutants in all the ventilation devices at once.

However, currently available sensors are too large and require additional construction for power supply and data transfer.

This study developed an IoT-based sensor tag that runs on batteries and uses wireless communication to transmit the collected data. This sensor tag can be easily attached to expected origins of pollutants to monitor the real-time occurrence of pollutants. In addition, precisely determining the origin of pollutants by using the IoT-based sensor tag developed through this study will enable the development of an air-conditioning system capable of distributed control and minimizing the spread of pollutants in the factory.

II. IOT-BASED SENSOR TAG

The IoT-based sensor tag developed through this study is an upgraded version of the sensor tag used to monitor the inside of refrigerated containers [3]. The tags are designed to run on batteries and detect temperature and humidity.

The tag uses UART(Universal Asynchronous Receiver/ Transmitter) interface so that it can link with other sensors for

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CO_2, dust, and stench, and assess the air quality in the factory. The three LED lamps provide a visible indication of the sensor tag's state of operation. The USB port allows access to the sensor tag's configurations and internal log management. The tag sends the data it collected via RF communication to a remote gateway. The tag sends the data it collected via RF communication to a remote gateway. A program for managing the sensor tags was also developed to enable users to conveniently utilize the IoT-based sensor tags.

As depicted in Figure 1, the IoT-based sensor tag uses a Cotex-M3-based MCU. To store the collected data, the tag uses a 2Mb EEPROM. The tag is powered by lithium-ion batteries.

If it detects the air quality every 10 min, it can last up to 100 days on a single charge. The battery can also be recharged by connecting to an external adapter. The RF antenna was developed as an "intenna," which is located within the sensor tag.

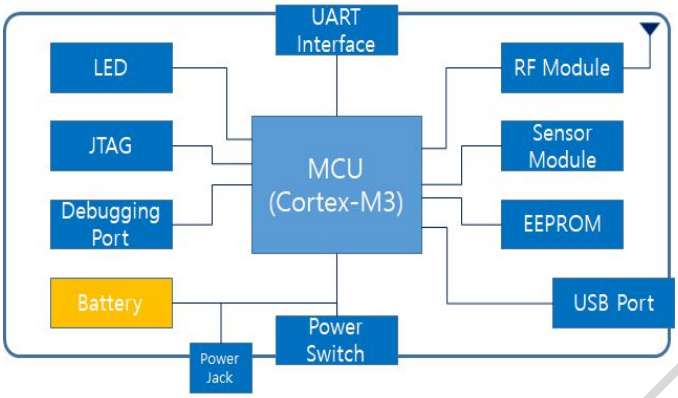


Fig. 1. Block diagram of IoT-based sensor tag

Figure 2 shows a prototype of the IoT-based sensor tag. The sensor tag is encased in an ABS(Acrylonitrile Butadiene Styrene)shell designed to withstand impact. There is also a fastening clip behind the tag to facilitate installation.



Fig. 2. IoT-based sensor tag

To secure the environmental reliability of the tags, they were tested at the Busan Techno-park to see if they met the water and dust resistance, as well as vibration standards in Table 1.

Table I: Environment Reliability Test Standards

Category	Testing Standards (Reference Documentation)
Water resistance	- Device: Vibration pipe - Number of nozzle openings: 12 each - Vibration angle: 180° on each side, vertically - Vibration interval: 12 s/cycle (2 ×360 °) - Total discharge: 0.84 L/min ± 5% - Testing time: 10 min **(IEC 60529 (IP ×4))**
Dust resistance	- Test dust: Talcum powder (IEC 60529), 2 kg - Testing time: 8 hr **(IEC 60529 (IP ×5))**
Vibration	- Shortened vibration test - Frequency (Hz): 10–150 - Acceleration/amplitude: 9.8 m/s² (1 G) - Sweep rate: 1 oct/min - Duration: 20 cycles **(KS C 0240)**

As a result, the prototype passed the test for the IP45 water and dust resistance rating to ensure its environmental reliability for use in factories.

Figure 3 depicts the software architecture of the IoT-based sensor tag. The sensor tag software is based on ucOS. Its key modules are the app module, device module, and framework module. The app module uses the API provided by the lower-level modules of the program to conduct the actual operation sequences of the sensor tag. The device module lies between the framework module and the app module. It includes drivers for the MCU, memory, sensor, and RF module. The framework module includes the libraries for the ucOS and MCU.

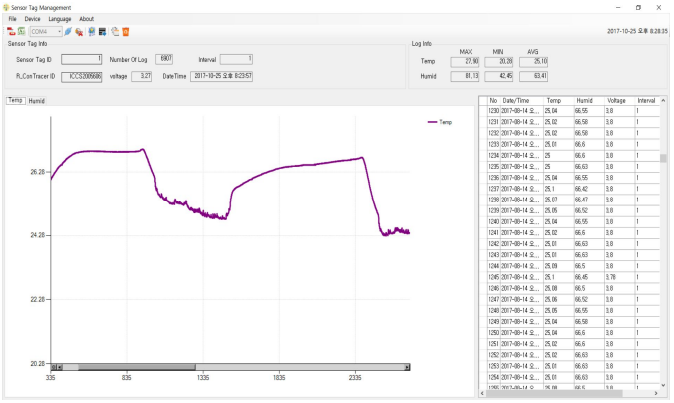


Fig. 3. IoT-based sensor tag management program

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The sensor tag works by following these steps: When the sensors are powered on, ① all modules except for the EEPROM of the sensor tag are initialized. This is when calibration occurs for the sensors to detect temperature, humidity, CO2, dust, and stench. ② As the main process of the sensor tags is run, data on temperature, humidity, CO2, dust, and stench levels are collected through the UART. ③ When environmental data are collected, they are sent to a remote location via RF communication. Up to three attempts are made to send the data via RF communication, and the results are saved in the internal memory of the sensor tag. ④ The data and RF transmission results are saved in the internal memory. The tags are put on low-power mode until the next sensing cycle.

As steps ①–④ are repeated, the USB port detects a connection with a computer, and the tag enters a separate configuration process to allow for internal log management and activation settings.

A program has also been developed to manage the sensor tag, as shown in Figure 4.

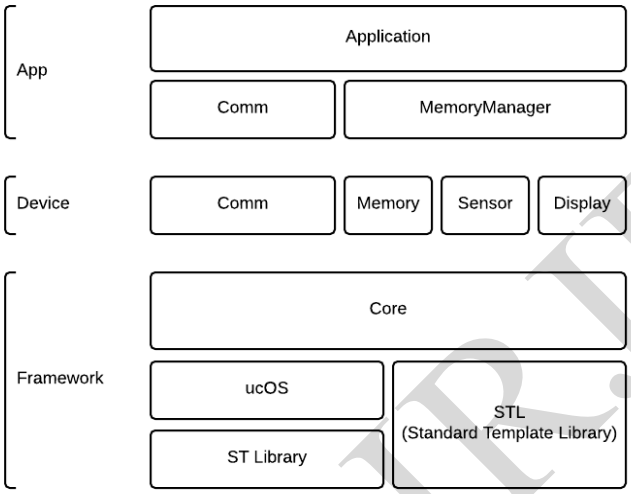


Fig. 4. IoT-based Sensor Tag S/W block diagram

Connecting a USB cable to the USB port of the sensor tag results in the sensor tag management software automatically detecting the tag and approaching the internal memory of the tag through a simple connection setting. Once the sensor tag is linked with the sensor tag management program, the time of the sensor tag is automatically updated to that used by the computer running the sensor tag management program. Such program has four functions.

First, the program approaches the sensor tag memory to provide the current configuration information of the sensor tag to the user including the TagID, Gateway ID where the data would be sent, number of internal logs, data collection interval, and internal time of the sensor tag. Second, the program automatically calculates and returns the maximum, minimum, and mean values stored in the internal log of the tag. The program also plots the log data onto a graph and allows the user to designate specific sections for a magnified view of the data in those portions. Third, the program converts the data log of the tag into an Excel spreadsheet. This allows for the easy digital management of the internal environment monitoring data of the factory. Lastly, you can change the setting of the sensor tag through the setting menu of the sensor tag setting program as shown in Figure 5. The program can configure the ID, Gateway ID, and data collection intervals of the sensor tag.

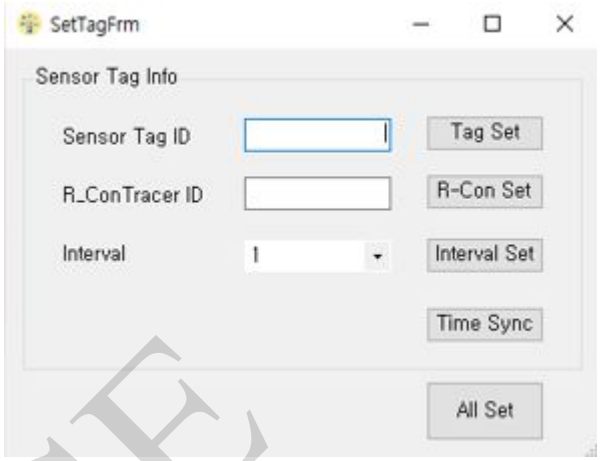


Fig. 5. Sensor Tag setting menu

III. CONCLUSION

This study developed and introduced an IoT-based sensor tag and a management software program for checking air pollution in factories. The sensor tag introduced here can detect temperature and humidity by default. If needed, it can also be extended with other sensors to detect CO_2 levels, stench, and particulate matter. The sensor tag management software allows users to check the configuration of the tag and easily manage the internal log. Using this sensor tag will provide real-time monitoring of pollutants and their locations, and therefore enable the distributed control of ventilation systems in the factory. Such distributed control could minimize the spread and at the same time remove the pollutants. This is expected to reduce the rate of defective products and ensure a healthy working environment for the employees.

In addition, the data can be sent wirelessly via RF communication, which facilitates the installation and recovery of the sensor tags. This makes it possible to install this system temporarily to diagnose the internal environment of a factory prior to designing a more permanent and optimized ventilation system.

Further studies should focus on developing simulation models that can predict the optimal locations for installing the IoT-based sensor tags introduced herein. This model should then be applied to ventilation devices under distributed control to design and certify smart ventilation systems optimized for various factory environments.

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