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산악 관리를 위한 지오펜싱 기술을 이용한 IoT 응용 구현

Implementation of IoT Application using Geofencing Technology for Mountain Management

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[요 약]

최근 우리나라에서는 지진, 산불, 태풍, 홍수, 산사태 등의 자연재해가 빈번하게 발생하고 있다. 산불의 경우 10년 평균, 발생빈도, 피해면적, 피해금액은 2021년 기준으로 감소했지만, 2022년 3월 4일부터 13일까지 9일간 경북 울진과 강원 삼척 일대에서 발생했다. 산불은 삼림 2만ha를 불태우고 213시간 43분 만에 진화를 완료해 산림청이 관련 통계를 작성한 1986년 이후 '최장기 산불' 기록을 남겼다. 피해 규모도 커지고 있다. 본 논문에서는 Geofencing 기술을 적용한 LoRa 기반의 센서 네트워크 구축을 통해, 저렴한 비용으로 효율적인 센서 네트워크 구축이 가능함을 확인하였으며 산불 등의 재해 관리에 대한 실효성 검증을 하였다. GPS와 자이로센서, 연소탐지 센서를 통해 변화량을 감지하고, 정확한 Geofencing Cell의 유효성 크기를 정의하였다. Node와 Node, Node와 Server사이의 효율적인 데이터 통신을 위해 LoRa Payload Frame Structure를 센서정보의 크기에 맞게 유동적 크기를 갖도록 설계하여 제안하였다.

[Abstract]

In this paper, we confirmed that an efficient sensor network can be established at a low cost by applying Geofencing technology to a LoRa-based sensor network and verified its effectiveness in disaster management such as forest fires. We detected changes through GPS, gyro sensors, and combustion detection sensors, and defined the validity size of the Geofencing cell accurately. We proposed a LoRa Payload Frame Structure that has a flexible size according to the size of the sensor information.

색인어 : 지오펜싱, 사물인터넷, 로라망, 센서네트워크, 산불관리시스템

Key word : Geofencing, IoT, LoRaWAN, Mountain Managements, Sensor Network.

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Ⅰ.Introduction

In recent years, irregular natural disasters such as earthquakes, wildfires, typhoons, floods, and landslides have occurred in South Korea. For instance, although the frequency, damage area, and damage costs of wildfires have decreased based on a ten-year average as of 2021, a large-scale wildfire that broke out for nine days from March 4 to 13, 2022, in Uljin, Gyeongsangbuk-do [7], and Samcheok, Gangwon-do, burned over 20,000 hectares of forest and was extinguished only after 213 hours and 43 minutes, setting a record as the "longest-lasting forest fire" since 1986, when the Korea Forest Service began compiling related statistics. Meanwhile, the frequency, damage area, and human and economic losses caused by landslides have been increasing over the past six years [6]. Therefore, This paper try to prevent forest disasters through information technology through Geofencing.

Table 1. Forest Fire Status for 10 years[6].

Division	Number of Case	Area [ha]
2012	394	144
2013	592	1,104
2014	984	274
2015	1,246	836
2016	782	755
2017	1,384	2,959
2018	992	1,788
2019	1,306	6,511
2020	1,240	5,840
2021	698	1,528
10 years Average	962	2,174

Ⅱ. Methods

2-1 Geofencing Technology

Ulrich Braeth and Axe Kupper, among others, announced in January 2011 in their paper titled "Geofencing and Background Tracking - The Next Features in LBS" that the first generation of LBS technology was established between 2000 and 2007[1]. At that time, the Wireless Application Protocol (WAP) was used, but the technology was not able to guarantee the accuracy of GPS on devices. Therefore, the network-centric access approach was used for positioning the existing cellular network infrastructure and was advocated for that purpose [2].

They identified the second generation of LBS as the period from 2007 to the present day, during which the technology has advanced significantly, allowing for more sophisticated applications and a wider range of PoI services. This includes various navigation applications, mobile marketing, and social communities. Popular social media platforms like Facebook and Kakao Story have also incorporated GPS-based LBS services, allowing users to share their location and receive related services in the surrounding area.

Based on this, the research aims to explore the potential of geofencing services based on GPS technology for comprehensive forest disaster management and prevention [1].

2-2 H/W Design for Geofencing Node

Using Or-CAD, a circuit was designed with LoRa ESP32 as the MPU, which is a 32-bit processing unit with relatively high performance compared to the initial model. The MPU-9250/6500 model was selected as the Gyro Sensor. For satellite positioning, the 6MV2 GPS receiver was used, and data was input through pin 13 using the MQ-2 sensor for wildfire detection [3], [4].

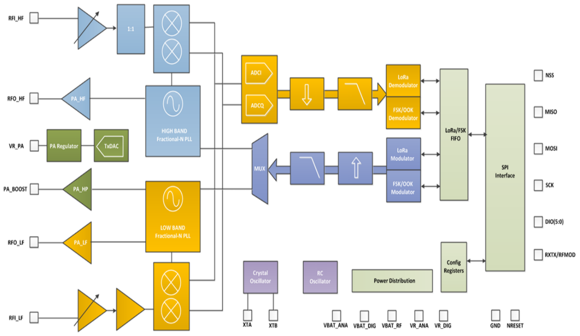

Fig. 1. Block Diagram for ESP32[3].

Since the ESP32 board does not provide software serial, it was a bit tricky to select the port, and Rx and Tx were transmitted and received through pins 15 and 16, respectively. Note that the GPS has opposite transmission and reception aspects between the chip and the board, so caution must be exercised. The DHT-11 was used to acquire environmental information on temperature and humidity, and wiring was done using pin 12. The internal I2C Pinout number uses SDA allocated to pin 4 and SCL to pin 15, which is connected to the OLED. However, when using the same I2C for the Gyro-Sensor, speed and stability must be carefully considered. Therefore, as the board provides two I2C, SDA and SCL were wired to pins 21 and 22, respectively.

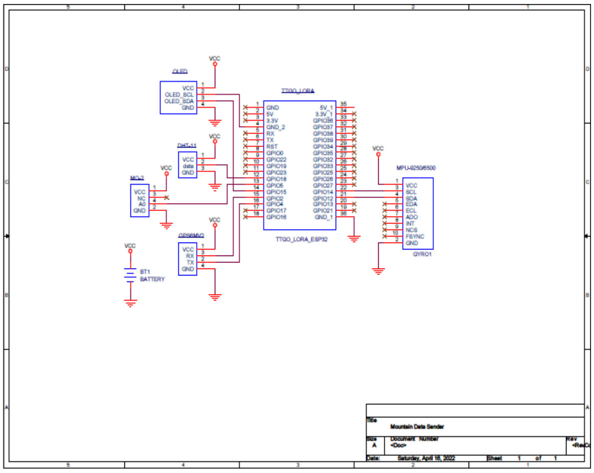

Fig. 2. Circuit design for Geofencing node.

The designed circuit was manufactured as a PCB (Printed Circuit Board). Initially, only the LoRa network was considered, so the GPS, temperature, humidity, and gas sensors were not taken into account. After PCB fabrication, the design was modified to add the GPS module, temperature and humidity sensors, and gas sensor. The GPS module uses Vcc, GND, Rx, Tx ports, so a 4-pin space was allocated for additional connections, and the Rx, Tx data ports were wired through pins 15 and 16. The gas sensor uses only 3 pins for Vcc, GND, and data port, which can be A0 or D0. Therefore, it was connected to pin 13 [5].

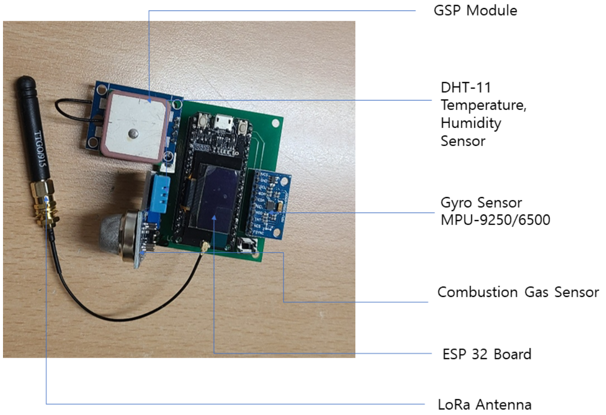

Fig. 3. Diagram of Geofencing node.

2-3 Proposed LoRa Packet Payload Design

After powering on, the process was followed during operation. Various sensor devices were loaded with libraries. Due to the characteristics of embedded systems, there is limited memory available, so the related libraries were modified to demonstrate maximum functional effects with minimal memory. For example, among GPS libraries that support the Arduino compatible embedded product line, most only support the Serial port, and even libraries specified for ESP-32 are based on the Serial port, so there were very few libraries that could be used properly. Therefore, the library was modified for the Hardware Port, and the EEPROM read and write parts were applied to the source code by referring to the developer forum. Also, when all libraries were actually uploaded, there was a conflict between OLED and MPU-9250/6500 in the I2C section, so each was tested as a module and problems were resolved one by one through a step-by-step process. Based on the library that supports the 6-axis + 3-axis, a total of 9-axis and temperature sensor of the MPU-9250, other devices were added one by one and operated.

It was not possible to process it like the initial model in a sequential manner like the Arduino Nano, so it was divided into sub-modules and processed. Since the loading time of each sensor is different, the priority was rearranged by reorganizing the order of the devices that need to be loaded first to try to match them as much as possible from the user's perspective so that they are output almost simultaneously on the sensor screen. First, basic wire and OLED related libraries were uploaded, and then LoRa and Gyro were loaded in order, but since detailed settings of the Gyro are required in the Setup part, the initialization part of LoRa was completed by outputting it to OLED, and the order of entering the loop was established. In the loop, local variables were declared for each device, and some were redefined to match the functions based on matching the global variables defined earlier so that the progress of each process can be monitored through Serial output. After the settings of each individual device were completed, the results defined in the functions were made into LoRa packet frames in the form of strings so that they could be sent to the receiving end. Each node was given an ID to indicate the location of each node and distinguish between them.

In the early version of the Proposed model, when the data of each sensor data is received and interpreted by the receiver, the size of n-byte is specified as the size of the data field to be classified in order, but the GPS data is sometimes noisy. As a result, a congestion of data may occur, and an error occurred due to the phenomenon of overflowing the data field. Therefore, in order to prevent this, a frame structure with variable length was used to distinguish each sensor data based on special characters as separators. In addition, the receiving unit classifies each sensor data based on each special character, receives the data, redefines it as a new variable, and receives the variable as a post or get when parsing in the web server and parses it as HTML within the tablet. It was processed so that the variable designation was passed on to be processed [5].

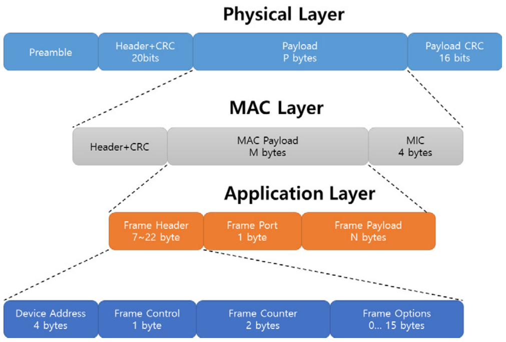

Fig. 4. LoRa Packet Structure.

The frame structure is designed as shown in Figure 5 so that fields can be added when additional sensor information is needed in preparation for future system expansion.

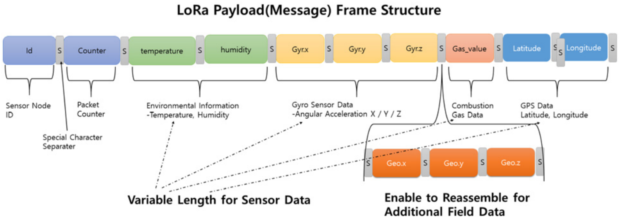

Fig. 5. Proposed LoRa Payload Frame Structure.

Ⅲ. Results

3-1 System validation for simulated wildfires

The purpose of this system verification experiment is to validate the effectiveness of wildfire detection and to determine the distance setting for sensor node placement for Geo-Fencing. A experiment was conducted to transmit 3-axis angular momentum information of MPU-9250 gyro sensor data to the receiver using the initial model. The nodes could only be classified by their ID, and there was no location information available, which meant that the initial setup had to be very accurate when installing the nodes in a field. To address this issue, a GPS module was added to the final model to improve the location accuracy.

Fig. 6. Node Device.

Figure 6. shows the initial booting after installing the sensor node device on the mountain.

The effective range of the sensor node for fire detection was confirmed to be 30 m in the verification experiment. Although there was no problem with the measurement up to 35 m, considering the sensitivity to fire depending on the diffusion rate of gas and the wind direction, it was concluded that maintaining the sensor[5].

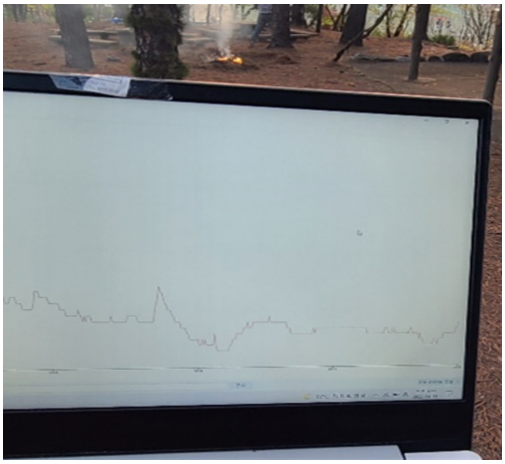

Fig. 7. Receiving geofencing node data in real time through the LoRa Sensor Network.

Figure 7. shows the state of the nature of the combustion experiment, measuring the concentration of combustion gases in real time.

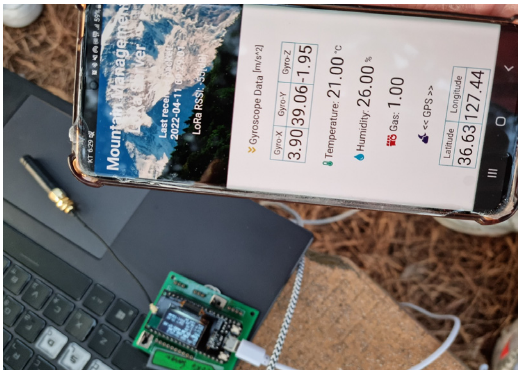

Fig. 8. Monitoring using LoRa Sensor Network through the app.

As a result of the combustion experiment, when the direction of the wind changes, a rapid change in the combustion gas concentration was detected, and through this, the gas combustion reference value could be set. A value of 97.5 or higher could be set as a reference value for determining whether or not to burn. Figure. 9 shows the result. Figure.10 shows the result of determining the effective radius of the sensor node of 30m.

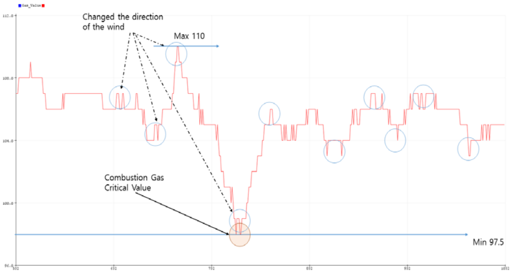

Fig. 9. Fire Detection Threshold Analysis.

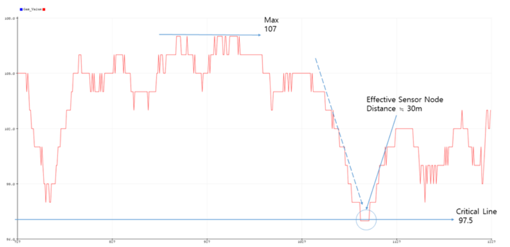

Fig. 10. The Maximum and Minimum values of the data at the 35 m point and the valid range of the sensor node.

Ⅳ. Conclusion

For real-time monitoring using a mobile device, a small web server through SPIFFS was built in and manufactured. Through this, it is possible to conveniently access and monitor the server anytime, anywhere, and it is programmed that a notification is sent to the administrator when a value above the set value is detected by setting a threshold value. When using this sensor node, the effective measurement area per node is approximately 706.85 m^2, and through this, the number of nodes for the sensor network per 1[ha] is 14.14, and when the price per node is converted to approximately $90, the price is within $1,300. It is economical because it can be installed at a cost. In the future, if solar power is used for LoRa sensor network devices, it is judged that more economical and efficient energy management will be possible. The effective range of a single sensor node is currently the widest using LoRa technology. Therefore, it is hoped that it will be actively utilized to contribute to the prevention of forest fires and landslides.

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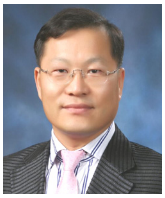

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