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Nawala Mangsa 2.0 – Weather Station with BLE Broadcaster

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Abstract

Nawala Mangsa is a weather station system owned by the Computer Science Faculty of Narotama University. The system has been installed in several locations and is used to monitor the temperature and relative humidity of the site for research purposes. All information from the remote, currently stored in the server online via an internet connection. In this latest version (ver-2.0), Nawala Mangsa had some updates, including the use of Raspberry Pi 3 boards, adding a sensor to measure sunlight illumination (TSL2561), and replacing temperature and humidity sensor with BME280 so it can also measure air pressure. The using of a board that equipped with Bluetooth version 4.1, which is Bluetooth Low Energy (BLE) ready, make this version of this Nawala Mangsa can also broadcast the data that are read by the sensor through BLE, in addition to sent to the server over the TCP/IP network. By this way, so the weather station data can be directly read by the mobile device that equipped with BLE observer.

Keywords: *weather station, Bluetooth, BLE, sensor, IoT*

1. Introduction

Plant Acclimatization Chamber, or often referred to as Plant Growth Chamber, is a chamber that designed to produce environmental conditions (light intensity, air temperature, and air humidity) that maximizes for growing plants. Growth chamber is a valuable controlled environment that allows researchers to determine the effect of specific parameters -either biotic or abiotic, in plants. Various plants can be grown in the artificial climates that all abiotic factors can be controlled [1-3].

Acclimatization chamber has been widely used in various studies [3]. Experiments in the container can involve all the conditions of care contained in the plant growth space. For example, to know the nutrients or water in various individuals in a single experimental room under the same abiotic conditions, or to check the sunlight requirement, air temperature or maximum air humidity that can be accepted by a new breed of varieties.

Acclimatization chamber used as a support facility in the field of agroclimate and horticulture studies. Plants needs -such as air temperature, humidity and light intensity characteristics that depend on the geographical location of the plant's native habitat are among the obstacles to researching with limited costs. With acclimatization chamber, the research can be done efficiently concerning time and cost [1].

In the year of 2017, Faculty of Computer Science, Universitas Narotama, and Faculty of Agriculture and Animal Husbandry, Universitas Muhammadiyah Malang, agreed to conduct research together to make and implement Automatic Plant Acclimatization Chamber (APAC).

APAC is designed to run automatically. Researchers need only enter information into the system, and then the chamber will simulate the environmental conditions of which location and which month. From the information already stored in the database, the controller will create the chamber condition close to real conditions in the field.

To implement the idea, the microcontroller that used require a wealth of information about the microclimate environment conditions of the location where the plant's native habitat originated or the plant will be grown in the wild. APAC will be automatically simulated the abiotic environmental variables needed for plants to grow. Researchers only need to determine the geographical location and month he/she need to be reproduced the microclimate by APAC.

To obtain the microclimate information, it needs to record the real condition of microclimate at the location. That was the intention of the Nawala Mangsa, the name of Weather Station, that designed to get the environment information at remote by online (picture 1).

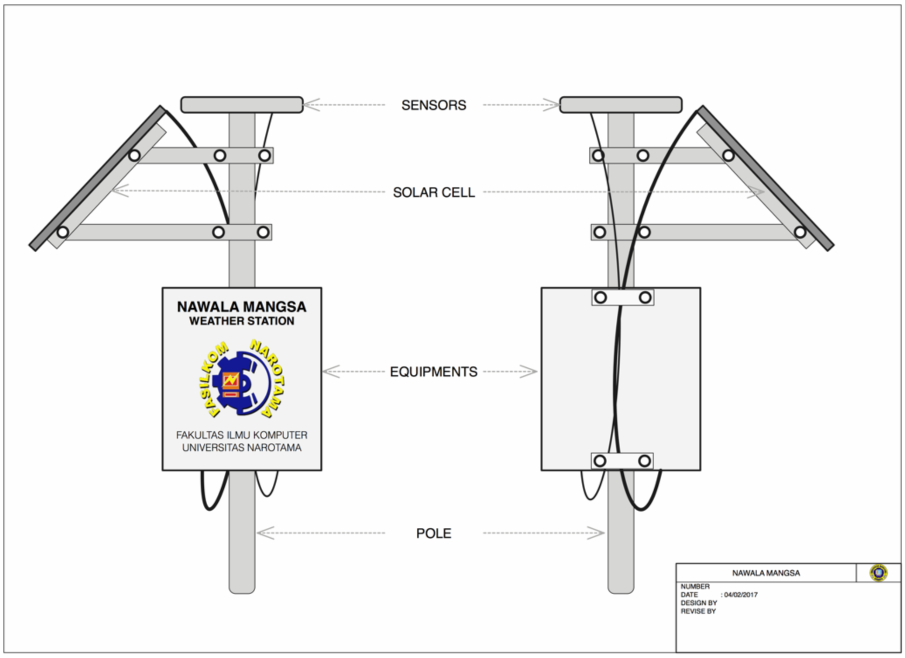

Figure 1: Nawala Mangsa Design Appearance

2. The Version of Nawala Mangsa

The first design Nawala Mangsa uses Arduino with a DHT22 sensor to get information of air temperature and relative humidity. This initial version not equipped with communication devices, so to store data measurement results are used storage media in the form of SD-card. The original design was intended only to be a proof-of-concept recording of environmental conditions within an Internet of Things (IoT) and only used in the laboratory.

The development of Nawala Mangsa approaching as the use of remote sensing is in version 1.1. This version equipped with an ethernet shield used by Arduino, as the brain of the weather station, to report on sensor readings online via TCP / IP, as well as the data stored in SD-card as the backup.

To meet the APAC requirements in light intensity, the version 1.2 of Nawala Mangsa, equipped with a light intensity measurement circuit using the Light Dependent Resistor (LDR) base [4]. This series is enough to provide information despite having an almost large variant.

Table 1 shows the development of News Newsletter from the original version up to the latest version 2.0.

Table 1. The Version of Nawala Mangsa

Nawala Mangsa	Air			Light			Data Storage	Mainboard
	Temp	Humidity	Pressure	Intensity	UV	IR		
Version 1.0	DHT-22		N/A	N/A	N/A	N/A	SD	Arduino
Version 1.1	DHT-22		N/A	N/A	N/A	N/A	SD/Online	Arduino
Version 1.2	DHT-22		N/A	LDR	N/A	N/A	SD/Online	Arduino
Version 2.0	BME-280			TSL2561	N/A	N/A	SD/Online	Raspberry Pi

3. The Version 2.0

In the latest of version 2.0, Nawala Mangsa has undergone very fundamental changes. Not only replacing all types of sensors to add the measurement feature and accuracy but also to the use of mainboard to facilitate the more complex programming. DHT22 replaced with BME280 so in addition to getting data on air temperature and relative humidity, also obtained data on air pressure. As for circuit LDR replaced with the TSL2561 sensor that has been well calibrated. The replacement of the sensors also makes wiring more straightforward to do, because these two sensors can communicate using Inter-integrated Circuit (I2C) protocol, so it only takes a pair of cable for mainboard to talk on both sensors.

Meanwhile, for the mainboard, Arduino replaced with Raspberry Pi 3. This replacement is primarily to facilitate the programming and access to the communication layer so that applications can be more easily to develop later. This board already equipped with the communication device, such as gigabit ethernet, wireless LAN, Serial Peripheral Interface (SPI), I2C, and Bluetooth version 4

3.1. Mainboard

Raspberry Pi is a low-cost and high-performance single-board computer developed by the Raspberry Pi Foundation. The foundation is based in the UK concentrating on placing digital power in the hands of people all over the world so that the entire world community can understand and shape the ever-increasing digital world, be able to solve their problems and be used for future work. One that the Raspberry Pi Foundation does is promote the teaching of basic computer science in schools and developing countries.

The foundation had released several generations of Raspberry Pi. The first generation (Raspberry Pi 1) released in February 2012 with a primary model A and with higher specifications on model B. Model A + and B + announced a year later. Then Raspberry Pi 2 Model B released in February 2015 and Raspberry Pi 3 model B in February 2016 [5,6].

The new version of this weather station uses Raspberry Pi 3 B (fig. 2) model equipped with Broadcom system-on-chip (SoC) system, which includes ARM as the central processing unit (CPU) and VideoCore IV graphics processing chip as the graphics processing unit (GPU). The CPU speed is 1.2 GHz and comes with 1 GB of Random Access Memory (RAM). As the storage medium, this system uses SD-Card in MicroSDHC.

This Raspberry Pi also equipped with four USB slots, HDMI output, and 3.5 mm jack for audio. Moreover, for digital communication, this board provided with 40 pins General-Purpose Input/Output (GPIO) that supports standard communication protocols such as I2C, SPI, and Ethernet, Wi-Fi 802.11n, and Bluetooth 4.0 [7].

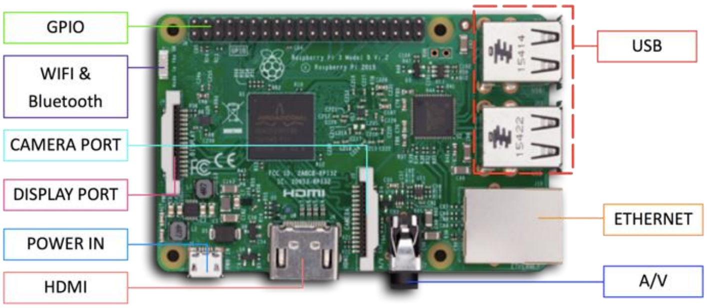

Figure 2: Raspberry Pi

3.2. Sensors

Two sensors are used in this version 2.0 Nawala Mangsa. Sensor for obtaining air temperature data, relative humidity and air pressure using BME280. Meanwhile, to measure the intensity of sunlight using a TSL2561 sensor.

The BME280 (Fig. 3) is Bosch Sensortec's built-in sensor, which used as an integrated environmental sensor developed with small size and low power consumption for mobile applications. This sensor has high linearity and accuracy for pressure, humidity, and temperature in 8-pin metal-cover packaging 2.5 x 2.5 x 0.93 mm^3 LGA, designed for low power consumption (3.6 μA @ 1Hz) and long-term stability [8].

This sensor has two digital communication systems, namely I2C and SPI. Both of these systems provide convenience in the design of cabling system and programming, primarily when used more than one sensors in one location with the same digital communication system. The I2C sensor has two address options, 0x76 and 0x77.

The TSL2561 (fig. 3) sensor is light-to-digital converters or luminosity sensors, made by Texas Advanced Optoelectronic Solutions, which convert light intensity into a digital signal. This digital light sensor is sophisticated and ideal for use in a variety of bright situations. Compared with Cadmium Sulfoselenide (CdS) cells, such as those used in LDR, these sensors are more precise, allowing for accurate and configurable Lux calculations for different gain/timing ranges.

The sensor is equipped with an integrated CMOS circuit capable of providing near-photopic responses with effective 20-bit dynamic range and integrates ADC to convert the photodiode current to a digital output that represents light radiation. Therefore this sensor can detect the range of light from up to 0.1 - 40.000 + Lux quickly. The Sensors also equipped with infrared diodes with full spectrum. It means that these sensors can measure separately infrared light, full spectrum, or visible light humans.

For digital communication, this sensor uses System Management Bus (SMBus) versions 1.1 and 2.0, and I2C protocols. The I2C protocol provides three available address options, which are 0x29, 0x39, or 0x49 [9].

Figure 3: TSL2561 and BME280

3.3. Cabling

Nawala Mangsa has two separate units. First is the central unit, containing the controller, power supply, and if necessary communication device. While the other groups are sensors units, which in version 2.0 includes BLE280 and TSL2561.

Since both sensors are used to communicate via the I2C protocol and have different I2C addresses, the communication between the central unit and the sensor unit requires only two pairs of cables used for VCC, GND, SDA, and SCL. Therefore, the connection between these two separate units uses an Unshielded Twisted Pair (UTP) or Shielded Twisted Pair (STP) cable with RJ-45 connectors on both sides of the units, as can be seen in picture 4.

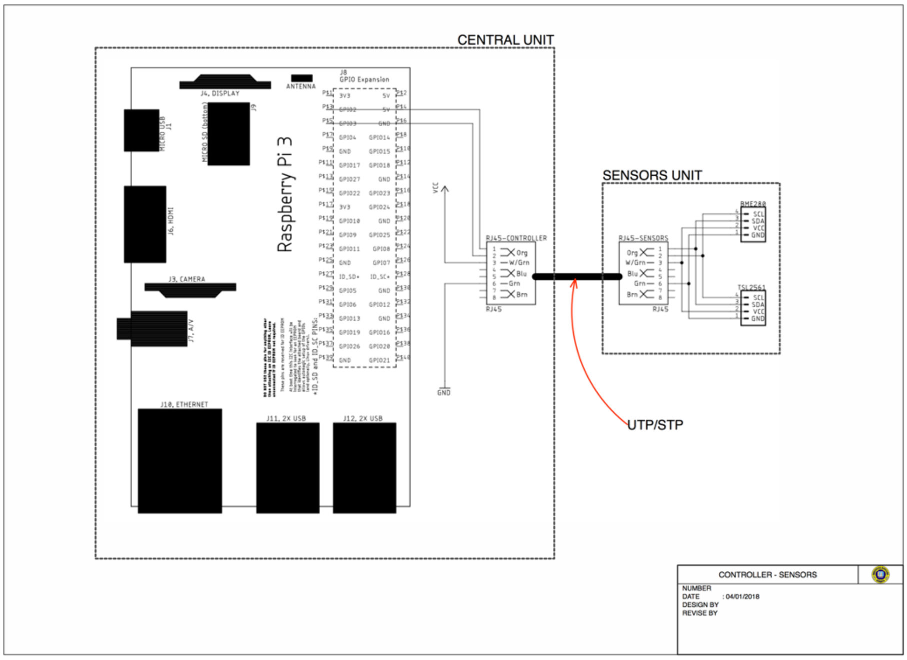

Figure 4: Communication Raspberry Pi and The Sensors

Raspberry Pi 3 has two pieces of the I2C master. In this first sensor unit using I2C master #1 which the Serial Data (SDA) pin located on GPIO pin #3 and the Serial Clock (SCL) pin located on GPIO pin #5. While for VCC and GND to the sensors unit does not take from pin GPIO but connected directly to the power supply, to avoid the short circuit possibility at sensors unit that can cause damage to the mainboard[5,6].

3.4. Programming

Programming in this weather station divided into three parts of the program, namely the data reader part of the sensor, the data sender to the server, and the data sender to the BLE. Since the mainboard using Linux-based operating systems, then this three parts of the program can be run separately and independently on a different process identifier (PID).

This program's PID distinction is intended to allow each application to run independently of each other. Problems that occur in one part of the program will not influence the program as a whole, because the problem is only happening on a single PID. Meanwhile, the communication between applications is used way through the data layer. This method resulted in making the program can be more focused on its function and ease the maintenance of the program later.

3.4.1. Reading the Sensor

Sensor reader program (Figure 5a) starts from the initialization process of sensors for sensor reading process. If this initialization process fails, then the process will stop because there is nothing the program can do, and then send an error message for this error.

The next process is the sensor reading. The sensor readings are carried out on two sensors, BME280 to obtain air temperature, relative humidity, and air pressure. Then sensor TSL2561 to get the intensity of sunlight. All reading results directly stored in the MySQL database without any data processing before. The data will be processing when the sending data program is doing its jobs.

The reading data sensor process will repeatedly continue at intervals of 5 seconds.

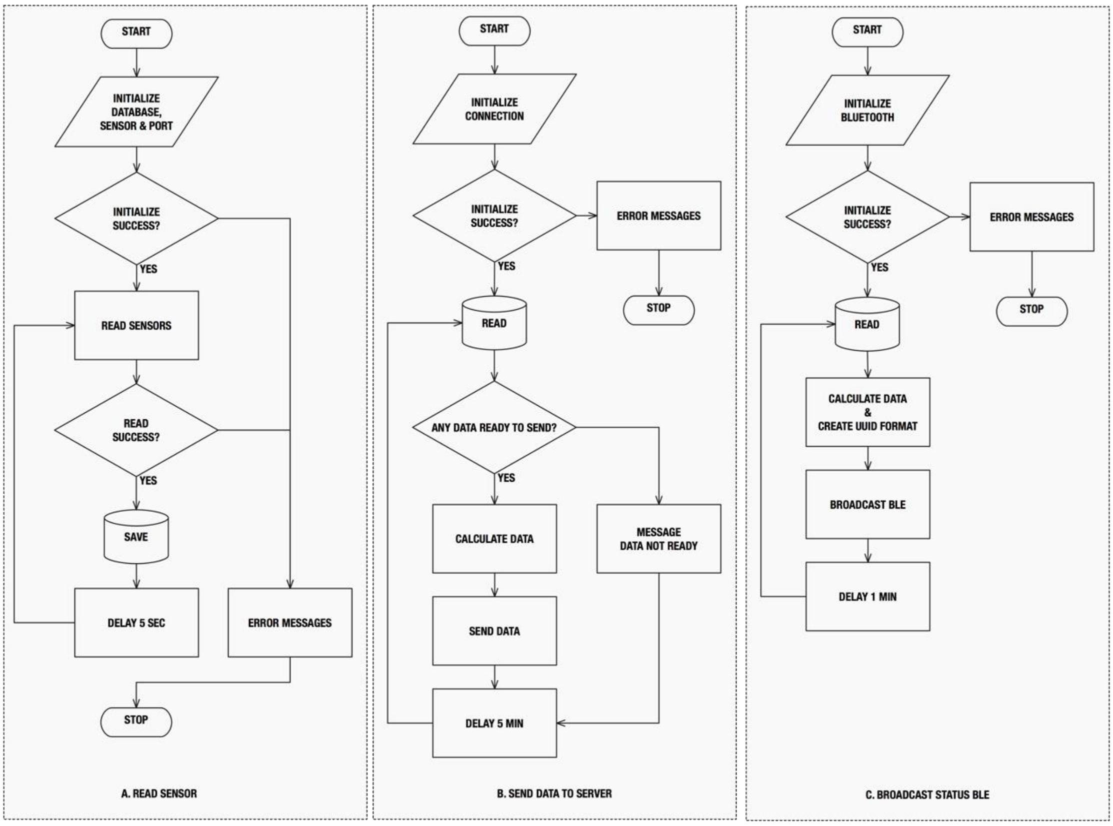

Figure 5: Flowchart Nawala Mangsa v-2.0

3.4.2. Sending The Data

The data that already read from the sensor and available in the database is raw data for the other program before it sent to the cloud server or mobile device via BLE. The sender program will send the data to the server within 5 minutes periodically, while the broadcaster program will broadcast the data within once in a minute.

Data sent by weather station to server and mobile device are a processed data based on the raw data that get from the sensors. Therefore the data in the weather station database must be treated first. The information that to be transmitted to mobile devices, the process is only to find the average value of the data obtained in the time range available (equation 1) -as well as air temperature data, relative humidity, air pressure, and light intensity.

$$\overline{x} = \frac{1}{n}\sum_{i=1}^{n} x_i \quad (1)$$

Meanwhile, the data that to be sent to the server, in addition to the above average process value (equation 1), there is also a process to find the median (equation 2 for an odd amount of data and equation 3 for an even amount of data). Also the process of to knowing the mode (Mo) or values that often arise, and standard deviation (equation 4). This three additional information will be used as information about the reliability of data sensors obtained by the weather station.

$$Me\ (odd) = x_{\left(\frac{n+1}{2}\right)} \quad (2)$$

$$Me\ (even) = \frac{1}{2}\left(x_{\left(\frac{n}{2}\right)} + x_{\left(\frac{n}{2}+1\right)}\right) \quad (3)$$

$$s = \sqrt{\frac{n\sum_{i=1}^{n} x_i^2 - \left(\sum_i^n x_i\right)^2}{n-1}} \quad (4)$$

The results of the raw data process above then sent to the server by using the HTTP XML protocol to the cloud server. As for mobile devices, the calculation results must be converted into a 128-bit Universal Unique Identifier (UUID) BLE format, before the broadcasting.

3.4.3. Bluetooth Low Energy

BLE is designed to transfer data of small size and with rare frequencies at the simplest data level with the least possible energy. This design is different from the classic Bluetooth design in general.

Bluetooth Special Interest Group (SIG) introduces two trademarks: Bluetooth Smart for single mode devices (devices that only support BLE) and Bluetooth Smart Ready for dual-mode devices (devices that support Bluetooth Classic and BLE). BLE itself has now begun to fit in various types of accessories such as mobile phones, tablets, notebook computers, and the Internet of Things (IoT) devices. Device wearing devices such as smartwatches are also equipped with Bluetooth 4.0 or later which also has a BLE function.

Technically, the BLE stack has two complementary layers to provide maximum performance (Figure 6). Differentiated into the lower layer and the upper layer. These two layers are separated by an adjustable control function from the top layer to do something on the bottom layer. The bottom layer on the BLE stack consists of Physical Layer (PHY), Link Layer (LL), and Direct Test Mode (DTM) for the test interface. PHY is responsible for sending and receiving data packets. LL is responsible for providing media access, connection establishment, error control, and data flow control[10-14].

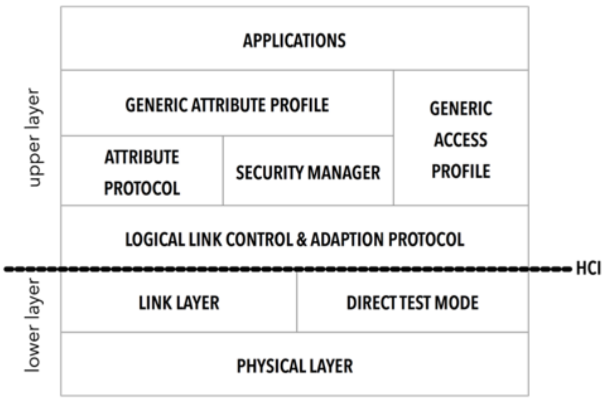

Figure 6: BLE Protocol Stack[10]

The top layer consists of Logical Link Control and Adaptation Protocol (L2CAP), Attribute Protocol (ATT), Security Manager (SM), Generic Attribute Profile (GATT), and Generic Access Profile (GAP). The Host Controller Interface (HCI) creates a separator between the lower layers, often implemented for BLE controllers, and the top layers, which often implemented as host stacks [10-14].

iBeacon, the name for Apple's technology standard, is one example of a product that uses BLE. This technology can determine how far away a BLE observer (smartphone) is relative to one or more BLE broadcasters. Apple later opened this technology and adopted by several vendors with using Beacon as its technological name [14].

The relative location positioning of the BLE observer against the BLE broadcaster uses a unique UUID BLE broadcaster as an identifier and calculate the Received Signal Strength Indicator (RSSI) to determine it’s distance (equation 5). By using triangulation calculation, then it can learn the position of BLE observer relative to three BLE broadcaster.

$$\text{RSSI}\ (dBm) = -10n\log_{10} d + A \quad (5)$$

The beacon data has a format like in figure 7. This proximity UUID contains four data fields :
1) proximityUUID: a unique data of 32 hexadecimal digits.
2) major: major number of the beacon.
3) minor: minor number of the beacon.
4) power: the power of BLE transmitted.

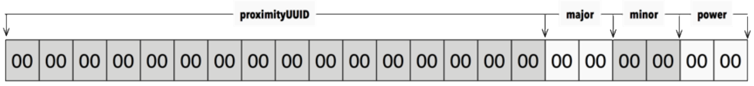

Figure 7: Beacon Data Format

The broadcasting data of the Nawala Mangsa to the smartphone is using the beacon concept. To do so requires modifications of the UUID format (figure 8). Proximity UUID divided into several data fields that need to send to smartphone, that is timestamp, temperature, humidity, pressure and light intensity. While the major number data and minor number data modified to be the data of Nawala Mangsa ID and the BLE transmit power data temporarily unused.

Figure 8: Modification of Beacon Data Format

The following description of the data format used:
1. Timestamp uses Unix epoch format; therefore it takes 32 bits (8 bytes).
2. Air Temperature from -127 to 127 degrees Celsius for the first two bytes and a number behind the comma from 00 to 99. Total required 4 bytes
3. Relative Humidity data from 0% to 100% for the first two bytes and the digits behind the comma from 00 to 99. Total required 4 bytes
4. Surface pressure using the standard of hectoPascal (hPa). The records of the highest sea level pressure are 1085.0 hPa. So it can be adopted with 4 bytes long.
5. Light intensity provided by 6 bytes.
6. Version and Nawala Mangsa ID provided as much as 8 bytes that using the data major and minor UUID fields. The first byte of the data major will used as the version of the data format and the rest used as the location code of weather station and a serial number of the weather station on that location.

4. Broadcasting BLE Testing

In this experiment, we tested broadcasting data from two Nawala Mangsa at different locations and times. This experiment was conducted several times with some distance to know the effectiveness of BLE broadcasting. For the observation, the researcher uses a smartphone that has equipped with BLE observer application that the user interface has been adjusting to the Nawala Mangsa UUID format. This app developed using hybrid programming with Cordova basis [15]. The received data UUID from Nawala Mangsa, then parsed by the program and displayed following the data format that already created.

The first experiment conducted in a location that has several obstacles in the form of a brick wall, from the position of Nawala Mangsa, as BLE broadcaster, to the smartphone, as BLE observer. The Screenshot of the report views like in picture 9, with the format of UUID as in picture 10.

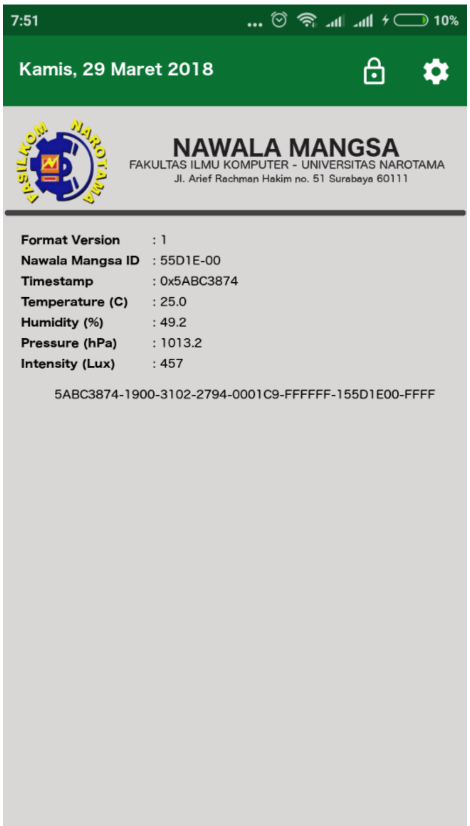

Figure 9: Screenshot mobile device BLE for Nawala Mangsa ID 55D1E-00 broadcasting

Figure 10: UUID Format Receive

In 10 test times (about 10 minutes) BLE broadcasting at some distance indicates diversity as in table 2. Up to a range of about 13 meters from BLE broadcaster, 100% of data read by BLE observer, and at a distance of about 20 meters only about 50% of data that can be read. While all data broadcasting successfully learned well, the data received is valid according to the readings of timestamp obtained from Nawala Mangsa.

Table 2: BLE Broadcasting Reliability for Nawala Mangsa ID 55D1E-00

Jarak Perangkat	Hasil Pembacaan	Kehandalan
< 10 meter	Normal	100%
11 meter	Normal	100%
12 meter	Normal	100%
13 meter	Normal	100%
14 meter	Normal	90%
15 meter	Normal	80%
16 meter	Normal	70%
17 meter	Normal	70%
18 meter	Normal	60%
19 meter	Normal	60%
20 meter	Normal	50%

For the second experiment, done at this location there is virtually no significant obstacle from the Nawala Mangas to the smartphone. Similar to that the first experiment, this experiments also performed ten times test at each distance and observations were made on the data transmitted using a smartphone. Screenshot of mobile device display and UUID format is in Figure 11 and Figure 12.

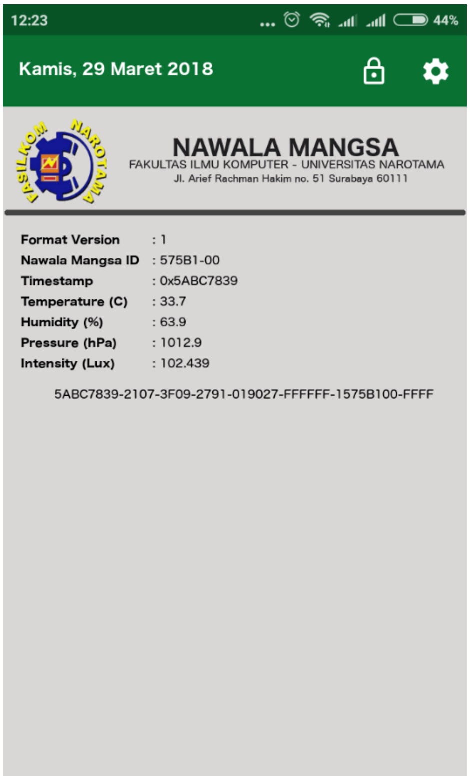

Figure 12:Screenshot mobile device BLE for Nawala Mangsa ID 575B1-00 broadcasting

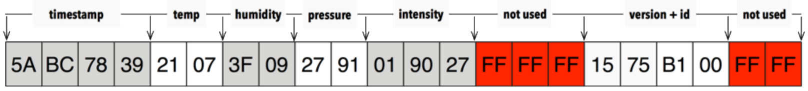

Figure 11: UUID Format Receive

The results of this observation on Nawala Mangsa at the second location (table 3) shows the better reliability of BLE transmission. Researchers consider this is because the second location does not have a significant obstacle that can inhibit the BLE signal from the broadcaster to the observer.

Table 3: BLE Broadcasting Reliability for Nawala Mangsa ID 575B1-00

Jarak Perangkat	Hasil Pembacaan	Kehandalan
< 10 meter	Normal	100%
11 meter	Normal	100%
12 meter	Normal	100%
13 meter	Normal	100%
14 meter	Normal	100%
15 meter	Normal	100%
16 meter	Normal	100%
17 meter	Normal	90%
18 meter	Normal	80%
19 meter	Normal	80%
20 meter	Normal	80%

5. Conclusion

The development of weather stations with the integration of an information broadcasting, through BLE, has been developed and presented. The results of this integration indicate that the data already read by the sensor of weather station can instantly broadcast as a piece of information to the needy that near the weather station located. In the experiment showed a smartphone with a distance of 20 meters can still receive the data well.

The use of BLE as information broadcaster, besides, can be used as a provision of instant information to the needy, also can facilitate the administrator of the weather station system for system maintenance. The administrator does not necessarily have to see the weather station, to know the condition. By receiving BLE information, the administrator can determine whether the weather station is in excellent condition or not.

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