SECURITY SYSTEM USING LORA TRANSMISSION : APPLICATIONS IN WAREHOUSE

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ABSTRACT

The widespread theft of storage warehouses, especially in rural areas, rarely supported by communication technology. A system was created to improve the security of storage warehouses with LoRa transmissions capable of sending data remotely. When there is an open warehouse door, this system will send the data to the warehouse owner's house with LoRa transmission in the form of open door information to detect theft early. The LoRa transmission test results in the early morning hours resulted in a success rate of 99.61% at a distance of 1.40 Km and a success percentage of 99.06% at a distance of 2.15 Km. The entire system has been tested at a distance of 1.4 Km, and the early morning hours resulted in a percentage success of 95.15%. An error occurred due to packet loss. As evidenced by the further distance of the test, the percentage of success will be reduced. Besides that, cellular connections around the testing area also affect. Where in the afternoon, cellular network traffic is denser compared to the early morning hours. As evidenced by the results of testing in the afternoon, there was a decrease in the percentage success by 5%. Overall, the security system created and tested resulted in the conclusion that the security system in this study had shown promising results.

Keywords: *LoRa, Security, Theft, Wireless, Android.*

1. INTRODUCTION

Many criminal cases happened in rural areas are due to the lack of existing security systems, such as the theft of a storage warehouse in Masaran, Sragen. In the case of theft, the warehouse owner suffered a loss of Rp. 307,450,000, (Radar Solo, 2019). The theft occurred due to the warehouse's lack of security so that thieves could quickly enter the warehouse. The Indonesian Police divide theft cases into three categories: motor vehicle theft, weighted theft, and violent theft (Zahra, 2019). Of the three types of theft, weighted theft is the most frequent. Theft in storage warehouses, especially in rural areas, is included in the category of weighted theft.

According to data from Polda Metro Jaya, during 2017, there were thefts with a weighting of 2043 cases, and in 2018 there was a decrease in the number of theft cases with a weighting of 1584 cases (Polda Metro Jaya, 2018). Even though there has been a decrease in the number of theft cases, it can be said that theft cases with weighting are still huge.

Seeing many thefts with weight, it is necessary to design a storage warehouse security system by monitoring existing warehouses in a rural environment in real-time when the owner is left so that theft activities can be detected early. To support a storage warehouse security system, communication is needed between warehouse owners who will receive information from the left warehouse.

In this research, a security system will be built using LoRa transmission to send information from the warehouse to the warehouse owner's house. The use of LoRa transmission is expected to solve the problem of distance in rural environments. To increase the level of warehouse security, a limit switch sensor used and will be placed on three warehouse doors which will be integrated with a microcontroller, as well as an android application connected to the microcontroller using a local wifi network which aims to indicate the warehouse is empty or not. Communication is used to connect three sensor nodes installed at each warehouse door and one gateway using a local wifi network. So that the four microcontrollers are integrated on one local wifi network, and there is one microcontroller that serves as a gateway to receive data from three sensor nodes and sends all sensor information to the coordinator in the warehouse owner's house using LoRa transmission and provides information on data received through LCD, LED, and Buzzer in the warehouse owner's house.

2. METHODOLOGY

According to (Yunus, 2018), the advantages of LoRa are the technology that combines the advantages of cellular communication and BLE, which has low power but can communicate over long distances. However, in terms of speed, LoRa only has a transmission speed of 0.3-50 kbps. This study will send data with a small size to minimize data loss during the sending process.

The LoRa equipment to be used refers to the Regulation of PERDIRJEN SDPPI No. 3 of 2019 concerning LPWA (Low power wide area) must meet the main characteristics, namely radio frequency bands with 920-923 MHz vulnerable (Kominfo, 2019).

In this study using LoRa with a frequency of 920 MHz, the frequency used is still included in the category according to government regulations. Several antennas can be used with LoRa devices. In this study, the antenna used is a 915 MHz SMA male connector with a gain of 3 dBi, which has Linear polarization.

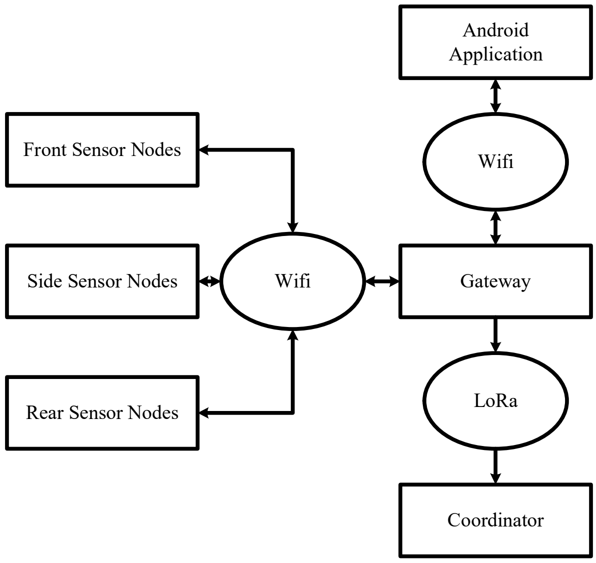

Figure 1. Design Model

a. Sensor Nodes

In this study, the number of sensor nodes used is three sensor nodes consisting of front nodes, side nodes, and back nodes. All nodes have the same function, which is to detect the warehouse door's status through the limit switch sensor. Each sensor node is equipped with a wifi communication module which is used as a path for sending sensor data from the sensor node to the gateway, which will then proceed to the coordinator via LoRa transmission and the LED as a marker of the system status in an active or inactive condition

b. Android application

The android application functions as an input device wherein the android application that will be made there are three input buttons, namely:

- Check Status: This is a button that is used to check the current condition of the system, whether it is active or not
- Active Mode: is the button used to indicate the warehouse is empty
- Inactive Mode: is a button that indicates the warehouse owner is already in his warehouse

c. Gateway

In this study, the gateway is a device that serves as a bridge between data communication in the warehouse to the warehouse owner's house with point-to-point communication. The sensor node data will be sent to the gateway via a wifi network and will be sent to the coordinator who is at the owner's house via LoRa communication. The gateway is also in charge of activating and deactivating all sensor nodes' function, where if there is warehouse data input in an empty state, all sensor nodes will be active and send data to the gateway, which will be continued to the coordinator. If the gateway receives input, it is safe, and then the gateway will deactivate the function from all sensor nodes in the warehouse through LED notifications.

d. Coordinator

The coordinator serves as the final destination for sending data. The coordinator is located at the warehouse owner's house and is responsible for receiving the gateway's data via LoRa transmission. The data received by the coordinator will be processed to produce the information required by the warehouse owner. Information from the data received will be conveyed by an output device in the form of an LED, LCD, and buzzer.

2.1 Hardware Design

The hardware design includes a schematic design that regulates the port on each module used, makes the circuit, and designs a prototype for each part, including sensor nodes, gateways, and coordinators.

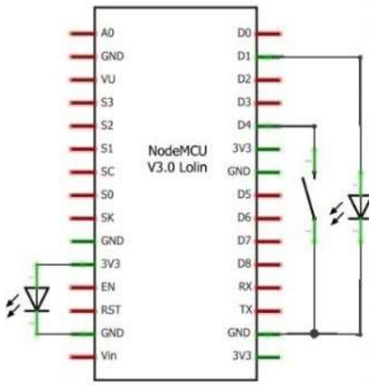

Figure 2. Schematic of Sensor Nodes

The limit switch on the sensor node is used to detect whether the warehouse door is open or closed. The limit switch has a normally closed and normally open condition, wherein in this study, the usually close condition is used. In the sensor node circuit, there are two LEDs, a red LED, and a white LED. The red LED on a series of sensor nodes is used to indicate standby status. The red LED will turn off when the status of the system is off and will light up when the system status is active or on standby.

Figure 3. Sensor Nodes Prototype

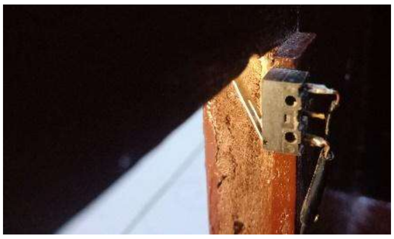

Figure 4. Placement of Limit Switch Sensor

Figure 5. Sensor Nodes Prototypes With Door

LoRa is used as a communication transmission from the warehouse to the owner's house. So that LoRa is only used at the gateway and coordinator as a point-to-point communication line. In the gateway circuit, there are two LEDs, a red LED, and a white LED. The red LED on the gateway circuit indicates the standby status or safe status received from the android application. The red LED will turn off when the system's status is off and will light up when the system status is active or on standby.

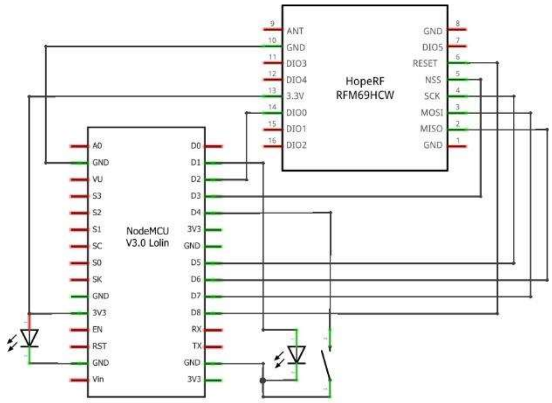

Figure 6. Schematic of Gateway

Figure 7. Gateway Prototype

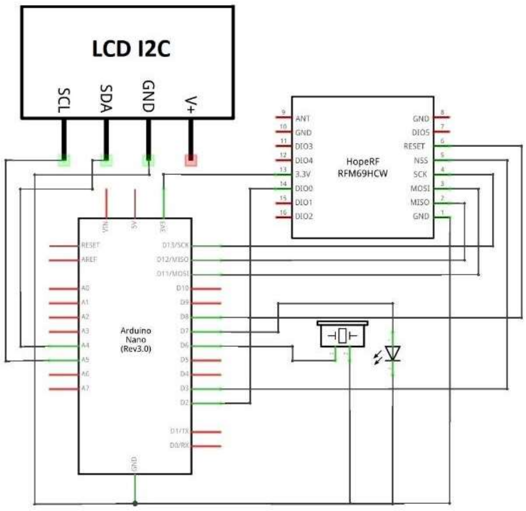

Figure 8. Schematic of Coordinator

LoRa on the coordinator is used as a communication transmission from the warehouse to the owner's house so that the coordinator can receive data sent from the gateway. The I2C LCD circuit is located on the coordinator as an output means to display the system status and warehouse doors. The buzzer circuit is used to indicate the detected status of theft. In the coordinator series, there is a red LED to indicate standby status. The red LED will turn off when the system's status is off and will light up when the system status is active or on standby.

Figure 9. Coordinator Prototype

2.2 Software Design

In this study, several data communication flows exist in the system, starting from the application to being received by the coordinator.

The communication flow in the system starts from sending data in the application, sent to the gateway using wifi communication. The data sent is data on the communication system's status on or off, obtained from pressing a button on the application.

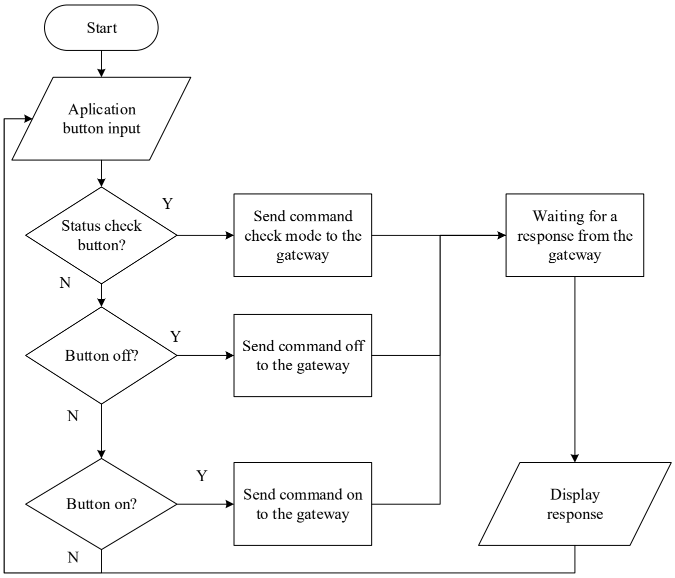

Figure 10. Android Application Flowchart

After the gateway gets an active or inactive status from the application, the gateway will forward the data to the sensor nodes alternately through the wifi network. The gateway will wait for a response from node one in sensor data from the gateway communication to node one. After the gateway receives sensor data from node one, the gateway will communicate to node two and wait for a response and communications made to node three after receiving the data sensor from node two. All sensor data collected at the gateway results from communication at nodes one, two, and three alternately.

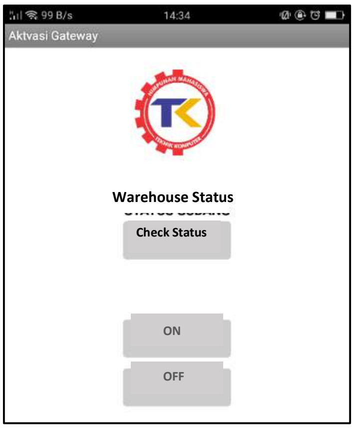

Figure 11. Android Application Display

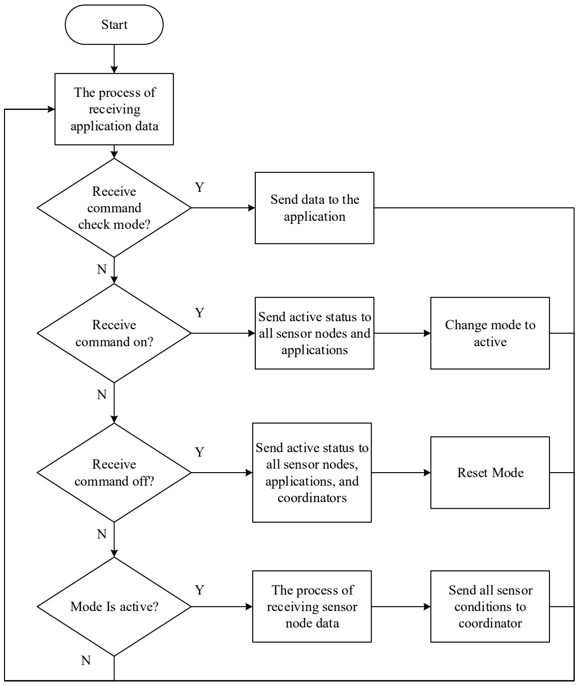

Figure 12. Gateway Flowchart

The data type used in sending to the coordinator is a byte where the goal is to send the minor possible data to minimize the occurrence of data loss. In 1 byte consists of 8 binary bits, which only use four binary bits from bits 0 to bit 3, as shown in Table 1.

Table 1. Binary Data Arrangement

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	0	0	0	Status mode	Back door status	Side door status	Rear door status

Explanation of the binary values 0 to binary 3 used in the algorithm:
- Status mode: 0 indicates off status, 8 indicates active status
- Front door status: 0 indicates front door closed, 1 indicates front door open status
- Side door status: 0 indicates the side door is closed, 2 indicates the side door is open
- Rear door status: 0 indicates the rear door is closed, 4 indicates the back door is open

The sensor node will receive active or inactive status data from the gateway. If there is active status data, the sensor node will read the sensor status at the warehouse door and send it to the gateway via the wifi network. If there is inactive status data, the gateway will stop sending door status data to the gateway.

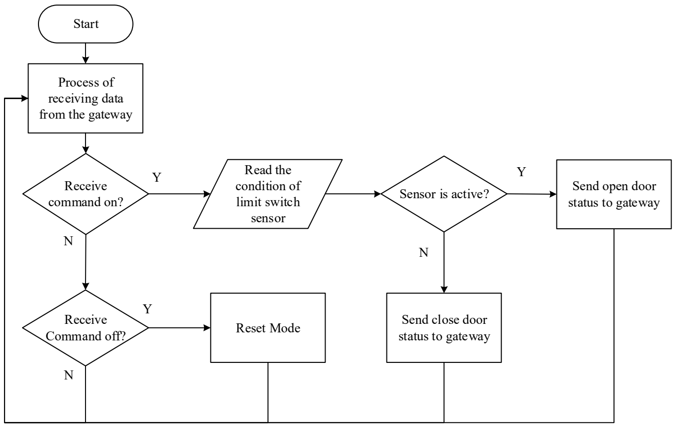

Figure 13. Sensor Nodes Flowchart

After the gateway gets the door status data from the sensor node, the gateway will send the door status data to the coordinator via LoRa transmission, which will then be displayed to the coordinator using LCD, LED, and buzzer as notification.

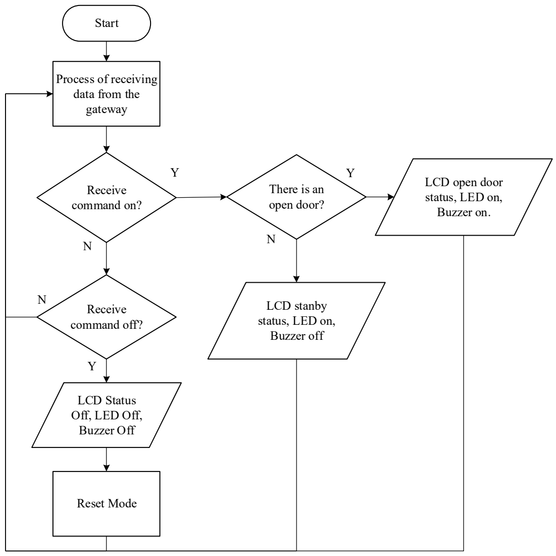

Figure 14. Coordinator Flowchart

3. RESULT AND DISCUSSION

3.1 Android Application

This test aims to ensure that communication between the gateway and the android application using wifi can run well.

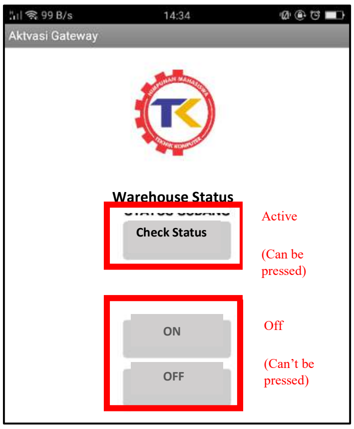

Figure 15. The Initial View of The Application

Figure 15 shows the initial display of the android application. There is one active button, namely the check system status button, to determine the current system condition so that there are no errors in activating or deactivating the system.

Figure 16 shows the display after pressing the on button. After the button is pressed, the off button and the system status check button are active, while the on button is in a disabled condition. After sending the data to the gateway, the android application will respond from the gateway in the form of the current system status.

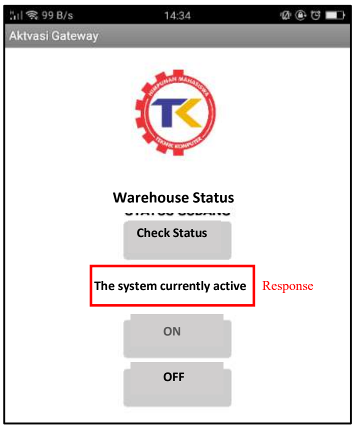

Figure 16. When System is Active

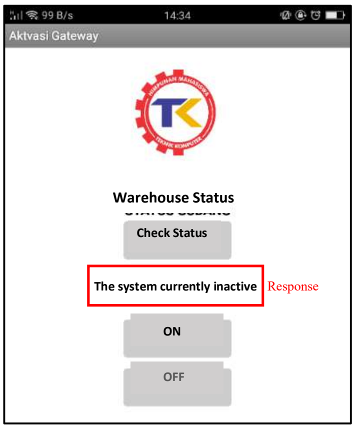

Figure 17. When System is Inactive

Figure 17 shows the display after pressing the off button. After the off button is pressed, the on and system status check button are in an active condition while the off button is in a disabled condition.

Table 2 shows the results of the serial monitor on the gateway. The serial monitor on the gateway displays the gateway's response to the data received from the application. When the check status button is pressed, the gateway will send the current system status. When the on button is pressed, the gateway sends the status "owner leaves" to the application, and when the off button is pressed, the gateway will send the status "owner is present" to the application.

Table 2. Serial Monitor Result

Time	Application Button	Serial Monitor Result on The gateway
12:43:31	Check Status Button	The Owner is There
12:43:38	On Button	Owner Away
12:43:56	Off button	The Owner is There

The android application testing results showed that the application could send data to the gateway using wifi communication, and the gateway can send responses to the android application according to the flowchart that has been made.

3.2 Wifi Communication

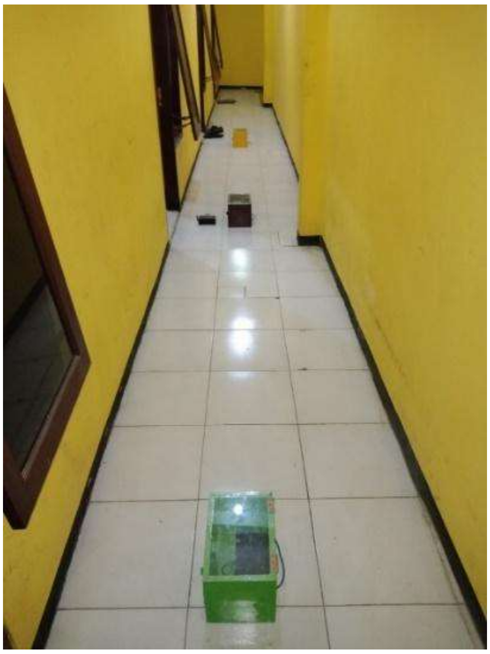

Figure 18. Wifi Communication Test Placement

The first test is carried out by providing a distance of 5 meters between the front door, side door, and rear door nodes, as shown in Figure 18. The test procedure includes testing all possibilities of the three open doors as shown in the input and output tables.

Table 3. Testing Wifi Standby Status

Time	Mode	Data Sent			Receive	System Status	Result
		Rear	Side	Front	Total		
09:20:15.839	8	0	0	0	8	Stanby	Correct
09:20:16.636	8	0	0	0	8	Stanby	Correct
09:20:17.480	8	0	0	0	8	Stanby	Correct
09:20:18.323	8	0	0	0	8	Stanby	Correct
09:20:19.120	8	0	0	0	8	Stanby	Correct

Table 4. Testing Status of Front Door Open

Time	Mode	Data Sent			Receive	System Status	Result
		Rear	Side	Front	Total		
09:20:25.167	8	0	0	1	9	Front	Correct
09:20:25.917	8	0	0	1	9	Front	Correct

09:20:26.714	8	0	0	1	9	Front	Correct
09:20:27.511	8	0	0	1	9	Front	Correct
09:20:28.355	8	0	0	1	9	Front	Correct

Table 5. Testing Status of Side Door Open

Time	Mode	Data Sent			Receive	System Status	Result
		Rear	Side	Front	Total		
09:20:46.964	8	0	2	0	10	Side	Correct
09:20:47.808	8	0	2	0	10	Side	Correct
09:20:48.605	8	0	2	0	10	Side	Correct
09:20:49.448	8	0	2	0	10	Side	Correct
09:20:50.292	8	0	2	0	10	Side	Correct

Table 6. Testing Status of Front and Side Door Open

Time	Mode	Data Sent			Receive	System Status	Result
		Rear	Side	Front	Total		
09:21:05.292	8	0	2	1	11	Front, Side	Correct
09:21:06.089	8	0	2	1	11	Front, Side	Correct
09:21:06.886	8	0	2	1	11	Front, Side	Correct
09:21:07.636	8	0	2	1	11	Front, Side	Correct
09:21:08.386	8	0	2	1	11	Front, Side	Correct

Table 7. Testing Status of Rear Door Open

Time	Mode	Data Sent			Receive	System Status	Result
		Rear	Side	Front	Total		
09:21:51.417	8	4	0	0	12	Rear	Correct
09:21:52.261	8	4	0	0	12	Rear	Correct
09:21:53.058	8	4	0	0	12	Rear	Correct
09:21:53.808	8	4	0	0	12	Rear	Correct
09:21:54.558	8	4	0	0	12	Rear	Correct

Table 8. Testing Status of Rear and Front Door Open

Time	Mode	Data Sent			Receive	System Status	Result
		Rear	Side	Front	Total		

09:22:15.651	8	4	0	1	13	Rear, Front	Correct
09:22:16.448	8	4	0	1	13	Rear, Front	Correct
09:22:17.292	8	4	0	1	13	Rear, Front	Correct
09:22:18.136	8	4	0	1	13	Rear, Front	Correct
09:22:18.933	8	4	0	1	13	Rear, Front	Correct

Table 9. Testing Status of Side and Front Door Open

Time	Mode	Data Sent			Receive	System Status	Result
		Rear	Side	Front	Total		
09:22:48.933	8	4	2	0	14	Rear, Side	Correct
09:22:49.729	8	4	2	0	14	Rear, Side	Correct
09:22:50.573	8	4	2	0	14	Rear, Side	Correct
09:22:51.370	8	4	2	0	14	Rear, Side	Correct
09:22:48.933	8	4	2	0	14	Rear, Side	Correct

Table 10. Testing Status All Door Open

Time	Mode	Data Sent			Receive	System Status	Result
		Rear	Side	Front	Total		
09:23:34.073	8	4	2	1	15	All Open	Correct
09:23:34.870	8	4	2	1	15	All Open	Correct
09:23:35.714	8	4	2	1	15	All Open	Correct
09:23:36.558	8	4	2	1	15	All Open	Correct
09:23:37.354	8	4	2	1	15	All Open	Correct

Table 3 to 10 show the results of all the possibilities that exist. From these results, it can be seen that the gateway can receive all data sent from all sensor nodes. After succeeding with a 100% proportion in testing a distance of 5 meters, the test is carried out at a longer distance to determine the maximum distance from wifi communication using nodeMCU. The next test is carried out at a distance of 20 and 25 meters using the gateway as the receiver and the front node as the sender.

Table 11 results from testing wifi communication at a distance of 5, 20, and 25 meters. It can be abbreviated that the safe distance for implementing sensor nodes is less than or equal to 20 meters.

Table 11. Testing Status All Door Open

Distance	Percentage of Success	Percentage of Error
5 Meter	100%	0%
20 Meter	100%	0%
25 Meter	96,67%	3,33%

3.3 LoRa Communication

The first test in LoRa communication was carried out between the Merr Bridge and the Nginden Bridge in Surabaya, which is 1.40 Km away. Testing is done by sending data from the gateway to the coordinator in binary data 0-255 as many as five times with a delay of 500 ms for each data sent.

Table 12 shows ten initial data from 1280 data. Testing is carried out at a distance of 1.40 km with LoRa communication. From the test results of sending binary data, some data do not match the data sent.

$$Percentage\ of\ Success = \left(\frac{1275}{1280}\right) * 100 = 99{,}61\% \quad (1)$$

Table 12. LoRa Testing at a Distance of 1.40 Km

Time	Data Sent from Gateway	Receive by Coordinator	RSSI	Result
01:51:41.053	0	0	-120	Correct
01:51:41.568	1	1	-120	Correct
01:51:42.131	2	2	-120	Correct
01:51:42.647	3	3	-120	Correct
01:51:43.162	4	4	-120	Correct
01:51:43.678	5	5	-119	Correct
01:51:44.240	6	6	-119	Correct
01:51:44.756	7	7	-119	Correct
01:51:45.272	8	8	-120	Correct
01:51:45.787	9	9	-120	Correct

The second test was carried out between the Merr Bridge and the Jiwo Long Bridge in Surabaya, which is 2.15 Km away. The test is carried out with the same scheme as the previous test, only with a difference in the gateway and coordinator distance.

Table 13 shows ten initial data from 1280 data. Testing is done by sending data from a distance of 2.15 Km with LoRa communication. From the test results of sending binary data, some data do not match the data sent.

$$Percentage\ of\ Success = \left(\frac{1268}{128}\right) * 100 = 99{,}06\% \quad (2)$$

Table 13. LoRa Testing at a Distance of 2.15 Km

Time	Data Sent from Gateway	Receive by Coordinator	RSSI	Result
02:30:28.146	0	0	-113	Correct
02:30:28.584	1	1	-119	Correct
02:30:29.099	2	2	-120	Correct
02:30:29.615	3	3	-120	Correct
02:30:30.177	4	4	-120	Correct
02:30:30.693	5	5	-119	Correct

02:30:31.209	6	7	-118	Correct
02:30:31.724	7			*Error*
02:30:32.287	8	8	-119	Correct
02:30:32.802	9	9	-118	Correct

The third test was carried out between the Merr Bridge and the Nginden Bridge in Surabaya, which is 1.40 Km. If the first and second tests are carried out in the early hours of the morning when it is not crowded from vehicles or other signal activity, the third test is carried out in the afternoon when the conditions are crowded with the same test scheme.

Table 14 shows ten initial data from 1280 data. Testing is done by sending data from a distance of 1.40 km with LoRa communication. From the test results of sending binary data, some data do not match the data sent.

$$Percentage\ of\ Success = \left(\frac{1211}{1280}\right) * 100 = 94{,}61\% \quad (3)$$

Although there was a decrease in the percentage of success in the afternoon test, the decrease in quality was only 5% and not too far from the early morning test results.

Table 14. LoRa Testing in The Afternoon

Time	Data Sent from Gateway	Receive by Coordinator	RSSI	Result
17:01:46.774	0			*Error*
17:01:47.282	1			*Error*
17:01:48.324	2	2	-122	Correct
17:01:48.865	3	3	-121	Correct
17:01:50.455	4			*Error*
17:01:50.964	5	5	-123	Correct
17:01:51.472	6	6	-122	Correct
17:01:52.011	7			*Error*
17:01:52.552	8			*Error*
17:01:53.057	9	9	-120	Correct

3.4 Entire System

Testing the whole system is done by looking at the best results from the previous test, namely sending data from the Merr Bridge to the Nginden Bridge with a distance of 1.40 Km and carried out in the early hours of the morning in order to get maximum results.

Table 15. Testing Status of Front Door Open

Time	Send	Receive	LCD Status	Buzzer	LED	RSSI	Result
03:23:34.020	8	8	System Standby	Off	Active	-110	Correct
03:23:34.771	8	8	System Standby	Off	Active	-110	Correct
03:23:35.527	8	8	System Standby	Off	Active	-110	Correct
03:23:36.286	8	8	System Standby	Off	Active	-110	Correct

03:23:37.015	8	8	System Standby	Off	Active	-110	Correct
03:23:40.026	9	9	Front Door Open	Active	Active	-110	Correct
03:23:40.783	9	9	Front Door Open	Active	Active	-110	Correct
03:23:41.534	9		Front Door Open	Active	Active		*Error*
03:23:42.339	9		Front Door Open	Active	Active		*Error*
03:23:43.151	9	9	Front Door Open	Active	Active	-110	Sesuai

Table 16. Testing Status of Side Door Open

Time	Send	Receive	LCD Status	Buzzer	LED	RSSI	Result
03:29:17.923	8	8	System Standby	Off	Active	-104	Correct
03:29:18.728	8	8	System Standby	Off	Active	-111	Correct
03:29:19.586	8	8	System Standby	Off	Active	-112	Correct
03:29:20.389	8	8	System Standby	Off	Active	-111	Correct
03:29:21.150	8	8	System Standby	Off	Active	-110	Correct
03:29:22.688	10	10	Side Door Open	Active	Active	-111	Correct
03:29:24.219	10	10	Side Door Open	Active	Active	-111	Correct
03:29:24.985	10	10	Side Door Open	Active	Active	-111	Correct
03:29:25.742	10	10	Side Door Open	Active	Active	-111	Correct
03:29:26.492	10	10	Side Door Open	Active	Active	-110	Correct

Table 17. Testing Status of Front and Side Door Open

Time	Send	Receive	LCD Status	Buzzer	LED	RSSI	Result
03:33:21.453	8	8	System Standby	Off	Active	-111	Correct
03:33:22.207	8	8	System Standby	Off	Active	-111	Correct
03:33:22.958	8	8	System Standby	Off	Active	-111	Correct
03:33:23.677	8	8	System Standby	Off	Active	-110	Correct
03:33:25.324	8	8	System Standby	Off	Active	-111	Correct
03:33:28.620	11	11	Front,Side Open	Active	Active	-111	Correct
03:33:29.478	11	11	Front,Side Open	Active	Active	-110	Correct
03:33:30.284	11	11	Front,Side Open	Active	Active	-110	Correct
03:33:31.089	11		Front,Side Open	Active	Active		Error
03:33:31.893	11	11	Front,Side Open	Active	Active	-110	Correct

Table 18. Testing Status of Rear Door Open

Time	Send	Receive	LCD Status	Buzzer	LED	RSSI	Result
03:33:21.453	8	8	System Standby	Off	Active	-111	Correct
03:33:22.207	8	8	System Standby	Off	Active	-111	Correct
03:33:22.958	8	8	System Standby	Off	Active	-111	Correct
03:33:23.677	8	8	System Standby	Off	Active	-110	Correct
03:33:25.324	8	8	System Standby	Off	Active	-111	Correct
03:33:28.620	12	12	Rear Door Open	Active	Active	-111	Correct
03:33:29.478	12	12	Rear Door Open	Active	Active	-110	Correct
03:33:30.284	12		Rear Door Open	Active	Active		Error
03:33:31.089	12		Rear Door Open	Active	Active		Error
03:33:31.893	12	12	Rear Door Open	Active	Active	-110	Correct

Table 19. Testing Status of Rear and Front Door Open

Time	Send	Receive	LCD Status	Buzzer	LED	RSSI	Result
03:37:17.109	8	8	System Standby	Off	Active	-111	Correct
03:37:17.861	8	8	System Standby	Off	Active	-111	Correct
03:37:18.620	8	8	System Standby	Off	Active	-111	Correct
03:37:20.278	8	8	System Standby	Off	Active	-111	Correct
03:37:21.082	8	8	System Standby	Off	Active	-111	Correct
03:37:21.939	13	13	Front, Rear Open	Active	Active	-111	Correct
03:37:23.594	13	13	Front, Rear Open	Active	Active	-105	Correct
03:37:24.397	13	13	Front, Rear Open	Active	Active	-110	Correct
03:37:25.203	13	13	Front, Rear Open	Active	Active	-111	Correct
03:37:26.006	13	13	Front, Rear Open	Active	Active	-110	Correct

Table 20. Testing Status of Rear and Side Door Open

Time	Send	Receive	LCD Status	Buzzer	LED	RSSI	Result
03:42:16.652	8	8	System Standby	Off	Active	-111	Correct
03:42:17.457	8	8	System Standby	Off	Active	-111	Correct
03:42:18.318	8	8	System Standby	Off	Active	-110	Correct
03:42:19.124	8	8	System Standby	Off	Active	-111	Correct
03:42:19.929	8	8	System Standby	Off	Active	-109	Correct
03:42:20.787	14	14	Side, Rear Open	Active	Active	-111	Correct

03:42:21.591	14	14	Side, Rear Open	Active	Active	-110	Correct
03:42:22.396	14		Side, Rear Open	Active	Active		Error
03:42:23.201	14	14	Side, Rear Open	Active	Active	-110	Correct
03:42:24.004	14	14	Side, Rear Open	Active	Active	-110	Correct

Table 21. Testing Status of All Door Open

Time	Send	Receive	LCD Status	Buzzer	LED	RSSI	Result
03:44:49.747	8	8	System Standby	Off	Active	-112	Correct
03:44:50.498	8	8	System Standby	Off	Active	-111	Correct
03:44:51.256	8	8	System Standby	Off	Active	-111	Correct
03:44:52.061	8	8	System Standby	Off	Active	-105	Correct
03:44:53.725	8	8	System Standby	Off	Active	-110	Correct
03:44:54.564	15	15	All Door Open	Active	Active	-111	Correct
03:44:55.385	15	15	All Door Open	Active	Active	-111	Correct
03:44:56.189	15	15	All Door Open	Active	Active	-112	Correct
03:44:56.993	15	15	All Door Open	Active	Active	-111	Correct
03:44:57.844	15	15	All Door Open	Active	Active	-112	Correct

Tables 15 to 21 show the results of all the possibilities that exist in the algorithm used.

Table 22. Result of The Entire System

Status	Percentage of Success	Percentage of Error
Front Door Open	96,89%	3,11%
Side Door Open	96,52%	3,48%
Front and Side Door Open	98,10%	1,90%
Rear Door Open	90,48%	9,52%
Front and Rear Door Open	98,98%	2,02%
Side and Rear Door Open	91,84%	8,16%
All Door Open	94,23%	5,77%

Table 22 shows the test results of the entire system. The whole system can work properly even though some data are missing or. Testing the entire system at a distance of 1.40 Km and early morning yields a total percentage of success of:

$$\left(\frac{96{,}89\% + 96{,}52\% + 98{,}10\% + \ 90{,}48\% + 97{,}98\% + 91{,}84\% + \ 94{,}23\%}{700\%}\right) * 100 = \ 666{,}0349 * 100$$
$$= 95{,}15\% \qquad (4)$$

4. CONCLUSIONS

The results of several security system tests that have been carried out have several conclusions, namely:

1. The gateway can communicate with the sensor node via a wifi network by sending active system data to the sensor node, and the sensor node will send a reply in the form of door status data to the gateway. The sensor nodes will continue to send door status data as long as the gateway sends no inactive system data. The results of testing communication gateways and sensor nodes via a wifi network can run well at a distance of 5-20 meters and produce a success percentage of up to 100%.
2. The gateway can receive all data sent by the sensor nodes via the wifi network by communicating alternately with all sensor nodes to get each door's status in the warehouse, and after all door status data has been collected, the gateway will send it to the coordinator via LoRa transmission.
3. Coordinator can receive data sent by Gateway via LoRa transmission well in the early hours of the morning and produce a success percentage of 99.61% at a distance of 1.40 Km and a success percentage of 99.06% at a distance of 2.15 Km.
4. Coordinator can display data received from the gateway correctly according to the output table that has been created.
5. Errors that occur due to packet loss. The distance from the delivery influences this, as evidenced by the farther the test distance, the percentage of success will decrease. Apart from that, the cellular connection around the test area is also influential. In the afternoon, the cellular network traffic is denser than in the early hours, as evidenced by the afternoon's test results, namely a decrease in the percentage of success by 5%.
6. Overall, the security system tested at a distance of 1.4 km and early morning results in a success percentage of 95.15%.

5. SUGGESTIONS

For further research, suggestions that can be used to develop the implementation of LoRa to make it even better include the following:

1. Using antenna specifications that can reach farther distances to reach the maximum distance from LoRa communications.
2. Test LoRa communication performance on several possible interferences such as buildings or trees to test signal resistance.
3. Analyze LoRa performance supporting parameters such as spreading factor, bandwidth to determine LoRa performance in specific environments.

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