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The Application of LoRa Module and Smart Card for A Large-Scale Area Attendance Monitoring System

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Abstract: The Internet of Things (IoT) is an emerging device type that shifts our traditional way of living into high technology lifestyle. IoT enables interconnection between electronic peripherals and sensor devices through internet. Thus, a flawless data communication method plays an important role to develop an IoT system. This study proposes an attendance monitoring system for use in large-scale areas that are difficult to be integrated by LAN using LoRa modular system. By integrating LoRa technology into the IoT system, a wide-range data transmission performance issue can be resolved with the utilization of smart card technology to develop a module for recording attendance portably. To evaluate the data retrieval effectiveness, a technique for value measurement of RSSI, SNR, and LoRa packet loss has been applied in indoor and outdoor experiments at a campus in Indonesia. The results show the average RSSI value of -81.4 in the indoor experiment, which has the best value close to 0. For outdoors, the data transmission distance is only able to reach 133.17 m in the case of the standard LoRa device configurations applied, for instance, the use of antennas for sending and receiving data on LoRa. Another influencing factor is the placement of the receiver and sender of LoRa at a location that is blocked by buildings. The use of RFID technology is employed to record employee attendance, which comprises components such as a microcontroller, RFID reader, and LCD to display information at that time. Writing data directly onto RFID eliminates the need to connect to a server to obtain employee information, providing an advantage in constructing infrastructure. Although data is written and read directly, security is still enforced by utilizing the authentication key contained in the RFID.

Keywords: internet of things, attendance monitoring, LoRa module, smart card, RSSI, SNR

1. INTRODUCTION

The *Internet of Things* (IoT) plays a very important role in various sectors such as education, agriculture, plantations, and smart cities [1], [2], [3], [4], [5]. In the plantation sector, IoT can be used to send the presence status of field workers working for a company. Attendance status is very important because it is used in calculating workers' income in addition to the basic salary they get every month. The status of attendance so far is done by being manually recorded by a staff member. This condition will be surely highly risky for fraud. After being recorded, it is then carried out to collect all attendance reports. These activities are carried out every day, which of course will take up a lot of time. The use of IoT technology will help in recording the presence of an employee, but another problem arises, namely that the location or plantation area is very large so that not all communication lines can be carried out, for example using Wifi or Bluetooth, both of which have a limited range. In fact, implementing IoT technology requires an internet connection as a medium for sending data to the server.

In addition to using *Wifi* or *Bluetooth* as a medium for transmitting data, there is a *LoRa protocol* with a range of 10 km in urban areas and up to 50 km in rural areas [6], [7], [8]. In addition, power consumption can last a long time, so it will be more efficient in carrying out maintenance, especially in areas that are not easy to reach, such as agricultural areas or large plantations. Meanwhile, to identify or track attendance, RFID technology is used, namely smart cards. RFID is an acronym for *Radio Frequency Identification*, which can automatically identify, track, and monitor an object in real-time on an object, animal, or person [9]. The working principle of RFID is to attach an RFID tag to a reader connected to a terminal. This RFID tag contains employee data such as UID, employee number, expired, and other supporting data [10]. When reading RFID tags is done offline because it is only communication between the RFID tag and the reader. Of course, this will be more efficient because it does not require checking data with the server online. To ensure that the data read is correct, namely cardholder data, the RFID tag is secured using a dynamic

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key where each card has a different key. With the existence of different keys, it is expected to be able to reduce the risk of data duplication or make changes to the data contained in RFID [11].

In this paper, we have succeeded in analyzing the use of LoRa both indoors and outdoors for data communication. Even though the use of LoRa is still not able to provide the best solution for sending attendance data, the results of both indoor and outdoor trials have not shown the expected distance. For example, the results of tests carried out on the ability to transmit data indoors are only capable of a few tens of meters, while outdoors it is not more than 150 meters.

The simulation we do is to send employee attendance data on a door access prototype. Employee data is stored on an RFID and then attached to an RFID reader. The data read by the RFID reader on the controller will be sent to a Raspberry Pi gateway. This gateway sends employee data to the cloud using the MQTT protocol which will be stored in a database. After the data is entered into the database, data monitoring can also be carried out using the website application that we developed.

We divides into several sections such as the first section about the introduction that presents the proposed idea, the second section describes the relevant previous research, the third section describes the methodology used in this research, while the fourth section describes the results and discussion, then the last section. namely the conclusion of the research that has been done.

2. RELATED WORKS

Several previous studies have proposed methods for recording attendance, such as using RFID, combining *RFID* and artificial intelligence or *Computer Vision*, and applying *Internet of Things* technology.

A. RFID usage

The use of technology in recording attendance has been widely carried out in the past few years using RFID technology, in [12] developing an android application that has an NFC feature as an RFID reader to record student attendance in class, besides being used for attendance in class, it is also used to record attendance in class. track student attendance at worship halls, chapel seminars, and church services. Student data that is successfully read using an Android mobile reader will then be sent via the internet and stored in a MySQL database. To be able to run, of course, a student must have a set of Android phones that have NFC features, unfortunately, cellphone models with NFC features are not owned by all types of cellphones. The use of a cheaper RFID reader is implemented in [13], [14], [15], [16] because it only functions as a reader that is connected to a microcontroller namely *Arduino*, the reader is also equipped with an LCD to display student or employee data information when reading RFID. After the data is read successfully then the data is transferred to a PC to be stored in a database.

B. Combination of RFID and Computer Vision

[17] combines RFID with Face ID information to complete the process of recording attendance in class, Face ID is used to avoid cheating when a student records attendance. The same concept was also adopted in [18], [19], but combined with computer vision to recognize a student's or employee's face. This was done, in addition to recording attendance, and was also carried out when COVID-19 cases were still occurring. Research is conducted by detecting the temperature first because a high temperature is one of the characteristics of a person having symptoms of the COVID-19 virus, then the system will send a notification to the relevant authorities.

The development of Internet of Things technology provides technical support in classroom attendance management in colleges and universities, an attendance management system based on RFID technology, and facial recognition technology under the Internet of Things platform[20], [21]. The experimental results show that a smart classroom attendance management system based on RFID technology can accurately identify student absenteeism and replacement and has a fast response and low cost. But the problem is that a student must place the RFID in a certain place. A facial recognition-based smart classroom management system is able to accurately record and identify students entering and leaving class as well as late or early leave conditions, absenteeism, and substitute classes[22], [23]. However, this system model is easily affected by light conditions, the student sitting positions, expressions, and other factors so it cannot be recognized [24].

C. Internet of Things usage

In [25] proposed a smart classroom attendance system that still supports the previous system as well as integration with security and classroom management. The *Revo FF-153BNC* finger spot module is used as input to the system, and The *NodeMCU* connects to a WiFi router as a controller. The system is connected to the information system and classroom display unit. The results show that each system unit successfully integrates and manages attendance, security, and class schedules.

In [26] also proposed an automatic classroom attendance system using artificial intelligence and Internet of Things technology that is integrated into a device in the room. The study claims that the system can record attendance data automatically and runs continuously during the learning process. When students are in class, the school and parents can monitor it in real time. The main component of the system is a camera device installed in the classroom, used to identify class participants, and connected to the cloud server via the IoT infrastructure. The experimental results show an accuracy per frame of 89%, with a speed of 82 ms to recognize faces at a distance of 4-15 meters.

D. Smart Attendance System

The attendance system is very important for monitoring someone's activities, for example at school. Some implementations of attendance systems in schools are to monitor student or teacher attendance, some studies use RFID technology to carry out this process.

Jeffrey et al [27] proposed a system to help educational institutions and instructors focus on academic activities instead of manually recording attendance. This is done to reduce errors in recording attendance, which can result in a reduction in grades or a lack of attendance. The attendance system uses an embedded computer to store time and track student attendance at any time on a repository, namely Google Firebase.

Ula et al [16] created a new model for attendance, namely an attendance system using RFID technology. Using RFID to make it easier for lecturers and students to monitor class attendance. The proposed model is to place an RFID reader complete with a computer in each room, the RFID reader will get an ID when the RFID is attached. Then the ID will be sent to the PC, then it will be compared with the ID that is in the database. The process of reading RFID tags is claimed to be able to read at a distance of 1 to 3 cm.

Mohanasundar et al [28] designed a real-time attendance recording system using RFID technology. The methodology used is to assemble the *Arduino Uno*, *MFRC522 RFID* reader, and *Node.js* running on a computer. To identify each teacher and student, each of them is associated with an identifier called a UID on RFID. When the appropriate UID is read, the system can find out whether a teacher or a student is late or not in class in real time. In addition, the system is able to store various types of information related to classes in tertiary institutions and send email notifications via a PHP application. From the tests carried out, the data is entered into the database, the RFID is read properly, and the check for delays works as expected.

Keau et al [29] designed a mobile application called Smart-Present to provide solutions to the problems of teachers losing attendance records, entrusting attendance to friends, students forgetting to record attendance, and challenges in monitoring attendance and analysis levels. Smart-Present does not use RFID technology in general but uses *NFC*, *QR code*, and *beacon technology*. Attendance records can be retrieved using the NFC or QR code displayed on a projector or by scanning the available beacons. Student attendance will be retrieved as soon as possible and stored in a database where teachers can view statistical reports, identify students, send attendance e-mails, and monitor student attendance behavior.

In previous studies that were dominated by the use of RFID and facial recognition to perform attendance using a WiFi connection, this study proposes a communication model using a different protocol, namely *LoRa (Long Range)* in terms of sending data[30], [31]. Additionally, incorporating devices into attendance systems can be expensive. For instance, installing an RFID reader on a computer or using a cell phone, which may not have NFC features, can be relatively costly. Matching the UID with the database to obtain user information can also pose several challenges, such as requiring a stable online connection. On the other hand, RFID technology can store necessary information, eliminating the need to conduct online user information checks. To ensure data security when using RFID, security measures must be implemented, and this research proposal aims to explore this concept.

3. PROPOSED SYSTEM

The proposed system is divided into 3 main parts, namely: front-end service, gateway service, and back-end service. For more details can be seen in Figure 1.

A. Front end service

In this section are a set of components that directly interact with the user. It consists of components such as a *real-time clock (RTC)*, *LCD*, *Solenoid Doorlock*, *Relay*, *PN532*, *ESP32*, and *LoRa Shield*. The ESP32 controller is not connected to the network, so the RTC is used to store the time in ROM. The LCD is used to display information or notifications, such as employee number information or notification of the status of the process being carried out. The Solenoid Doorlock aims to open or close door access on the prototype. The relay itself is used to distribute electrical voltage to component devices. PN532 is used to read and write RFID, which is connected to the ESP32. LoRa Shield is used to transmit data on employee number, card number, MAC address, RSSI, SNR, and transaction time. All these components are installed on the ESP32. In general, the flow contained in the front-end service is that someone will attach an RFID to the PN532 reader, then the RFID will be validated offline using a previously defined key. When the validation is successful, it will trigger the Solenoid Doorlock to open the door access prototype and the LCD will display information in the form of a message in the form of an employee number and will send transaction data to the Gateway service, while when it fails to read the RFID caused by not being a registered card, it will also be displayed information on the LCD. The circuit of the device is shown in Figure 2.

In addition, on the front-end service, there is also a desktop-based application that has a role in writing user data into RFID. User data is retrieved from the database contained in the *Cloud service*.

B. Gateway service

The main function of the Gateway service is to receive data from the front-end service, which is then forwarded to the cloud to be stored in the database. Data received from the front-end service is sent using the *MQTT protocol* to the back-end service.

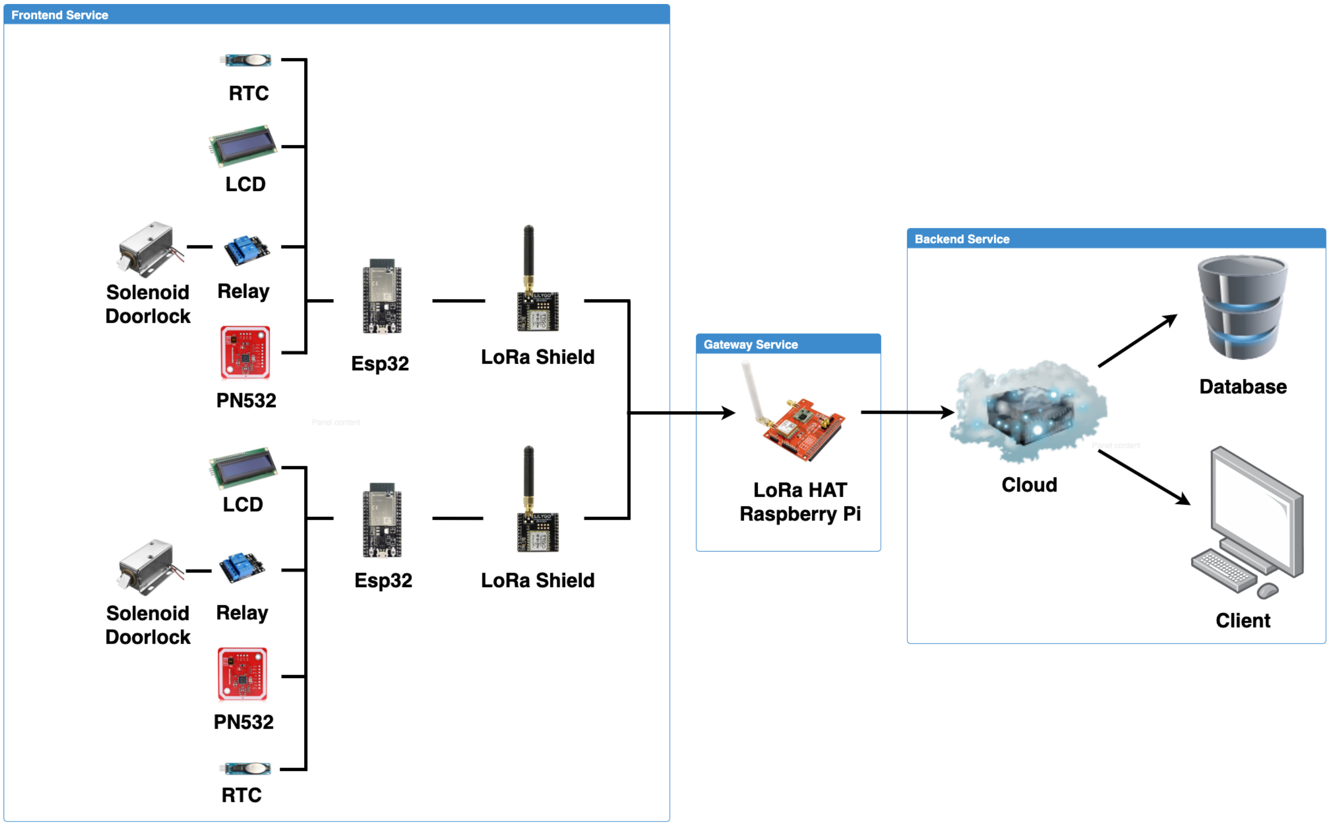

Figure 1. System architecture

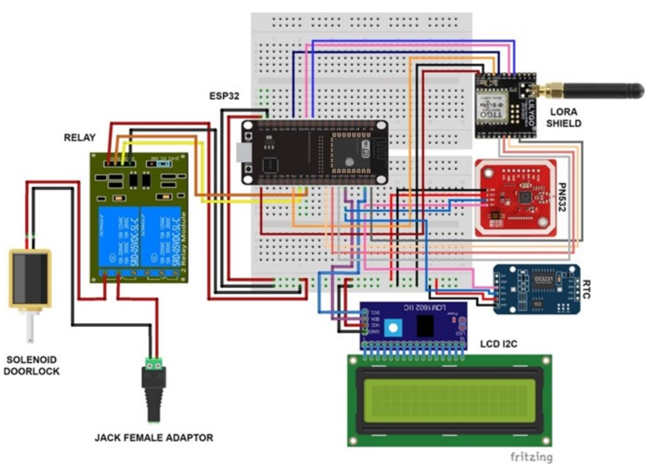

Figure 2. Attendance system module

C. Backend app

The back-end service resides in a cloud environment with web-based application components, subscriber applications, and databases. Data sent from the Gateway service will be received by the subscriber application, then stored in the database. The web application will display transaction data in the form of a person's activities using door access, in addition to being used in device management and employee management.

D. RSSI of LoRa

The *RSSI (Received Signal Strength Indicator)* is a relative measurement that aids in determining whether the received signal is sufficient to establish a solid wireless connection with the transmitter. Usually, the RSSI value is between -30 dBm to -120 dBm, if it is close to -30 dBm it means the signal is strong while close to -120 means it is weak. The RSSI value can be found using the equation 1 [32], [33].

$$RSSI(dBm) = -10n\ log10(d)\ + A \tag{1}$$

A is the signal strength measured in decibels (dBm) at a distance of one meter, and n is the path loss exponent value [30]. The normal LoRa usage environment is not located in a free area. It is usually placed in a location where there are trees, buildings, or even hills around it. This can result in attenuation of the signal due to diffraction, reflection, or scattering. The attenuation characteristics over a long distance follow the lognormal distribution, which is generally used by the normal logarithmic block model. Therefore, the path loss model equation is shown in equation 2 [34].

$$PL(d) = PL(d_0) + 10 \times n \times log(\frac{d}{d_0}) + X\sigma \quad (2)$$

In the above equation, $PL(d)$ represents the absolute power value (in dBm units) of the signal received at a distance (d), which is also known as path loss. d_0 is a reference distance of 1 meter, and $X\sigma$ is *Gaussian Distribution Random Variable*. The average value of $X\sigma$ has a standard deviation range of 4-10. By using the *PL equation*, we can calculate the RSSI value of a node at a distance d using the following equation 3.

$$RSSI(d) = P_{send} + P_{amplify} - PL(d) \quad (3)$$

P_{send} is a Power Transmitter, $P_{amplify}$ is a gain of antenna [35], [36], as well as to find the value of A is the same as the RSSI formula is shown in 4.

$$RA = P_{send} + P_{amplify} - PL(d) \quad (4)$$

So to get an estimate of the distance (d) between the nodes from the RSSI and A parameters use the equation 5. The value of n is the path loss exponent 2-5, each environment is different. For example, for an area that is free to use, the value of n is 2.

$$d = 10^{\frac{(A-RSSI-X_\sigma)}{10n}} d_0 \quad (5)$$

E. SNR *of LoRa*

SNR is the ratio between the received signal power (dB) and the noise level (dB), SNR can be used to determine the signal strength level. SNR values range between -20 dB and +10 dB, with an SNR value close to +10 dB indicating that the received signal is slightly damaged. To determine the SNR value, can use the equation 6.

$$SNR = \frac{P_{signal}}{P_{noise}} \quad (6)$$

Where P_{signal} (dB) is the strength of a signal, while P_{noise} (dB) is the strength of a noise or noise level.

4. System Implementation

A. Hardware implementation

The system that has been designed as shown in Figure 3 is useful for making it easier for users to access door locks and remote attendance using LoRa without having to worry about the distance to transmit data. The user needs to place the card on the sensor so that the data on the card can be read by the sensor then the data will be sent with the LoRa receiver module as shown in Figure 4. Then the solenoid door lock can be opened. When the data is successfully entered into the database, the user (admin) can monitor attendance activities. In the monitoring system, there is a device registration feature to enter the location where the device is placed and a filter feature to find out where the device has sent data from.

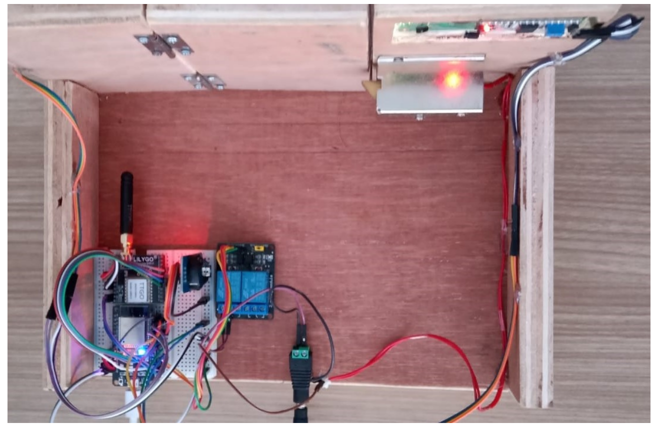

Figure 3. The hardware

Figure 4. Lora recipient

B. Software implementation

The smart card that will be used to record attendance must first be entered into the smart cardholder data using a web-based application, then the cardholder data is entered into the smart card using a desktop-based application.

The web-based application functions for employee management, smart card management, and device management, and displays LoRa data in graphical form as shown in Figure 5.

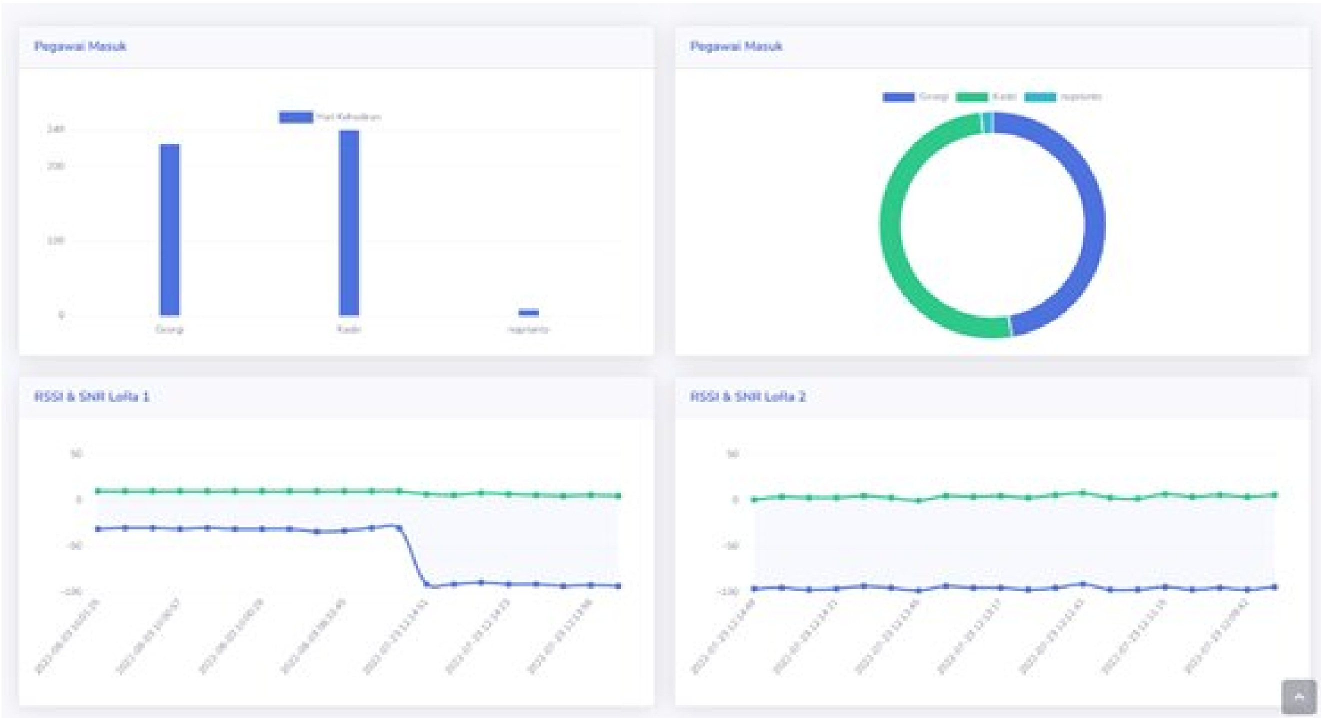

Figure 5. The implemented web app

On the dashboard page shown in Figure 5 there is information such as the status of device (LoRa sender), employee statistics by name in graphical form, as well as statistics on RSSI and SNR information for each LoRa sender. With this dashboard, you can quickly find out information on employees who are in attendance and then directly analyze LoRa delivery information on RSSI and SNR parameters.

Furthermore, the desktop application has a function to write and read smart card data. The desktop application is connected to a reader device, namely the *ACR122U*. Cardholder data is written into the smart card taken from the database, which has previously been entered using a website application. The desktop application Desktop applications written using the *Java* programming language and the *Swing* framework, it can be shown in Figure 6.

From Figure 6, it can be seen that there are 3 tabs, namely *Personalization*, *Reading*, and *Employee List*. Personalization is a field that includes the employee number, name, gender, and date of expiration, as well as a search button and a personal button. The person button is used to enter employee data from the database into the RFID, while the search button is useful for searching for employees from the database. The Reading menu has a function to read RFID data, and the *Employee List* menu displays a list of employees from the database.

Writing employee data into RFID is intended when an

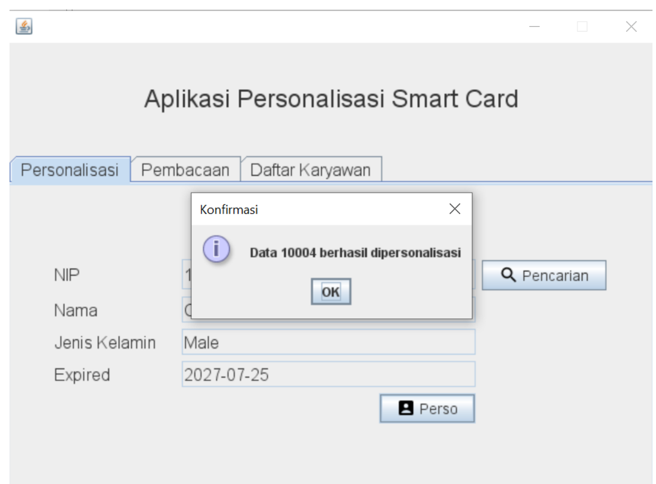

Figure 6. The implemented desktop app

employee makes attendance can be done offline by attaching it to the RFID reader. Unlike the method of only reading the UID [27], [16], [28], [29], the UID will then be sent to the server to match or retrieve employee information. The process of reading and writing to RFID does not need to worry about being modified because it has been secured using a security key and stored at a specific address (sector or block).

There is also a controller application in charge of reading or writing door access transaction data to RFID or front-end service applications. LoRa sender is found in this application with the *LoRa32 T-Highrow LoRa SHIELD TTGO 915 MHz* specification which still uses the default antenna. Developed using the *C/C++* programming language. While for LoRa receivers or those included in the gateway service, the use of a Raspberry Pi device with LoRa HAT DRAGINO 915 MHz is implemented using the C programming language.

Figure 7 is the sample code of *recipient LoRa* that shows the process when the *RSSI* and *SNR values* are successfully received by the *receiving LoRa*. Then, the received data is validated first by checking the characters, namely ASCII values between 0 and 127. The invalid data will not be sent to the cloud server.

```
printf("Packet RSSI: %d, ", readReg(0x1A) - rssicorr);
printf("RSSI: %d, ", readReg(0x1B) - rssicorr);
printf("SNR: %li, ", SNR);
printf("Length: %i", (int)receivedbytes);
printf("\n");
printf("Payload: %s\n", message);
boolean valid = false;
for (size_t i = 0; i < receivedbytes; i++)
{
    printf("%i ", (int)message[i]);
    if (message[i] >= 0 && message[i] < 128)
        valid = true;
    else
    {
        valid = false;
        break;
    }
}
```

Figure 7. Sample code of recipient LoRa

5. Evaluation and Discussion

A. Test scenario

The LoRa testing process is carried out with several data transmissions carried out at indoor and outdoor locations. In this test, we use parameters in the form of distance to get the RSSI, SNR, and lag time values. The lag time is calculated by subtracting the time received by the LoRa recipient from the transaction time.

1) Indoor testing

Testing in a building with a floor height of 3 m, while the thickness of the floor is 30 cm. Meanwhile, the number of rooms on each floor is 16 rooms, with an area of 64m2 for each room, so that the area of each floor is 1024m2. Wall and floor surfaces are made of concrete. The floor plan can be seen in Figure 8 and Indoor scenarios can be shown in Table I.

From the test results, it is found that in the room the best RSSI value is when the sending LoRa is placed on the 6th floor, this happens because the receiving LoRa placement is also on the 6th floor. The delay in sending is seen on the 7th floor has the smallest value or the data sent is received faster by the receiving LoRa, this happens on the 7th floor which is closer to the sending LoRa. Figure 9 is a comparison of the average RSSI for each floor, while Figure 10 is a comparison of the average SNR for each floor. Then Figure 11 is the average lag time when the receiving LoRa receives data from the sending LoRa.

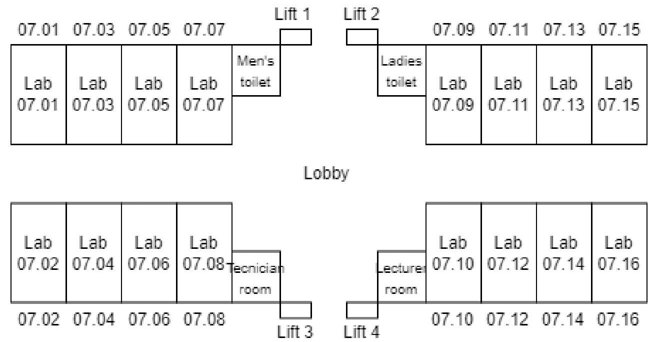

Figure 8. Floor plan each building

TABLE I. Indoor test scenario

No	Scenario
1	Placing *LoRa receiver* on the 6th floor
2	Placing the *LoRa sender* on the 4th floor and attaching RFID to the door access prototype 5 times.
3	Placing the *LoRa sender* on the 5th floor and attaching RFID to the door access prototype 5 times.
4	Placing the *LoRa sender* on the 6th floor and attaching RFID to the door access prototype 5 times.

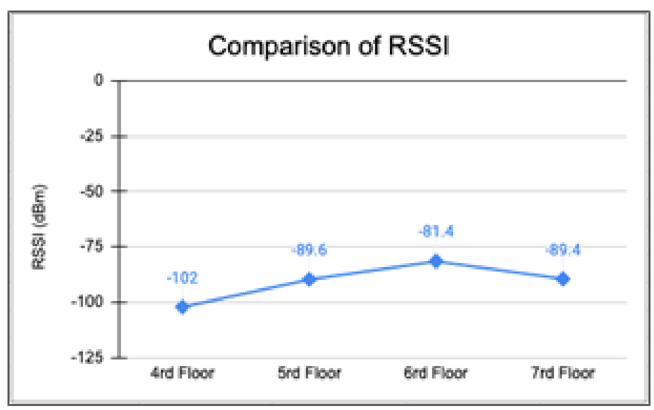

Figure 9. Average RSSI value for each floor

2) Outdoor testing

This test is carried out outside the building in placing the *Sending LoRa* and *Receiving LoRa* positions. Then, the

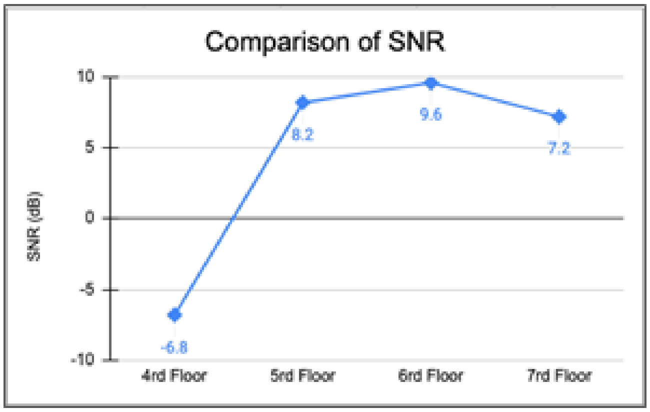

Figure 10. Average RSSI value for each floor

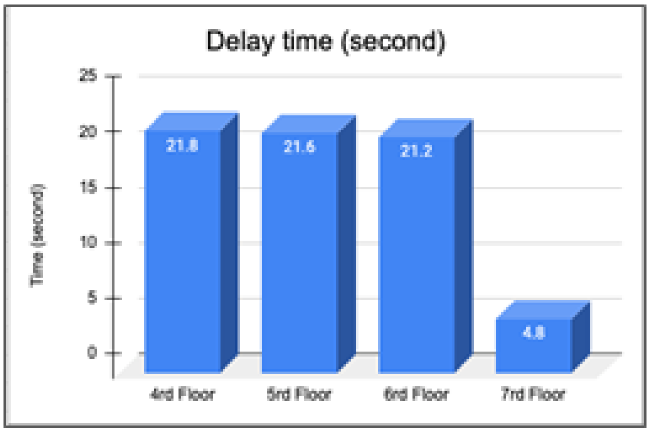

Figure 11. Average delivery time lag

test is started by conducting outdoor trials as shown in Table II.

TABLE II. Outdoor test scenario

No	Scenario
1	Putting the LoRa receiver at the gazebo of the middle prayer room.
2	Placing the LoRa sender at the Gazebo Tengah and attaching the RFID to the door access prototype 5 times.
3	Placing the LoRa sender at the Gazebo Taman and attaching the RFID to the door access prototype 5 times.
4	Calculates the waiting time between sending LoRa and receiving LoRa.
5	Compare the RSSI value and SNR value for each floor.

The outdoor testing is performed by placing the LoRa receiver in the *Gazebo Musholla(002)* with the first transmitter device on the *Gazebo Kantin Tengah POLINEMA(003)* with a total distance of 48.26 m. While the second transmitter device is placed in the *Gazebo Taman POLINEMA(001)* which has been visualized on *Google Maps* with a distance of 47.50 m as shown in Figure 12.

Figure 12. Visualization using *Google Maps*

The results of data retrieval taken from several different locations and distances are obtained based on Table III, the RSSI and SNR LoRa values will be better if the location and distance are closer to the gateway. The furthest distance in the room in the testing of this research system reaches a distance of 2 floors between the receiver and the gateway. Meanwhile, testing outside the room for data transmission cannot be carried out with a maximum distance of 133.17 meters by placing the device at a low altitude and using the standard antenna of the device from LoRa. These standard techniques, methods, and devices have not shown the potential of the LoRa module which is claimed to be able to transmit data over a distance of 10 km. The placement of the receiving LoRa device can be seen in Figure 15, and the sending LoRa device can be seen in Figure 13 and Figure 14.

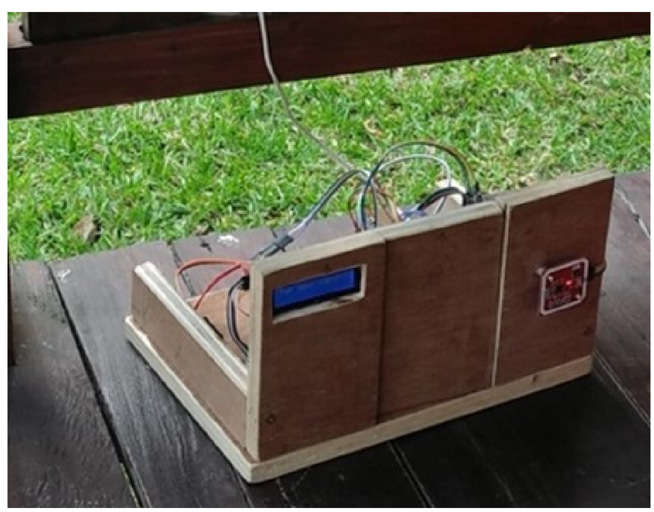

Figure 13. Lora sender at the *Gazebo Tengah*

TABLE III. Outdoor measurement

ID	Place	Distance (meter)	RSSI (dBm)	SNR (dB)	Time delay (s)
003	*Gazebo Kantin Tengah*	1	-48	10	5
001	*Gazebo Taman*	1	-47	9	4
003	*Gazebo Kantin Tengah*	48.26	-95	3	22
001	*Gazebo Taman*	47.50	-92	6	21

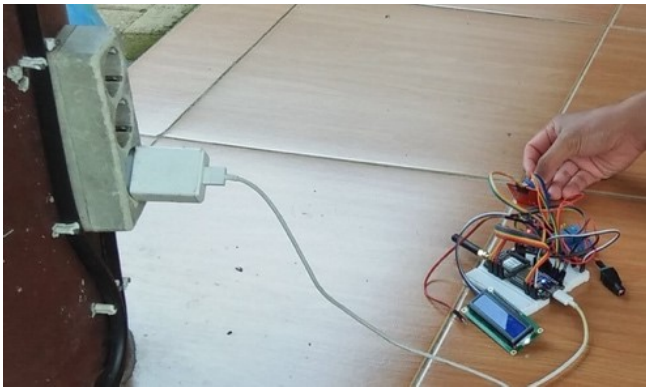

Figure 14. Lora sender at the *Gazebo Taman*

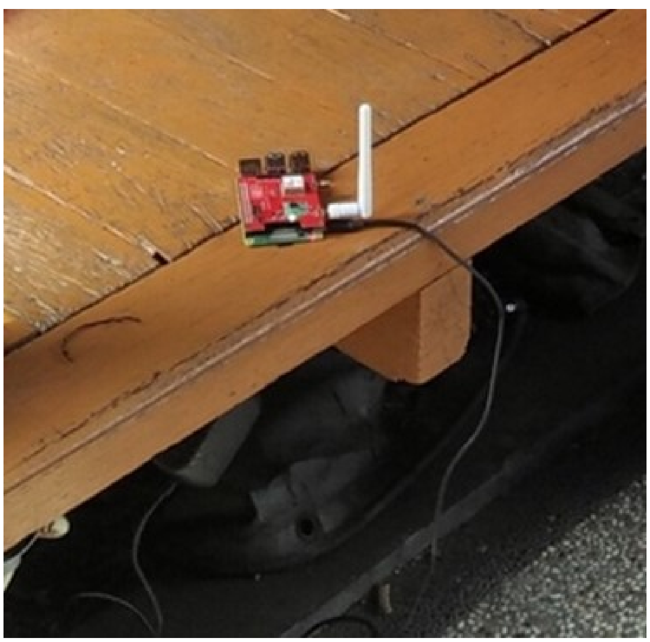

Figure 15. Recipient LoRa at the *Gazebo Musholla*

B. Discussion

The use of LoRa is still not able to provide a solution for sending attendance data. From the results of tests carried out both indoors and outdoors, it still does not show the expected distance. In addition to the standard LoRa device configuration, for example, the use of antennas on the default LoRa sending and receiving LoRa. Another factor that causes the placement of the receiving LoRa and the sending LoRa at the location is blocked by tall buildings or buildings.

Even though information on the use of LoRa can be presented in this study, it still needs to be supplemented with more detailed test parameters. For example, the sender distance parameter should be tested at shorter intervals (1 meter, 10 meters, 20 meters, and beyond until it is unreachable). In addition to the distance parameter, the *Spread Factor (SF)*, bandwidth, and *Time on Air (ToA)* parameters should also be included.

Other similar technologies can be implemented, for example using the *Narrow Band Internet of Things* (NB-IoT). *NB-IoT* technology has characteristics such as power-saving technology, strong coverage technology, large connection technology, and low cost. This technology needs to be considered when LoRa is not able to meet the expected needs. The use of *LoRAWAN architecture*[37], [38] also needs to be used in order to be able to take advantage of more nodes being used, because currently it still uses a peer-to-peer architecture with the limitation of not being able to send data simultaneously.

While the data contained in RFID tags are already secured with key security, using a *Secure Access Module (SAM) device* for security would be an even better approach[39], [40].

6. Conclusion

In this paper, we have analyzed data on the use of LoRa in data communication both indoors and outdoors. Based on the results of tests that have been carried out, the RSSI value at each point of the test location has been determined. The closer the transmitter is to the receiver or gateway, the stronger the value. Then, the farther the distance between the transmitter and receiver, the delay in data transmission time will increase by 0.2 seconds on the average time delay test. The use of the LoRa module will be suitable for an outdoor environment that is not obstructed by buildings, walls, or other obstacles that can cause attenuation or reduction in the signal quality of the LoRa module. RFID is very helpful for recording attendance because it can store data, making it easy to read data from an RFID reader. Under these conditions, there is no need to connect first to find the appropriate information based on the UID read. RFID readers attached to a microcontroller are cheaper than cellphones or even computer devices. Then, the LCD can display information on application conditions directly.

For further research, so that the LoRa performance can be farther away, it is necessary to add a *LoRa Fiber-Glass antenna*[41] and a higher quality LoRa concentrator module[24]. Another alternative that can be done is to use technology such as NB-IoT[42].

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