Development of environmental monitoring systems based on LoRa with cloud integration for rural area

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Abstract. Wireless Sensor Network (WSN) is widely used in field environmental monitoring recently, because of its ease of use and being able to simplify the complexity installation in real application. Indonesia is an agricultural country with more than 16.5 million of farming land, most of the farming land is located in a rural area. The problems on the implementation of IoT-based environmental monitoring system in a rural area is the limited signal and energy. Accordingly, the objective of this study was to develop an Environmental Monitoring System based on LoRa in a rural area with the implementation of the Local Management Subsystem (LMS) and Global Management Subsystem (GMS) framework to optimize the existing development of the Environmental Monitoring System with focused on optimum distance by measuring the RSSI, signal strength and packet loss. The research was conducted in Bulaksumur Universitas Gadjah Mada, Yogyakarta, with four zones and various obstacles. As the result, Zone D with line of sight was the best result for getting the affordable distance for data transmission. This Zone can reach over 800 m distance with only 20% packet loss.

1. Introduction

The environmental monitoring system based on IoT is a necessity in modern agriculture recently. The use of IoT in the Environmental Monitoring System is very helpful in observing and analyzing the conditions of plants and the environment which will be a reference for farmers in caring their plants to improve the quality and quantity of agricultural products. One of the important things in developing an environmental monitoring system is data transmission and data management. The popular environmental monitoring system at the moment is Wireless Sensor Network (WSN) because its performance and easy to use in sensing and transferring data. There are various types of WSN in term of connection type that has been developed recently, some of them are Radiofrequency, GSM, Zigbee, and Wi-Fi [1-2]. However, most of them still have some disadvantages in certain conditions such as large power usage, transmission data distance and signal limitations (blank spot). Indonesia is an agricultural country with more than 24 million hectares of land consisting of plantation land and rice fields [3]. The majority of the land is in the rural area which sometimes has difficult signals and also limited energy.
According to the previous challenges, it is necessary to develop a new system which is able to work in rural areas on signal limitations and energy savings. LoRa is a technology that is capable of transmitting long-distance data using energy-efficient radio frequency so that it is very good when applied to rural areas. The use of LoRa for sensor data acquisition in agricultural environment monitoring can be applied system peer to peer connection that is sensor node and gateway for storing data [4]. However, management data are needed to improve performance and minimize data loss. The Local Management Subsystem (LMS) Framework for Environmental Monitoring System, and the web data providing and management system as the Global Management Subsystem (GMS) to establish a simple and flexible remote environmental monitoring and control based on a cloud platform can maintain the sustainability of environmental monitoring under an unstable network connection [5, 7, 8, 9, 10].

The objective of this study was to develop an Environmental Monitoring System based on LoRa in a rural area with the implementation of the Local Management Subsystem (LMS) and Global Management Subsystem (GMS) framework to optimize the existing development of the Environmental Monitoring System with focused on Received Signal Strength Indicator (RSSI), signal strength and packet loss.

2. Material and Method
This research was conducted at the Smart Agriculture Research Group, Laboratory of Energy and Agricultural Machinery, Faculty of Agricultural Technology, Universitas Gadjah Mada. This research was following two steps, the design of the system and performance evaluation. The design consists of planning, assembling and programming the device. The programming software used in this study is Arduino IDE 1.8.7. The performance evaluation of the system was conducted in Bulaksumur, Universitas Gadjah Mada, Yogyakarta with various distance, obstacle, and landscape.

2.1. System Design
The system consists of an integrated Sensing Node, Gateway and Cloud Server which uses two connections for transmitting data, that is LoRa connection and internet connection as can be seen in Figure 1. LoRa connection was selected as peer to peer communication between the sender and gateway node which is suitable to be applied in rural areas with limited signal or Blank Spot Area (A place without GSM signal for Internet communication).

Figure 1. System design of environmental monitoring system
2.1.1. Sensing Node (Sender). This node is functioning as a sensor reading and the sender for transmitting data to the gateway. The devices consist of temperature & humidity sensors (DHT22), solar radiation sensors (TSL2561), TTGO LoRa32 V2 as a sender. The Sensors will sense data and transferring to the LoRa Gateway using LoRa Connection with 915 MHz Radio Frequency. The Deep Sleep feature is embedded in this system. After sending data, sensing node has been going to sleep for a while, and wake up afterward. Deep Sleep can reduce power consumption and making device saving energy. The schematic design of the sender can be seen in Figure 2, and the flowchart diagram of a sensing node can be seen in Figure 3.

![Figure 2. Schematic design of sensing node and gateway](image)

![Figure 3. Flowchart diagram of LoRa Sender (a) and LoRa Gateway (b).](image)
2.1.2. Gateway System. In this node, the data received from the sender node will be read and forward to the cloud server. This node will check the Internet connection, if the connection is unavailable then the data will be saved locally, so the data will not lose. After that, the data will be sent again to the cloud if the Internet is available. The device used in this node consists of time initiation (RTC DS3231), local data storage (SD Card module), and TTGO LoRa Receiver. The data are transmitted to the cloud using the "UGM Hotspot" with a Wi-Fi feature that is already in the TTGO LoRa32 Receiver. The flowchart diagram can be seen in Figure 3(b). Data received from the gateway will be stored to the cloud that can be monitored real-time and accessible based on the website. The data also can be downloaded with some format such as “.csv, .xlsx” with phpMyAdmin Database. In this study the server used is http://agrieye.tp.ugm.ac.id.

2.2. Performance Test
The system performance was tested in Bulaksumur Universitas Gadjah Mada. The performance testing method based on several parameters such as packet loss, distance, and RSSI (Received Signal Strength Indicator). The Signal strength is calculated from the RSSI value. The maximum value of RSSI of TTGO LoRa32 V2 is -139 dB. A higher value of RSSI is indicating that lower signal strength. The Signal Strength \((P_r)\) can be calculated using equation (1) as follow:

\[
\frac{\text{RSSI}}{\text{Max_RSSI}} \times 100\% \tag{1}
\]

Furthermore, in packet loss testing, will be calculated the percentage of data received by the server. The data will send 20 times with one-minute delivery period with variations in distance of 0 m, 200 m, 400 m, 600 m, 800 m, and 1000 m, and also including a variety of field condition (with obstacle and without obstacle) that classified into four different Zone. The results of these measurements are including the value of temperature and humidity, solar radiation, and also the value of RSSI. The RSSI value obtained will be mapped according to the strength of the signal.

3. Result and Discussion

3.1. Sensor measurement
There are three parameters to measure in this environmental monitoring system, that is temperature, humidity, and solar radiation. Figure 4 shows the example of measurement in environmental monitoring system at Bulaksumur UGM in 200 m distance. The Data is relatively stable because it has been done only 20 minutes of measurement. The temperature in Bulaksumur is between 31.8-32.6°C with humidity between 58.8-60% in a daylight condition, and the lux measurement is fluctuate depending on sunlight with ranged between 15500-17000 Lux.

3.2. Performance Test

3.2.1. RSSI Measurement. RSSI (Received Signal Strength Indicator) is the technology that used to measure signal strength which are received in wireless technology. This measurement of RSSI in mapping the distance and signal strength are also have limitations, because RSSI is susceptible to noise, multi-path fading and disturbance, so that is making the strength of the signal in the receiver are fluctuate [6]. Figure 6 shows the value of RSSI in various distances and condition. The maximum distance is in Zone D (Line of Sight - LOS) is 800 m reached. The Zone A & C can reach 400 m in the obstacle area (building and trees). The Zone B is only 200 m reached with average RSSI is -124dB. The obstacle in Zone B is Grha Sabha Pramana building with the width of the building is 57.5 m and high of the building is 39 m from the ground which blocking the communication of the sensing node and the gateway.
Figure 4. Chart of temperature & humidity (a), and solar radiation (b) measurement in 200 m

Figure 5. RSSI Maps testing TTGO LoRa32 V2 in Bulaksumur UGM

3.2.2. Signal Strength and Packet Loss. The value of signal strength is decreased over increasing of the distance and obstacles. As we can be seen in Figure 5, the percentage of signal strength is different from each other even at some distance. The maximum signal strength with 0 m distance is 74%, and the lowest value is 11% in the 200 m with an obstacle (Zone B). Packet loss is data missing from the
sender when the connection is unstable or disconnected. There are several causes that making packet loss occurs at LoRa connection, including distance, signal interference and also external factors such as environmental conditions. Figure 6 shows the packet loss in various Zones and distances.

The packet loss in Zone A is 40% in 400 m distance. Even in the Zone C has the same obstacle (building and trees), but in 400 m measurement does not have a packet loss, because of the condition is not same, the position of the building, high of trees is another factor that can make a different result. The higher packet loss in the Zone B 200 m distance with percentage 80%, and the smaller packet loss is 20% in the Zone D 800 m.

![Figure 6. Chart of signal strength & packet loss](image)

4. Conclusion and recommendation
In this paper, we have presented the development of the environmental monitoring system in rural areas based on LoRa and integrated into a cloud server. This system is divided into three subsystems that are sensing node, gateway, and cloud server. The system has successfully transferring data temperature, humidity, and solar radiation from the sensing node to the gateway and forwarding to the cloud server with a Wi-Fi connection. This research classified signal strength mapping to the four zones with a various obstacle. The best scenario to optimize data transmission is Zone D (LOS). In this research, in LOS area can reach 800 m distance with only 20% packet loss. The obstacle (building and trees) can interfere the communication and reducing the performance of LoRa data transmission. This system is suitable when placed in a rural area with a blank spot condition. Integrating to the cloud is also easy to monitor real-time and accessible for the farmer to monitor the field condition. For the future works will try to use the dedicated LoRa Gateway device to cover a lot of LoRa sensing nodes, and its installation in a higher position, so the data can receive easily.

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