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Weather monitoring for local area based on Lora module using STM32 microcontroller

Rifaldo Saputra[1], Muldi Yuhendri[1], Riki Mukhaiyar[1], Fadhli Ranuharja[1]
[1]Department of Electrical Engineering, Faculty of Engineering, Universitas Negeri Padang, Padang, Indonesia

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ABSTRACT

The need for an efficient and reliable weather monitoring system in areas with limited communication infrastructure has led to the development of an Internet of Things (IoT)-based solution utilizing LoRa (Long Range) technology. This study presents the design and implementation of a local-area weather monitoring system using the STM32F103C8T6 microcontroller and the LoRa RA-02 communication module. The system monitors environmental parameters such as temperature, humidity, wind speed, and air pressure using various sensors including DHT-21, BMP280, A3114, and INA219. Sensor data is collected by the transmitter node and sent via LoRa to a receiver node equipped with an ESP32 microcontroller. The receiver processes the data and sends it to the Blynk IoT platform and Google Sheets for visualization and storage. Experimental results show reliable transmission over distances up to 530 meters in dense environments and 2 kilometers in open areas. The system demonstrated low power consumption, making it suitable for solar-powered applications. The proposed solution is practical, flexible, and cost-effective, providing valuable support for weather-dependent decision-making in remote locations..

Corresponding Author:

Rifaldo Saputra
Department of Electrical Engineering, Faculty of Engineering, Universitas Negeri Padang
Kampus UNP Pusat, Jl. Prof. Hamka, Air Tawar, Padang 25131, Indonesia
Email: rifaldo.s1704@gmail.com

1. INTRODUCTION

Weather is an occurrence of atmospheric phenomena caused by various factors such as temperature, air humidity, air pressure and wind speed. Changes in weather in a fast time span can have a significant impact on several sectors, such as agriculture, aviation transportation, and natural disaster management [1]-[3]. Climate change in Indonesia with an increase in average temperature of 0.03°C / year since 1981, as well as rising sea levels by 0.8 meters to 1.2 cm / year, changes in rainfall patterns with an increase and decrease in rainfall in various regions with changes up to ± 2,784 mm in the last 30 years [4]-[6]. For effective money weather monitoring using technologies such as Automatic Weather Station (AWS), useful for measuring and simultaneously collecting meteorological data to support weather monitoring and climate change, in agriculture to improve the efficiency of food production, aviation to maintain safety, and marine to support ship navigation and fisheries activities [7]-[9].

AWS technology in general has a dependency on the internet network to transmit sensor data to the receiver, this dependency is a drawback especially for areas where there is no internet network with inadequate infrastructure [10]-[12]. To anticipate obstacles in sending sensor data, the LoRa (Long Range) module technology which is categorized as LPWAN (Low Power Wide Area Network) is used [13]. LoRa is a wireless communication protocol specifically designed to support IoT (Internet of Think) devices that require low power and wide coverage because LoRa utilizes CSS (Chirp Spread Spectrum) modulation, enabling long distance data transmission with low latency and low power consumption [14]. LoRa has advantages such as power efficiency, transmission distance up to several kilometers that do not depend on internet networks that tend to be expensive and complicated maintenance [15]. The LoRa module-based weather monitor uses the STM32 BluePill microcontroller (STM32F103C8T6), because this microcontroller has advantages in terms of high performance, low power consumption and easy communication integrated with various types of sensors [16]. Using this system on weather monitors has a great opportunity to be implemented in various regions, especially areas with communication infrastructure constraints that do not have an internet network.

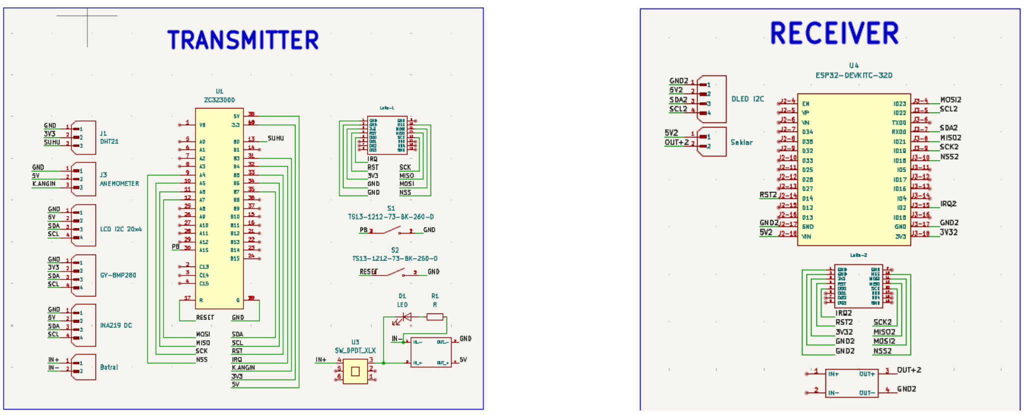
2. METHOD

In collecting data in this study, experiments were carried out experiments with several kinds, among others, 1) validation testing of the value of the sensor with measuring instruments, 2) testing the receiver, from receiving data from the validation of the sensor value with the measuring instrument, 2) testing the receiver tool, from receiving data from the transmitter, connection to the Blynk platform and Google Sheet, 3) testing the distance of the transmitter, Blynk platform connection and Google Sheet, 3) testing the distance of sending data packets with some conditions, the first condition is dense buildings, the second condition is dense buildings, and the third condition is dense buildings. distance of sending data packets with some conditions, the first condition is dense buildings and without obstructions, and 4) the distance of sending data packets to the transmitter. and without obstructions, and 4) overall testing with data retrieval experiments within a few hours. data retrieval within a few hours. In the design of weather monitors for local areas using 2 kinds of tools, the first tool as a data sender and the second tool as a receiver, which have their respective functions in the weather monitor. on the weather monitor. Transmitter as a data sender that is collected from the sensors are then sent using LoRa as the intermediary and receiver as a data receiver from the transmitter transmitter. For the design of the weather monitor weather monitor has 2 designs using Solidworks software as a 3D design, as shown in Figure 1.

(a) (b)

Figure 1. Design of data communication tools. a) transmitter, b) receiver

The hardware design of the electrical part uses KiCad software which aims to reduce the connection between components using cables which will result in the risk of a short circuit that can damage these components, in the hardware design of the weather monitoring tool in Figure 2.



(a) (b)

Figure 2. Circuit design, a) Transmitter, b) Receiver

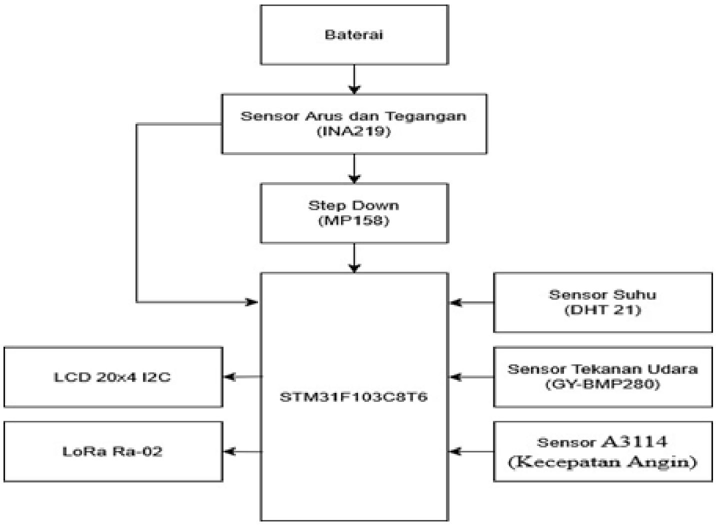


Figure 3. Block diagram of components in a trasnmitter

In the block diagram of the transmitter tool, as shown in Figure 3 indicate that the component scheme used in the transmitter tool as follows, 1) DHT-21 which functions as reading the temperature and humidity of the surrounding area, 2) GY-BMP280 which functions as measuring air pressure and temperature readings, 3) A3114 which functions to read the wind speed value using the principle of converting the propeller rotation into a digital signal value, 4) INA219 is a sensor that is useful for reading the voltage of the power source, current and power, 5) I2C 20x4 LCD serves as a display of sensor values that have been processed by the same microcontroller, 6) LoRa type Ra-02 as a component that functions to send sensor data to LPWAN-based receivers, 7) STM32 BluePill (STM32F103C8T6) functions to manage data from sensors, which are then processed until the data can be displayed on the LCD and send data via LoRa.

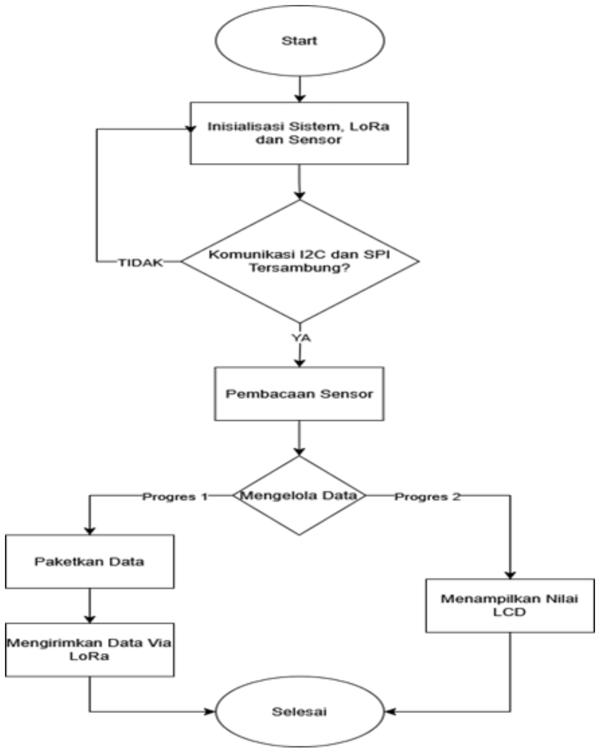


Figure 4. Flowchart of how to work on the transmitter

The Flowchart in Figure 4 shows how the transmitter tool works from the start until the sensor data is sent via LoRa. To the receiver. For the initialization of the system there are several sensors that have 2 states when the initial life or during the system runs, among others, sensor 1) GY-BMP280, 2) INA219 and 3) LoRa. At the beginning of life, the sensor must be connected to the microcontroller via I2C and SPI communication on LoRa, when one of the sensors and LoRa is not connected, the system will not run until the sensor is reconnected to the microcontroller and when the system is running one of the sensors or LoRa is disconnected from SPI communication, the system will stop. If the system is not problematic, the data obtained from the sensor will be processed by the STM32 microcontroller, and then the sensor data will be displayed on the LCD at the same time the data is sent via LoRa to the receiver. The system will repeat when the sensor value data every 10 seconds.

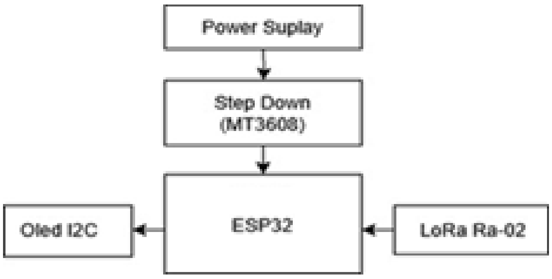


Figure 5. Block diagram of components in the receiver

Furthermore, the Receiver tool section as shown in Figure 5 is useful for receiving information such as sensor data from the transmitter, the receiver tool is not as complicated as the receiver where only a few components are used such as, 1) LoRa which is useful for receiving information sent by the transmitter, 2) Oled screen as displaying information that has been received from LoRa, 3) ESP32 is the main component that functions to manage and 3) MT3608 module functions as a safety and voltage drop that is flexible depending on usage.

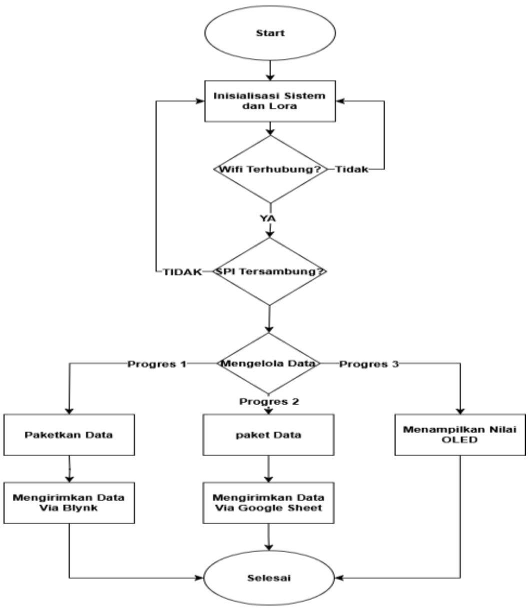


Figure 6. Flowchart of how to work on the receiver

The Flowchart of the receiver tool in Figure 6 shows that the system on the tool uses a WiFi connection which is useful for connecting to an internet connection, when the Wifi network is connected before managing the data it will see whether LoRa is connected to SPI communication with the microcontroller or not, if it is not connected then the system will initialize again until LoRa is connected to the microcontroller via SPI communication. When Wifi and LoRa are connected, the sensor data received from the transmitter will be processed by the esp32 microcontroller, after the data is processed in esp32 the system carries out 3 progresses at the same time which are useful for packaging sensor data to be sent to the Blynk server which is useful for displaying sensor values on the Dashboard which can be accessed anywhere and sending sensor data to google sheets which function to store sensor data, finally displaying sensor values on the Oled screen.

3. RESULTS AND DISCUSSION

Testing of weather monitors for the first time validates the sensor value using measuring instruments, for validation temperature values using a glass thermometer, for wind speed using an anemometer measuring device, for INA219 sensor values using a multimeter as a comparison between sensor and real values, humidity and pressure values using BMKG weather monitoring, for the results can be seen in the table below as follows.

Table 1. Validation of sensor values with measuring instruments

No.	Sensor	Measured Parameters	Measurement Result (Unit)	Testing Conditions
1	DHT-21	Temperature	33,2 ^{0}C	33 ^{0}C
		Humidity	74 %	69 %
2	BPM289	Air Pressure	1007,23 hPa	1012 mb
3	A3114	Wind Speed	3.6 m/s	3.6 m/s
4	INA219	Battery Voltage	12,48 V	12.48 V
		Battery Current	0,05 A	0.05 A

From the validation results for sensor values with measuring instruments obtained, some sensor values are not too far from the measurement results of the tools used for validation. Furthermore, testing the receiver tool is done with several experiments as described in Table 2.

Table 2. Testing the receiver

No.	Testing Aspects	Testing Results
1	Receiving LoRa Data to Receiver	Connected
2	Delivery to Blynk	Connected
3	Delivery to Google Sheets	Connected

From the receiver experiment, it is found that the tool works well seen from the data that can be received from the transmitter with the marked sensor value appearing on the OLED screen, then the data is entered in the Google sheet and in the Blynk dashboard. From the receiver experiment, it was continued with the experiment of the signal range emitted by the transmitter, in this experiment using an omni antenna with a gain strength of 5 dBi, the experiment of the range of data transmission from the transmitter was carried out in 2 kinds, namely, experiments in local areas of dense buildings and experiments without obstacles such as the beach. For the results of the experiment can be seen in the Table 3.

Table 3. Signal coverage distance experiment in dense building conditions

No.	Testing Distance	Signal Strength (dBm)	Connection Status
1.	0 km	-20	Connected
2.	530 km	-150	Connected

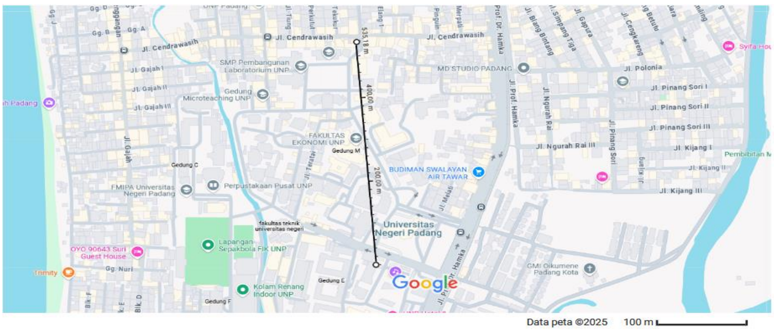


Figure 7. Lora signal coverage points in dense building conditions

From the experiment, the signal strength sent from the transmitter uses the RSSI (Received Signal Strength Indicator) method, which is a measure of how strong the signal received by the receiving device is. In experiments in dense building areas at close range, the RSSI value was found to be -20 or a strong signal, when giving a distance from the transmitter transmitter as far as 530 meters, the RSSI result was found to be -150 which is considered too weak a signal. The second experiment was carried out in an obstacle-free place that could interfere with the lora signal, for the results can be seen in the table below as follows.

Table 4. Signal coverage distance experiment in obstacle-free condition

No.	Testing Distance	Signal Strength (dBm)	Connection Status
1.	0 km	-20	Connected
2.	2 km	-150	Connected

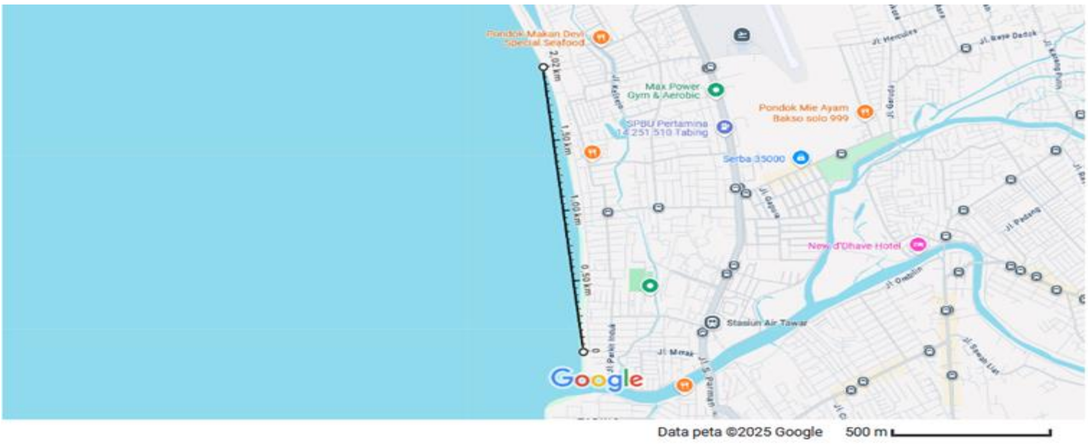


Figure 8. Lora signal coverage points under obstruction-free conditions

From the experiment in an unobstructed state, the data in the table above is found close to the transmitter found RSSi -20, when giving a distance from the transmitter found only 2 km with RSSI -120 with a signal lora too weak. Overall testing is carried out for 4 hours which is useful for seeing the overall performance of the tool and seeing the power consumption within an hour.

Table 5. Overall tool trial average value

time	Temperature (°C)	Humidity (%)	Wind Speed (m/s)	Air Pressure	Battery Voltage	Current (A)	Power (Wh)	RSSI (dBm)
15.00-16.00	31.14	75.17	1.77	1002.09	12.44	0.0508	0,633	-94.15
16.00-17.00	30.88	76.00	1.70	1007.17	12.34	0.0508	0,632	-94.72
17.00-18.00	30.43	75.14	0.87	1003.28	12.23	0.0500	0,632	-95.05
18.00-19.00	29.00	82.13	0.12	1008.58	12.10	0.0523	0,637	-94.75

In testing the entire weather monitoring tool from the transmitter and receiver which is taken as a data sample for 4 hours, the results in the table are obtained from the sensor value sent by the transmitter to the receiver every 10 seconds, and make the data every hour in Table 5.

4. CONCLUSION

From the results of experiments on weather monitoring tools using LoRa as an intermediary between the transmitter and receiver is effectively used to transmit sensor data without using the internet network or Wifi. In the use of power used by the transmitter as a signal transmitter is quite small with an average of 0.63 wh (Watt hour) in one hour which can effectively use its own power source, one of which uses solar panels. It can be concluded that the use of weather monitoring tools using LoRa both transmitter and receiver tools is very simple and practical by being designed to make it easier to use for various needs.

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