Prototype weather station uses LoRa wireless connectivity infrastructure

Eko Murdyantoro\textsuperscript{1,2}, Ridlo Setiawan\textsuperscript{1}, Imron Rosyadi\textsuperscript{1}, Azis WW Nugraha\textsuperscript{1}, Hesti Susilawati\textsuperscript{1}, Yogi Ramadhani\textsuperscript{1}
\textsuperscript{1}Electrical Engineering Department, Universitas Jenderal Soedirman, Indonesia

E-mail: \textsuperscript{2}eko.atmojo@unsoed.ac.id

Abstract. This study develops a prototype of a weather station with LoRa wireless infrastructure. LoRa is a wireless connectivity technology supporting the internet of things (IoT) system. This technology is an alternative to other wireless connectivity modules that have already been popular such as GSM modules, Wifi Modules and Bluetooth (BLE). The use of the LoRa network serves to increase the range of wireless cells that can reach distances of up to 5 kilometers while still having low power consumption. One LoRa network cell can connect end devices to hundreds of nodes. Weather parameters measured include temperature, humidity, air pressure, rain detection, and wind speed. The prototype consists of Arduino UNO, DHT11 sensor, raindrop sensor, anemometer sensor, BMP180 sensor, LoRa shield, LoRa Gateway, and ThingSpeak web application. While the number of end device nodes built is 3 nodes in one cell. As a result, the system can function properly. This system has the potential to be implemented in urban and rural areas with various types of sensors connected. Between cells can be managed to form a Low Power-Wide Area Network as a wider sensor network.

1. Introduction
Weather is related to the conditions of temperature, humidity and wind in a place for a certain period. The weather is generally always changing. Sometimes there is a dry season, rain, until snowfalls. The weather is generally influenced by three elements namely the sun, water, and wind. Sunlight produces energy that can control the water cycle. The wind carries clouds that contain water vapor moving towards places with lower air pressure. The air and clouds shrink to become heavier and fall to the ground so that it rains. Weather conditions are very influential in human activity so it is very necessary to measure weather conditions in real-time. The weather data will be used for weather prediction and agricultural planning, health, tourism, and so on.

In the process of weather observation, a set of instruments is needed to be placed in a certain location to represent the environmental conditions of the surrounding area. A weather station is a set of tools used to observe conditions or changes in weather, climate, and atmosphere in an area and record it in the form of data. After being recorded, the data is stored in a data logger and subsequently to be studied by users or researchers. An automatic weather station is an instrument that measures and records meteorological parameters using sensors. This sensor serves as a measuring tool to measure any changes in the weather. After the measurement data from the weather station is collected, the process can be carried out locally at the location of the weather station or the data can also be collected at the acquisition data center unit, which later the data collected is automatically forwarded to the data processing center and then processed as needed.
There have been many developments of IoT-based weather stations with GSM, Wifi, Bluetooth, Zigbee modules [1][2][3]. But there are still rarely studied in Indonesia that discusses the use of LoRa technology. LoRa is different from other technology modules such as GSM, Wifi, Bluetooth and Zigbee modules. In short, LoRa is a lower power than GSM / LTE modules and LoRa has a long range of up to 10km further than Wifi, Bluetooth and Zigbee [4][5].

This study develops a prototype of a weather station network with wireless LoRa infrastructure. Weather parameters measured include air temperature, air humidity, air pressure, rainfall and wind speed. The number of end-nodes in the prototype developed is two. But in practice later if needed it can be multiplied by dozens of end-nodes. End-nodes consisting of various sensors will be placed in an area within the reach of LoRa to process weather monitoring results in that area. Data obtained from these sensors will then be transmitted wirelessly through a LoRa gateway device connected to the cloud server.

2. Related Works

2.1. IoT Technology

The IoT system is a network with many nodes that form a Low-Power Local Area Network (LP-LAN) or Low-Power Wide Area Network (LP-WAN) for wider elements and areas. Called low power because the requirements needed in the IoT system are the machine to machine communication (M2M) which does not need to use high data rates. With sufficient data speed, bandwidth efficiency will be obtained so that it can support more node elements. On the other hand, the system protocols in the IoT technology module are simplified so that efficiency is obtained in the case of low power consumption requirements [6].

Communication between nodes in the IoT LP-LAN / WAN network is implemented with the use of low power wireless connectivity modules. Viewed from the wireless access media used, the wireless modules can be divided into 2 categories [7][8].

1) Modules with short reach, less than 100 m. Included in this category include:
   a. Proximity NFC (EMV), IrDA, with a very short distance of 0-10 m.
   b. RF modules for wireless personal area networks (WPAN) such as Zigbee, 6LOWWAN, Bluetooth LE, Z-Wave, ANT, WirelessHART.
   c. Low power Wi-Fi chips (IEEE 802.11) such as G2M5477, QCA4004, GS1011M, and ESP8266.

2) Modules with a range of far more than 100 m. These categories include LoRa, NB-IoT, Sigfox, and DASH7. LP-WAN networks with this remote reach module can be analogous to low power versions of cellular networks, with each cell can include up to thousands of node devices.

2.2. LoRa

LoRa, an acronym for the long-range, is a wireless connectivity technology module product primarily aimed at IoT systems. There are many claims of LoRa technology's superiority, as a wide area network solution that promises coverage range with very low power consumption and safer securities, with thousands of node devices that can be connected in a network making it very suitable for the Internet of Things.

LoRa operates in the open ISM spectrum, so that system designers can manage their networks. On the other hand, with LoRa it is possible to manage data rates to adjust sensitivity in a fixed bandwidth channel. The system designer can set the power and data speed that will determine the range, to optimize network performance in constant bandwidth. This is implemented by setting orthogonal spreading factors, data speed variables, and power.

The LoRa module belongs to the physical layer category but is easily configured with a higher layer. This makes LoRa can be integrated and interoperate with existing network architectures. This
technology can minimize interference so that network efficiency increases. The specifications are below [8].

a. LoRa supports OOK, FSK modulation schemes, and new LoRa modulation modulations. If the modulation scheme used is changed, the format of the data packet also changes.
b. The working frequency can be selected at 109 MHz, 433 MHz, 868 MHz, or 915 MHz.
c. The range can reach 10 km (with the optimum power and antenna system).
d. Its main advantage is that the demodulation process is possible with noise levels of less than 20dB.
e. The capacity of one LoRa gateway can support up to thousands of nodes.
f. Power consumption is very low, so the battery lasts more than 10 years.

2.3. LoRa Shield and LoRa Gateway LG01-S

LoRa Shield is a remote transceiver on the Arduino board and has an open-source library that allows users to send data and reach very long ranges on low data. The LoRa shield is shown in Figure 1. LoRa LG01-S is LoRa gateway which is open source. This tool can bridge LoRa wireless networks to WiFi, Ethernet, 3G, or 4G-based IP networks. LG01-S runs on embedded Linux systems that are open source. The LoRa gateway is shown in Figure 2.

![Figure 1. LoRa Shield](image1)

![Figure 2. LoRa Gateway](image2)

2.4. Weather Station Sensor

2.4.1. Rain Detector Sensor. Rain detector is a component that has a working principle that can detect and determine a certain magnitude. Rain detector sensor is made by utilizing the conductivity of rainwater so that if the part is exposed to rain water, the sensor will be active.

2.4.2. Sensor DHT11. DHT11 is a temperature and humidity sensor. The data sent by the DHT11 sensor to the controller is 40 data bits in which, the first 16 data bits are binary humidity data, the next 16 bits are temperature binary data, and the last 8 data bits are the result of the sum of temperature and humidity values.

2.4.3. Sensor BMP180. BMP180 is a sensor that functions to read the compressive value of the surrounding air.

2.4.4. Anemometer. Anemometer consists of three cups connected to the arm mounted on the drive shaft. The cup shaft is mounted with a one-degree dish as a speed reading counter. Anemometer needs to be calibrated first. The initial step that needs to be done is to find the revolution per minute value of the sensor using the equation (1).

\[ RPM = \frac{(\text{Count}) \times 60}{\left(\frac{n}{1000}\right)} \]  

(1)

with:

- \( RPM \) = Revolution per minutes
- \( \text{Count} \) = Counter value in one reading
- \( n \) = Number of gaps in the disk.
Next is to find the value of the wind speed using the equation (2).

\[
Speed (m/s) = \frac{2\pi r \times RPM}{1000} \tag{2}
\]

with:
- \(RPM\) = value of revolution per minutes,
- \(\pi\) = 3.14 and
- \(r\) = Long disc radius (cm).

To obtain the reading value in kilometers per hour scale can use the equation (3).

\[
Speed (km/hour) = \frac{Speed (m/s) \times 3600}{1000} \tag{3}
\]

3. Methods

The study was conducted at the Unsoed Electrical Engineering Laboratory, Jalan Mayjend Sungkono KM. 5 Blater, Kalimahah District, Purbalingga Regency, Central Java. The equipment needed is a laptop, Arduino software (IDE), Proteus software, ThingSpeak web, multimeter, thermometer, hygrometer, barometer and digital anemometer. LoRa gateway LG01 915 MHz, LoRa shield 915 MHz, Arduino UNO Rev3, power bank, anemometer sensor, rain drop, DHT11, BMP180 jumper cables, PCB boards and USB connectors. System architecture shown on Figure 3.

![Figure 3. System Architecture.](image)

The LoRa shield section acts as a node that functions to send data to the LoRa gateway. In this study, the LoRa shield is used with a working frequency of 915 MHz. LoRa gateway will be used by type LG01-S with a working frequency of 915 MHz. The implementation phase is carried out by realizing the design of tools including designing Arduino UNO and LoRa shield as LoRa node, designing LoRa gateway, designing sensors and LoRa nodes, and the process of uploading data to ThingSpeak cloud server. This stage adjusts ThingSpeak’s source code and configuration so that it can display the data from the sensor correctly.

4. Results

4.1. End-Node Implementations

The weather station’s end-node hardware consists of sensors, Arduino Uno and LoRa Shield. Anemometer sensor has 3 legs that are connected to GND, VCC (5V) and A1 on the LoRa shield. The raindrop sensor has 3 legs connected to pins A2, GND, and V5V on the LoRa shield. DHT11 has 3 legs connected to pins A0, GND and VCC (5V) on the LoRa shield. Pin A0 must be pulled up by adding a resistor of ± 5KΩ mounted parallel between the VCC and A0 pins. BMP180 has 4 legs
connected to GND, VCC (5V) A4, and A5 pins on the LoRa shield. The prototype of the LoRa 1 and 2 weather stations are shown in Figure 4.

![Weather station end-node hardware.](image)

**Figure 4.** Weather station end-node hardware.

4.2. Konfigurasi LoRa Gateway

The LG01-S LoRa Gateway device supports various network modes such as WAN Internet Port Mode, WiFi Client Mode, WiFi AP Mode, Mesh WiFi Mode, USB Dial-Up Mode, and USB Ethernet Mode. In this study, the device is configured as a WiFi Client Mode. Setting parameter use TxPower 13, spreading factor 9, and coding rate 8.

4.3. IoT Server Configuration

To use the ThingSpeak server, it needs to create an account on ThingSpeak. Then configure the channel that is used. For the LoRa gateway to communicate with channels on ThingSpeak, API Keys and API methods are required. API Keys and API call methods can be seen on the API Keys page on ThingSpeak as shown in Figure 5.

![API Keys and ChannelID ThingSpeak](image)

**Figure 5.** API Keys and ChannelID ThingSpeak

4.4. Testing the LoRa Weather Station System

The sensor readings displayed on the Arduino IDE serial monitor are shown in Figure 6 and Figure 7.
Figure 6. Monitoring node 1 reading

Figure 7. Monitoring node 2 reading

4.5. Testing Gateway System LoRa LG01-S

The reading results of each weather station are shown in Figure 8. If the LG01-S gateway has successfully sent data to the ThingSpeak IoT server that has been made before, then the reading data from each sensor will appear in the fields that have been available in the form curve or graph. The reading data of each sensor on the SpeakSpeak website is shown in Figure 9.

Figure 8. Monitoring gateway reading.
4.6. Testing Result of System Function

Based on Figure 6, Figure 7, Figure 8 and Figure 9, it can be seen that the reading of the values contained in the Arduino IDE serial monitor and the ThingSpeak web has the same value. These values are shown in Table 1.

| Parameter          | Node 1 Value | Node 2 Value | Gateway Value | ThingSpeak Value |
|--------------------|--------------|--------------|---------------|------------------|
| Temperature node 1 | 30           | 30           | 30            |                  |
| Humidity node 1    | 64           | 64           | 64            |                  |
| Temperature node 2 | 27           | 27           | 27            |                  |
| Humidity node 2    | 65           | 65           | 65            |                  |
| Raindrop           | 5            | 5            | 5             |                  |
| Anemometer         | 3            | 3            | 3             |                  |
| Air pressure       | 1012         | 1012         | 1012          |                  |

Based on Table 1, it can be seen that the system test has been successfully carried out because the data read on the node can be forwarded to the ThingSpeak web with the right value. The overall system test results are shown in Table 2.

| Pengujian          | Status   |
|--------------------|----------|
| Temperature function 1 | Succeed |
| Humidity function 1  | Succeed |
| Temperature function 2 | Succeed |
| Humidity function 2  | Succeed |
| Raindrop function    | Succeed |
| Anemometer function  | Succeed |
| Air pressure function | Succeed |
| Data transmitting    | Succeed |
| Multi node           | Succeed |

The study also tested sensor accuracy compared to other instruments. However, due to the limited scope in this article, the data is not written. However, if there are differences in the reading of the condition of air temperature, humidity, wind speed and air pressure between the LoRa weather station...
and other comparative instruments, it is generally caused by differences in the type and level of accuracy of the sensor.

5. Conclusions

Based on the results of the discussion it can be concluded as follows.

1. The prototype of a LoRa-based weather station consisting of a LoRa gateway and two functional nodes can function properly because the value read by the sensor can be displayed on the ThingSpeak interface precisely and accurately.

2. The use of the LoRa platform is an opportunity and alternative in designing sensor networks that require a large number of nodes in one cell and low consumption, LoRa-based systems can be implemented sensor networks with a wide cell radius with a greater number of nodes.

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