

Air Pollution Measurement Platform Based on LoRa and Blockchain for Industrial IoT Applications

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Abstract. Air pollution poses risks such as global warming and ecosystem changes. Contaminants such as harmful gas, particulate matter and residual material generated in factories are the main causes of air pollution. Therefore, there is a need for strict control of contaminants occurring in the factory. In this paper, we propose a new platform using the Internet of Things (IoT) and blockchain to monitor the air quality without restriction of space. The proposed platform provides a service that collects data in real-time through the IoT sensor device based on LoRa (Long Range) based on the contaminant generated in the factory and transmits the encrypted data to the cloud through the transaction technology of the blockchain. Using this platform, air pollution generated in factories can be managed in real-time and data integrity can be preserved. Through this study, it is possible to measure and monitor contaminants generated in the air and use them as important data to improve and overcome environmental problems caused by air pollution.

Keywords: Air pollution · IoT · Blockchain · LoRa · Cloud computing

1 Introduction

Technological development and industrialization are leading to risks such as global warming and ecosystem changes. Air pollution is a contaminant exposed to air such as harmful gas, particulate matter, and residual material. In particular, contaminant generated in factories is a major cause of air pollution. Global warming is caused by contaminants such as carbon dioxide (CO_2), methane, ozone (O_3), and nitrogen dioxide (NO_2) reflecting and absorbing solar radiation, which increases the average surface temperature of the earth over a long period of time, which causes temperature rise and sea level rise, ocean acidification, hydrological cycle changes, etc. According to the World Health Organization's (WHO) 2014 report, air pollution is the leading cause of death worldwide. Particulate matter refers to a small substance of less than PM2.5 in air, which penetrates into the human lungs and circulatory system and is very harmful to the human body. Exposure to particulate matter can cause cardiovascular disease, lung disease, respiratory disease and various cancers [1].

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According to the Organization for Economic Cooperation and Development (OECD), the Republic of Korea's partition matter level is serious, which is three times the average of 38 countries, and the early death rate from air pollution is expected to increase by about three times in 50 years. Looking at the seasonal changes in domestic air pollution, the concentration of sulphur dioxide (SO_2), nitrogen dioxide (NO_2), and carbon monoxide (CO) in winter is high due to the increase in heating fuel consumption in winter. Particularly, particulate matter appears to be high in spring due to eolian dust. In addition, in China, smog occurs frequently in the winter when the amount of coal dependence is increased by about 70%, and this is a phenomenon in which air pollution concentration increases due to flying to the Republic of Korea in the west or northwest wind. The government of the Republic of Korea measures and manages the air pollution level at each industrial site through government agencies considering the seriousness of the contents. One of the methods is a measurement test through an external organ, and because the tester judges the measurement result, it causes side effects such as measurement timing, inaccuracy, deterioration, and manipulation. Due to this, it is difficult to obtain accurate inspection results, which makes it difficult to manage air pollution.

Therefore, in this paper, we propose a new platform using the Internet of Things (IoT) and blockchain to monitor the air quality without restriction of space. The proposed platform provides a service that collects contaminant generated in the factory in real-time through a LoRa (Long Range)-based IoT sensor device and transmits encrypted data to the cloud through the transaction technology of the blockchain. Using this platform, air pollution generated in factories can be managed in real-time and data integrity can be preserved. LoRa IoT network, an IoT-only network, is a low power wide area (LPWA) technology that helps objects communicate with each other and improves data processing efficiency and maintains data integrity through blockchain encryption technology and message distribution transmission protocol. It provides a sharing function, cloud provides various services such as Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS). LoRa IoT network provides differentiated network service suitable to meet various requirements in fusibility and expandability of IoT sensor.

The composition of this paper is as follows: Sect. 2 describes the relevant research. Section 3 introduces the designed architecture of the proposed IoT platform, and Sect. 4 conducts experiments on the proposed platform. Finally, Sect. 5 presents conclusions and future research directions.

2 Related Work

Air pollution through technology development and industrialization is causing serious environmental pollution worldwide [2]. Changes in the ecosystem due to global warming cause problems such as climate change, disasters, and various diseases, and the economic loss caused by these increases significantly each year [3]. In particular, particulate matter can penetrate human respiratory organs and circulatory systems and cause various diseases [4]. The contaminant is standardized according to the concentration in air. There are several methods to measure air quality, and IoT is very effective

in measuring contaminant and concentration in air. IoT is growing as the most representative technology in industry 4.0 by connecting objects and providing data for interaction [5]. IoT provides a high level of extendability and flexibility by enabling communication between different objects [6]. The study of [7] proposes a system supporting IoT protocol for data collection and analysis. The study of [8] ensured stability by integrating a universal IoT framework for real-time analysis of IoT data in an uncontrolled environment. The study of [9] studied blockchain-based industrial IoT cyber physical system (CPS) to protect data collected from IoT. In addition, the study of [10] proposed four methods to enhance the security of the IoT sensor device, and the study of [11] presented the IoT blockchain platform for data integrity. Air pollution is measured through IoT sensor and collected data is transmitted to local server and cloud. Cloud is being used for network support for IoT technology [12]. IoT-based cloud big-data storage system is studied [13]. The next section introduces the designed architecture of the proposed IoT platform.

3 Air Pollution Measurement Platform

We present an air pollution measurement platform using IoT sensor device, LoRa wireless network, and blockchain. The proposed platform implements an optimized IoT network based on the LoRa wireless network, uses blockchain technology to transmit the integrity of the collected data, and transmits it to the cloud to provide air pollution measurement service and visualization. This section introduces the four components necessary for platform configuration. The architecture of the air pollution measurement platform is shown in Fig. 1.

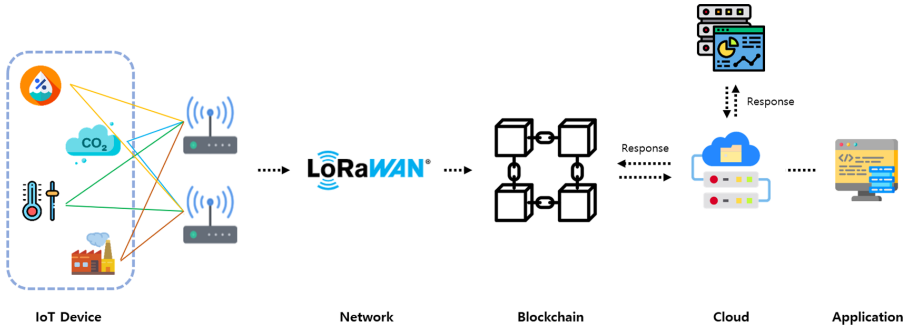

Fig. 1. Architecture of the air pollution measurement platform.

3.1 IoT Architecture

IoT is a device that can sense, store and transmit data over the Internet without human intervention. Data can be collected from the inside or outside of objects, locations and people. IoT realizes the integration of various manufacturing devices with sense, identification, process, and communication functions. First, data is collected through

sensors and actuators, and then connected to a network that can be delivered to an IoT gateway. It then consists of an IoT data system that can convert the collected low data into digital signals, filter and pre-process it for analysis. The third layer is a Fog or Edge device responsible for data processing and data analysis, and this layer is where visualization and AI technology can be applied. Finally, it is transmitted to the cloud to store, manage, and analyze data. Figure 2 shows described in detail as four layers of the IoT architecture.

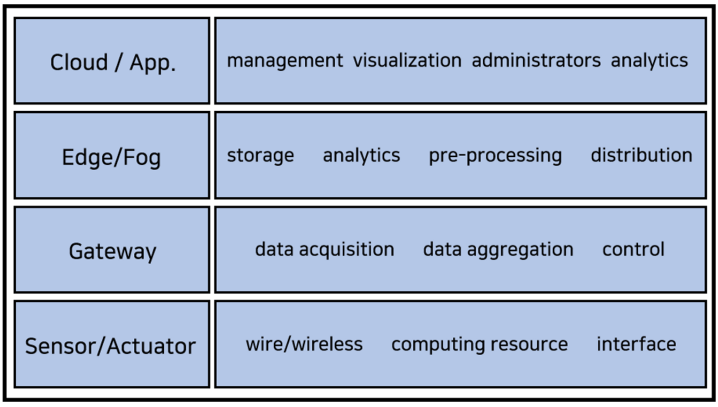

Fig. 2. Four layers of IoT architecture.

3.2 LoRa Network

LoRa network, an IoT-only network, is a LPWA network that helps objects communicate with each other. Unlike a network that requires hypervelocity, broadband network equipment and communicates over 10 km with minimal power consumption, there is no need for a separate base station or repeater equipment. By applying the chip directly to the IoT device, data can be exchanged, and the infrastructure construction cost is lower than LTE or 5G, and it has high extendability. Because of these features, it is used as an IoT-only network and provides network services that meet various requirements such as availability, extendability, and security. With the LoRa network, the power consumption is low, allowing the device battery life to last for years. The LoRa technology standard implements IoT with low data transmission speed and machine-to-machine wireless communication with a battery that lasts more than 10 years in the range of up to 10 miles. Figure 3 is the structure of LoRa network.

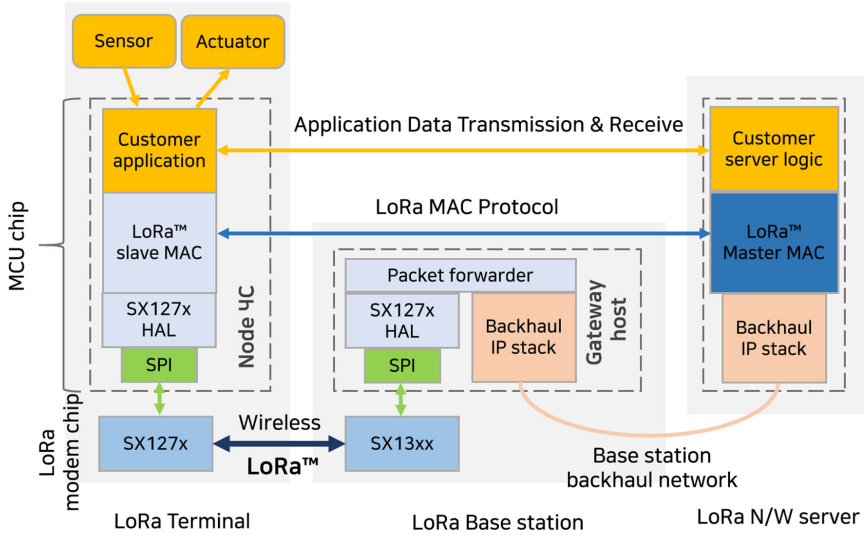

Fig. 3. Architecture of LoRa network

3.3 Blockchain Technology

The blockchain technology securely preserves the data collected through the IoT sensor and transmits it to the manager. Blockchain is a new technology that integrates decentralization, encryption, time stamp, and consensus algorithm, and provides functions of sustainability, compatibility, and extendability. The data collected through the IoT sensor consists of a distributed structure that is recorded in each block and stored as a private blockchain. In addition, it is possible to guarantee the integrity of data by granting authority to access a node to a specific party and directly comparing and verifying the data of distributed stored nodes. Figure 4 is the service function of the blockchain provided by the proposed platform.

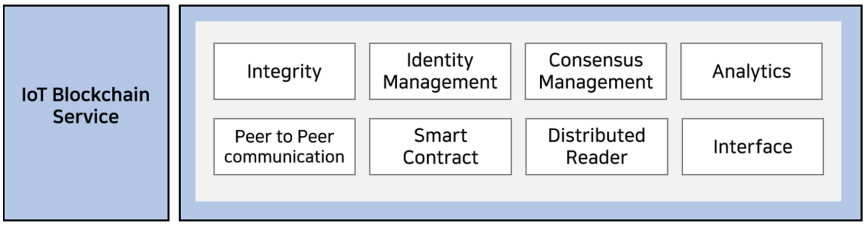

Fig. 4. IoT blockchain service

IoT blockchain service provides various services such as integrity, identity management, consensus management, analytics, peer-to-peer communication, smart contract, distributed leader, and interface. The distributed ledger is a consensus of

replicated, shared, and synchronized digital data that spread across the whole blockchain network, where all participants with the network can have their own selfsame copy of the ledger. It also provides a secure storage space for recording data collected through IoT sensors. Any changes to the ledger are reflected in all copies in real-time. The leader is either authorized or not authorized, regardless of whether a specific person can execute the peer to verify the transaction. Through big-data analysis, blockchain provides efficient services for data storage.

3.4 Cloud Computing

Application utilizes the encrypted data through the blockchain to use the application program suitable for the purpose. Application is composed of storage device and analysis tool. Services include data analysis and extended storage. Cloud can process and analyze big-data that Edge system cannot support. If furnished with proper user application solutions, the cloud can provide business intelligence and presentation options that help humans interact with the system, control and monitor it and make informed decisions on the basis of reports, data viewed in real time. These features allow users to control and manage the system through mobile and web applications. Data transmitted through the application layer at the industrial site can be monitored by personnel in remote management and supervisory institutions.

4 Experiments

In this paper, an experiment was conducted to measure and monitor the air pollution condition to verify the proposed platform. In this experiment, Particulate Matter (PM 2.5), Ozone (O_3), Nitrogen Dioxide (NO_2), and Carbon Monoxide (CO) data were collected and the description of each gas is shown in Table 1.

Table 1. Introduction and description of detection gas.

Detection gas	Unit	Standard (avg.)	Measurement method
Particulate matter (PM 2.5)	$\mu g/m^3$	0–35 (24 h)	β-ray absorption method
Ozone (O_3)	ppm	0–0.090 (1 h)	U.V photometric method
Nitrogen dioxide (NO_2)	ppm	0–0.1 (1 h)	Chemiluminescent method
Carbon monoxide (CO)	ppm	0–9 (8 h)	Non-dispersive infrared method

The sensor data collected through the IoT sensor collection board is stored on the blockchain network via the LoRa network, encrypted and transmitted to Application & Cloud. Data sent to the cloud detects air pollution and abnormal data. IoT sensor collection board is easy to collect data in the field and is advantageous for single task execution. The power supply voltage of the IoT sensor collection board used in the experiment is 5 V, the maximum current consumption is 40 mA, and the general purpose input/output (GPIO) is 20. Figure 5 shows the IoT sensor collection board.

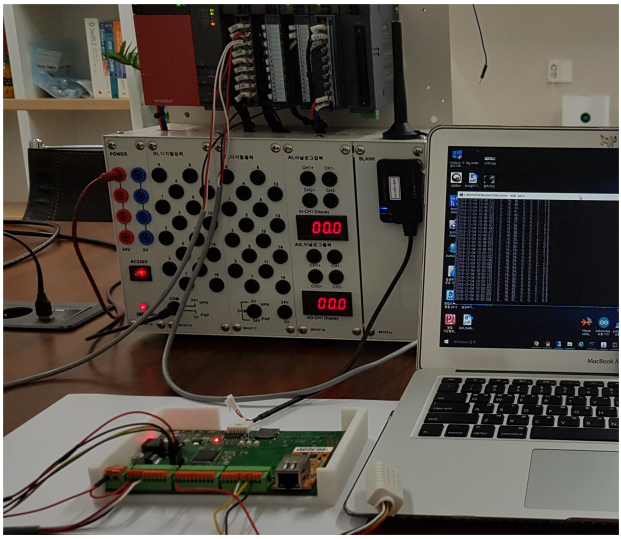

Fig. 5. IoT sensor collection board

Data collected through the sensor board is connected to the network through the LoRa module. When the network is established, data is transmitted to the Luniverse blockchain Platform. Encrypt the data by applying the measured data to the blockchain. Create a DApp and store the measured data in the DApp. Then, apply the created DApp to the side chain and connect it with the main chain. When a transaction occurs, it is compensated with a cryptocurrency created by itself. Lastly, the encrypted data is transmitted to the Amazon Web Services (AWS) cloud, and the data analysis and visualization application is performed. The aforementioned four gases are the result of the measurement in Seoul from March 1 to 10, 2020 and are as follows.

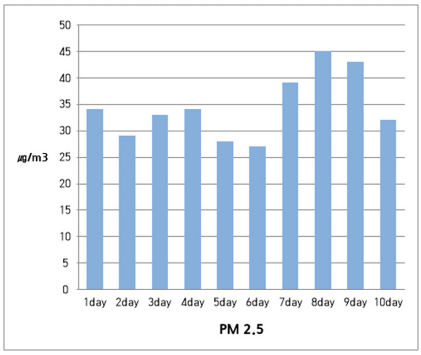

Fig. 6. Concentration of PM 2.5 measured over 10 days

Figure 6 is the result for Particulate Matter (PM 2.5). The normal standard of PM 2.5 is 0–35 μg/m^3 on average for 24 h and 25 μg/m^3 on average for 10 days. However, the values on the 8th and 9th days were measured higher than the normal standard.

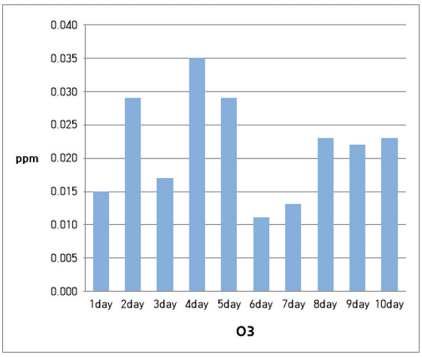

Fig. 7. Concentration of O_3 measured over 10 days

Figure 7 is the result for Ozone (O_3). The normal standard of O_3 is 0–0.090 ppm for 1 h average and 0.025 ppm for 10 days average. However, the values for days 2, 4, and 5 were relatively high, and days 6 and 7 were relatively low.

Figure 8 is the result for Nitrogen Dioxide (NO_2). The normal standard for NO_2 is 0 to 0.1 ppm for an hour, and 0.029 ppm for 1 h average of 10 days. The values on days 2, 4, and 5 were relatively low. I guess this has to do with the weather.

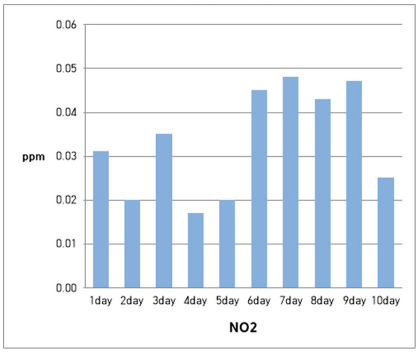

Fig. 8. Concentration of NO_2 measured over 10 days

Figure 9 is the result for Carbon Monoxide (CO). The normal standard of CO is 0–9 ppm for 8 h, and 0.518 ppm for 10 days. Most of the gas was in the normal range. The measurement results may differ depending on the season and location, and different results may be obtained depending on the measurement method.

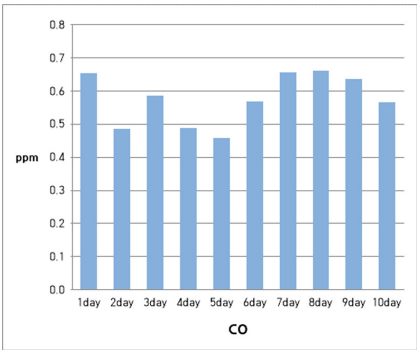

Fig. 9. Concentration of CO measured over 10 days

5 Conclusion

Contaminants such as harmful gas, particulate matter and residual material generated in factories are the main causes of air pollution. We deviated from the traditional measurement methods mentioned above and utilized IoT for strict control and management of data. We proposed a new platform using Internet of Things (IoT) and Blockchain and provides services to collect data in real time through IoT sensor devices based on LoRa (Long Range) and transmit encrypted data to the cloud through the Blockchain's transaction technology. It is expected that this study will contribute slightly to overcoming environmental problems caused by air pollution. Future research will monitor the runoff and concentration of chemical substances in the factory based on the proposed platform, and will study an intelligent air cleaning system that can be ventilated automatically when a failure indication occurs. In the future, we will continue to conduct various research activities in this field to collect, process, and analyze various data through IoT in smart factory.

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