Tourism Bike Tracking Design with The LoRaWAN Network Approach to The Meikarta Central Park Area

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Abstract

Technological developments in Indonesia are relatively rapid, and most people have become part of the Internet of Things era. There are a couple of new technologies in the Internet of Things, one of which uses long-range (LoRa) communication technology, a wireless delivery method using radio signals at a frequency of 433 MHz. Meikarta Central Park is a city park that provides tourist bicycle rentals. Problems often occur when visitors rent bicycles, resulting in tourist bicycles being lost or placed incorrectly. All these problems make it difficult for operators to find abandoned bicycle locations. This research develops a system to detect the location of Meikarta's tourist bicycles using a GPS tracker with an Arduino microcontroller based on a long-range working principle. On the other hand, the location point can be seen on the map's application so that the whereabouts of the bicycle can be known. The research results of the tracking from the tourist bicycle GPS tracker using LoRa were 5 test locations, the furthest range of 625 meters on the first tourist bicycle with an accuracy value of 11.2 meters. Meanwhile, the second tourist bike has the most extended range of 590 meters with an accuracy level of 4.4 meters.

Keywords: LoRaWAN, Lora Communication, Tracking System, Tracking Design, Tourism Bike Monitoring, IOT.

I. INTRODUCTION

Currently, green open space is necessary for human activities. One of the green open spaces is the Meikarta Central Park area, Bekasi Regency, Indonesia [1]. One thing that attracts attention is the tourist bicycle. Visitors do not need to bring bicycles of their own because there is a tourist bicycle rental facility for visitors who want to go around cycling and enjoy the beautiful park area and artificial lake there. However, since the operators cannot continuously monitor the tourist bicycles during rentals, they struggle to locate them, leading to a problem. Apart from that, problems often occur, such as bike tires leaking, loose chains, accidents, and cyclists getting tired of riding it [2]. These problems have caused visitors to abandon tourist bicycles on the cycling track in the Meikarta Central Park area. According to the Meikarta tourist bicycle rental operator, bicycles are not returned to the bicycle rental point every day in 2-3 cases.

Location searches can use a navigation tool called GPS (Global Positioning System) [3]. This tool is a monitoring system developed by the United States. This system provides information on position on coordinates [4][5]. Additionally, GPS provides speed and time information that many people can use. By utilizing IoT technology, searching for tourist bicycles can easily performed with the collaboration between the LoRa module and the GPS module [6][7]. These two modules can then be developed as a tool to help send the location from the tourist bicycle, called an end device, and then integrated with a gateway application server. Thus, developers created a bicycle tracking system [8] that monitors the bicycle's position based on coordinates sent using LoRaWAN communication.

Research on the use of Lorawan networks is advanced research on the application of the Internet of thing (IoT), where several similar studies have developed towards more advanced. Thae study [9] and [10] provides results on long-distance GPS tracking monitoring carried out using an application in the form of vehicle tracking. In line with this, this study has a similar impact to the object of searching for tourist bicycles. The other Studi [11], [12] and [13] provide an understanding of the nearest Lora navigation signal to provide green traffic in an emergency. Comparable to that, the principle of path mapping fixed similarities to the main focus of this study in the extent to which the Lorawan network can cover the tourist bicycle area and provide emergency signals when cyclists need help. Studies such as [14] and [15] illustrate that researchers can set LoRaWAN statically at each predetermined gate along the bicycle route. Unlike this study, we arrange it dynamically for the tourist bicycle route. The LoRaWAN Gateway module directly communicates with the LoRaWAN nodes, which researchers have calculated within the required turning radius of the LoRa network signal. Other studies, such as [16], illustrate how researchers combine LoRaWAN with Pi cameras to monitor animals passing through railroad crossings. We did not use the Pi Camera module in our research because it is not the main focus of this study. Other studies [17] and [18] focus on the Human Activity Recognition (HAR) system. The monitoring application approach using Activities of Daily Living (ADL) is the main focus for tracking and ensuring user safety. Our research has a similar impact, namely applying the Activities of Daily Living (ADL) approach to the tourist bike system. However, it offers better features, including real-time location notifications and integration with a buzzer to monitor conditions in the field for locating the tourist bike. Other studies, such as [19] and [20], discuss LoRaWAN-based disaster monitoring, focusing on signaling the locations affected by disasters. Because LoRaWAN operates locally, the infrastructure built is cost-effective and easy to implement. However, our research does not focus on disasters but on bicycle tourism based on real-time monitoring technology for users with the addition of emergency features in the Lora node module on each bicycle.

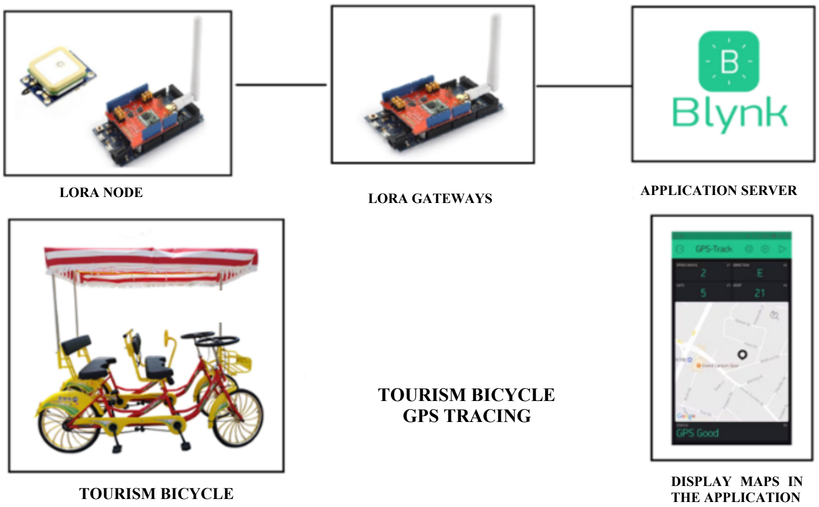

Figure 1. Bicycle Tracking

II. RESEARCH METHODS

The research model used in this study is research and development. This study is an implementation based on the basic theory of Lora networks applied to the aspect of tourist bicycles in Meikarta Park. Previously, we carried out simple modelling to determine how far the LoRa signal extends within the coverage of the turning radius. Furthermore, the researchers focus on conducting direct field surveys based on the interaction between LoRa nodes and LoRa gateways. The team prepared tools and materials, analyzed design results, and detected the bicycle's position by designing a tracking system for the tourist bicycle as shown in Figure 1. The data sender uses LoRa node hardware to design this bicycle tracking system. At the same time, LoRa Gateway is the data receiver [21], which later bypasses the data to the Blynk application [22] as a medium to simplify the location monitoring process. The LoRa node hardware installation on the bicycle frame lies on the underside of the tourist bicycle roof. The data on the LoRa node hardware will be sent by radio frequency connection to the LoRa gateway. After receiving data on the LoRa gateway, the gateway will forward the data to the network server application via Wi-Fi. After Blynk obtains the data, the final process is checking the location of the bicycle on maps and the location of the tourist bicycle and analyzing the results of the tourist bicycle tracking design [23][24]. The team will place the LoRa gateway hardware in the middle of the cycling area within the Meikarta Central Park area.

a. Procedure

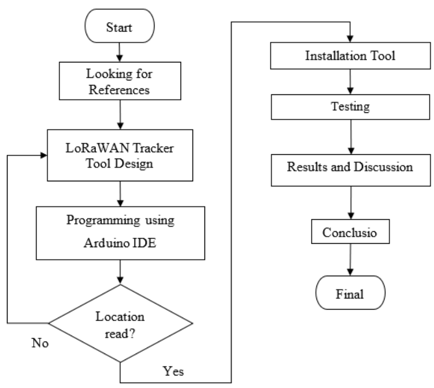

Figure 2. Flowchart of LoRaWAN – Tracking Design

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The flowchart in Figure 2 is a flow diagram designed for the bicycle tracking system. Literature studies in the initial stage facilitate the research. This research's focus is the same as that of [7], [18], [25], and [26]. Next is the design of the Lorawan module. The module uses Arduino Uno [27] as the main code, and the tracking module uses the NEO-6M GPS module [28]. Furthermore, the LoRa RA-02 module [29] is a communication module between each Node and Gateway in order to constantly update tracking in the Blink application with settings in such a way as to connect. We hope all the modules can work in detecting locations accurately. The team will redesign and recalibrate each module if a tracking error occurs. After all the work is complete and precise, the next stage is installing the Lora-tracking module on the object. The object used is the tourist bicycle in the Meikarta Central Park area. The team conducts the test carefully until they obtain the circuit and mathematical analysis results, which are the basis for conclusions.

b. Research Location

The research on tourist bicycles using the LoRaWAN approach is conducted in the Meikarta Central Park area in Jayamukti Village, Central Cikarang District, Bekasi Regency, West Java, Indonesia [3]. The following is a picture of the location of Meikarta Central Park:

Figure 3. Location of Meikarta Central Park

Figure 3 above shows the cycling area's location in Meikarta Central Park. The bicycle rental point is at the entrance, marked with 1. Meanwhile, the cycling route that includes the road around the artificial lake is marked with numbers 2, 3, 4, and 5, respectively, until it returns to the bicycle rental point.

c. LoRa Design

The hardware design below is a complete description of the tool for tracking the whereabouts of tourist bicycles using LoRa communication in the Meikarta Central Park area. Apart from the tourist bicycle, the components in this hardware also include LoRa nodes and LorRa gateways, as seen in Figure 4 and 5.

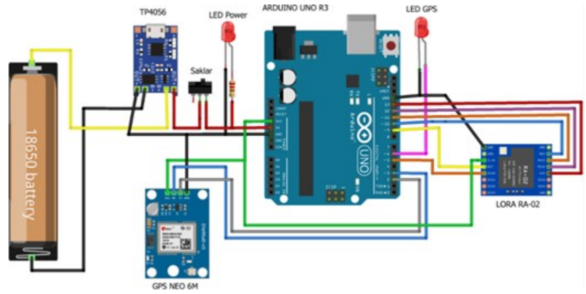

Figure 4. LoRa Gateway Wiring Design.

The LoRa node software is designed to send location data to the LoRa Gateway. When powered on, the LoRa Node device requests the current location data. If the location is available, the LoRa node sends the location data to the LoRa gateway. If there is no location data, it re-requests the latest location. The team designs the LoRa node software using Arduino IDE programming.

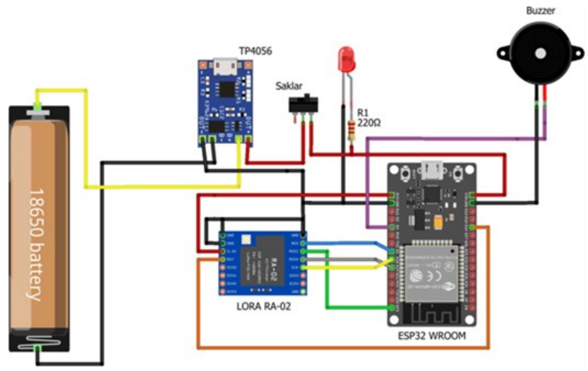

Figure 5. LoRa Node Wiring Design.

LoRa gateway software is designed and built to forward location packets from LoRa nodes to the Internet. When the GPS tracker is turned on, the LoRa Gateway will wait for the location data sent by the LoRa node. If the location data has been obtained, a validation check will be carried out for the data. When the location data becomes available, the system will send it to the Blynk application. The LoRa gateway software design itself uses Arduino IDE programming (Figure 6).

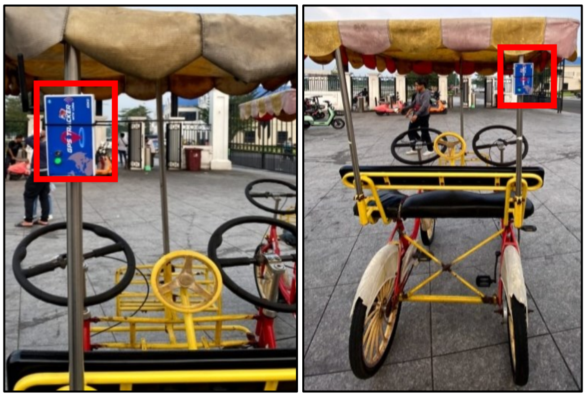
Figure 6. Installation of GPS Tracking 2 LoRa Node.

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d. Testing Stages

The testing stages performed in this research are as follows: First, the team tests the GPS tracker location readings using LoRaWAN. The team conducted this test to check the latitude and longitude readings from the GPS sensor, which can be sent using LoRa and displayed on the Blynk application at the specified location. The second research will test the Tourist Bicycle GPS Tracker Range with LoRaWAN. The team conducted this test to evaluate the reachable range in the design of the Meikarta Central Park tourist bicycle GPS tracker. Last, the accuracy of the tourist bicycle GPS tracker was tested by comparing the results of latitude and longitude data readings from predetermined points between the tourist bicycle GPS tracker and the GPS on the smartphone [30].

III. RESULT AND DISCUSSION

The implementation of the GPS Tracker system, which functions as a LoRa Node, is then attached to the tourist bicycles in Meikarta Central Park. There are 2 LoRa Nodes installed on each different tourist bicycle. Figure 7 below shows the results of the GPS tracker installation:

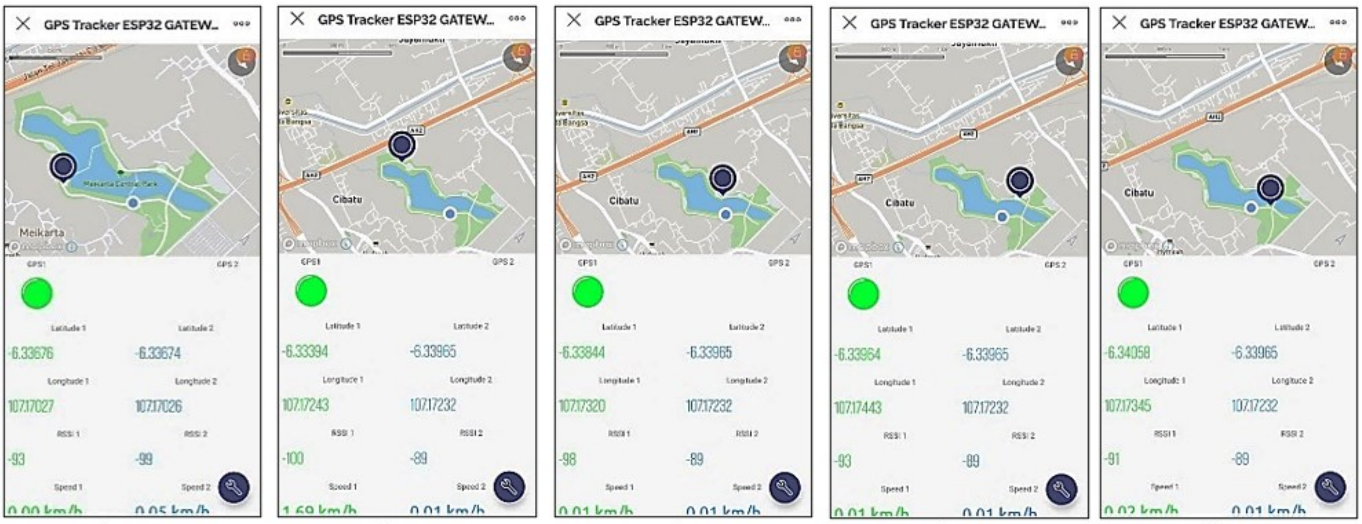
a. Function Testing using GPS Tracker Location by LoRaWAN connection

This test determined the success of designing a GPS tracker using LoRaWAN. The test showed a direct display of the coordinates on the bicycle at the predetermined point. Below is a table of the results of the tourist bicycle GPS tracker location reading in the Meikarta area, along with screenshots of the application display. Table 1 shows that the GPS tracker successfully reads the location of the tourist bike, as evidenced by the screen capture, demonstrating that the GPS tracker can operate effectively using LoRaWAN.

Figure 8 below shows the Blink application displaying the location plan, longitude, latitude, and RSSI on each touring bicycle. Received Signal Strength Indicator (RSSI) is a signal measurement unit based on the LoraWAN signal strength value set to cover the entire area [31]. This value ranges from 0 to -120 dBm. The prototype test results in Table 1 provide an overview of the RSSI value range, which falls between -89 dBm and -100 dBm. According to the TIPHON standardization for RSSI test results, the resulting value falls within a reasonable range. Based on the values obtained, the average RSSI value is -93 dBm.

Table 1. Tourist Bicycle GPS Tracker Location Reading Results.

Location Node	Lora Gateways		Tourist Bicycle 1		RSSI	Tourist Bicycle 2		RSSI
	Latitude	*Longitude*	*Latitude*	*Longitude*	*dBm*	*Latitude*	*Longitude*	*dBm*
1			-6.33676	107.17027	-93	-6.33674	107.17026	-99
2			-6.33394	107.17.243	-100	-6.33426	107.17249	-89
3	-6.339566	107.172323	-6.33844	107.17320	-96	-6.33815	107.17295	-89
4			-6.33964	107.17443	-93	-6.33959	107.17443	-89
5			-6.34058	107.17345	-91	-6.34065	107.17345	-89



1 2 3 4 5

Figure 7. Display on Blynk Based on GPS Tracker Using LoRaWAN Communication in 5 Node Locations.

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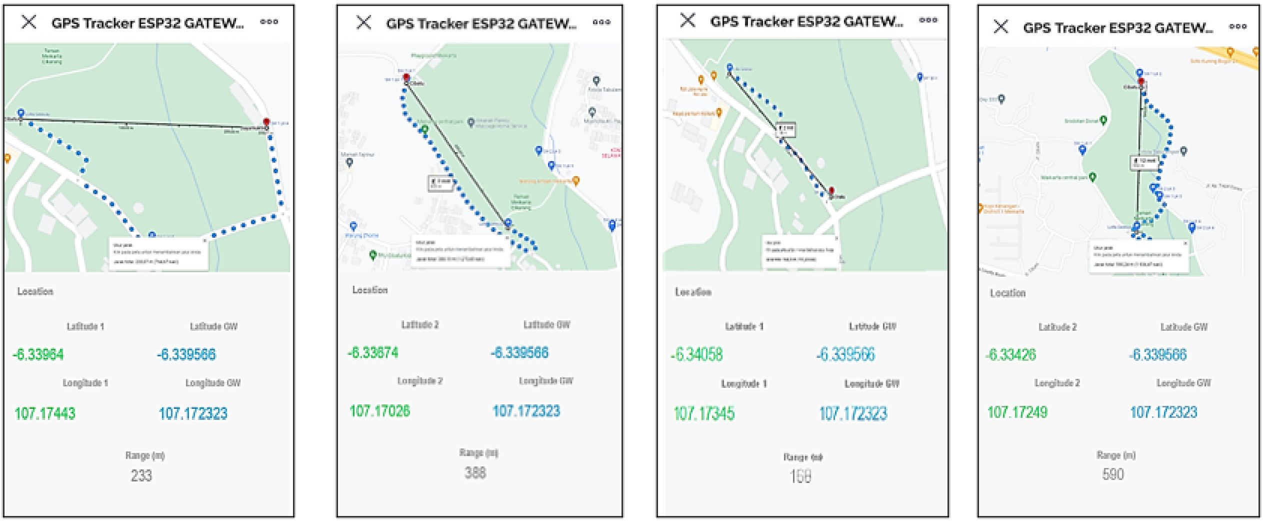

Tourist Bicycle 1 node 4 | Tourist Bicycle 1 node 5 | Tourist Bicycle 2 node 1 | Tourist Bicycle 2 node 2

Figure 8. Samples of GPS Tracker Bicycle 1 and 2 Range Distance with LoRaWAN Communication.

b. Range Testing using GPS Tracker Location by LoRaWAN connection

The team tests the range using the GPS tracker installed on the tourist bicycle, which connects to the center of the LoRa Gateways. The range testing stage used the test data of the available latitude and longitude data functions by combining them with the Google Maps APIs. Moreover, it will produce the range from the LoRa gateway to the LoRa node. The LoRa gateway set point is at the latitude = -6.339566 and longitude = 107.172323. The following are the results of the GPS range of Tourist Bicycle Tracker 1 and Tourist Bicycle Tracker 2.

Table 2. Tourist Bicycle GPS Tracker 1 Range Results with LoRa Gateway

Location Node	Tourist Bicycle 1		Range (m)
	Latitude	Longitude	
1	-6.34056	107.17348	167
2	-6.33394	107.17243	625
3	-6.33844	107.17320	174
4	-6.33964	107.17443	233
5	-6.33674	107.17026	388

Table 3. Tourist Bicycle GPS Tracker 2 Range Results with LoRa Gateway

Location Node	Tourist Bicycle 2		Range (m)
	Latitude	Longitude	
1	-6.34058	107.17345	168
2	-6.33426	107.17249	590
3	-6.33815	107.17295	172
4	-6.33959	107.17445	238
5	-6.33674	107.17028	386

Tables 2 and 3 summarize the sampling results of the range for the GPS tracker on tourist bicycle-1 and tourist bicycle-2, with the LoRa gateway set to static. The team measures the distance in the Blynk application by integrating it with the Google Maps API. Fig. 8 below shows the monitoring screens and samples of several examples of location, latitude, longitude, and distance data. The distance results produced in meters (m) are the directional point-to-point distance between Lora nodes and Lora gateways. The value of the prototype test results ranges from 168 m - 625 m. Based on precision, tourist bike 1 and tourist bike 2 tend to have the same range of values when lined up. A striking difference occurs at node 2, where the distance value on tourist bike 1 and tourist bike 2 exceeds 500 m, and the reading distance values vary significantly. We tried several times at the same point and got anomalous values from the reading results. With these results, we can conclude that Lora RA02, with a reading distance exceeding 500 m, will be at risk of coordinate reading errors with a range of up to 100 m.

c. Accuration Testing using GPS Tracker Location by LoRaWAN connection

Accuracy testing on the GPS tracker was carried out by comparing the location point of the tourist bicycle GPS tracker with the GPS on the smartphone to determine the difference and accuracy in implementing direct measurements. The following Table 4 and 5 are the results of comparing the accuracy of a tourist bicycle GPS tracker with GPS on a smartphone. The comparison uses two cellphone brands: Redmi 9 Pro and Samsung A01.

Table 4. Tourist Bicycle GPS Tracker 1 Accuracy Using Redmi 9 Pro Smartphone

Node Location	Tourist Bicycle 1		Redmi 9 pro		GAP (m)
	Latitude	Longitude	Latitude	Longitude	
1	-6.33676	107.17027	-6.336660	107.170282	11
2	-6.33394	107.17243	-6.334093	107.172463	15
3	-6.33844	107.17320	-6.338502	107.173202	7
4	-6.33964	107.17443	-6.339816	107.174513	16
5	-6.34058	107.17345	-6.340576	107.173453	0

Table 5. Tourist Bicycle GPS Tracker 1 Accuracy Using Samsung A01 Smartphone

Node Location	Tourist Bicycle 1		Samsung A01		GAP (m)
	Latitude	Longitude	Latitude	Longitude	
1	-6.33676	107.17027	-6.336728	107.170329	7

2	-6.33394	107.17243	-6.334261	107.172485	0
3	-6.33844	107.17320	-6.338167	107.172958	2
4	-6.33964	107.17443	-6.339628	107.174458	5
5	-6.34058	107.17345	-6.340583	107.173496	8

The tables above generated the difference by measuring the distance between the tourist bicycle location point 1 and the smartphones. The results tables showed that there are two different pieces of accuracy data. The differences result in the difference in accuracy between GPS tracking with the Redmi 9 Pro Smartphone and GPS tracking with the Samsung A01 Smartphone. The team used the general mean formula to calculate the average error by dividing the sum of the distance differences by the total number of trials. The following are the results of measuring the difference in the location between the readings on the GPS tracker and each smartphone using a formula.

$$\% \, Accuration = \frac{\sum GAP}{\sum Node} * 100\% \quad (1)$$

Table 6. Summary of Accuracy test (%)

Accuracy Test		**Accuracy %**
GPS Tracker 1	Redmi 9 pro	9.8
	Samsung A01	4.4

Based on Table 6, the accuracy values obtained by comparing a GPS tracker with two smartphones are 9.8% and 4.4%. Our focus is not to test the accuracy of certain smartphones or brands. This Comparison tests GPS tracking under every possible condition on conventional equipment.

IV. CONCLUSION

Based on the design, implementation, and testing results, the tourist bicycle successfully implemented the GPS tracker tool for monitoring using LoRaWAN communication and displaying it on the Blynk application. Moreover, the GPS tracker can display 5 locations, including the tourist bicycle track area, with a distance of 625 meters for tourist bicycle 1 and 590 meters for tourist bicycle 2 by measuring the distance between the LoRa Node and the LoRa Gateway. Also, the GPS tracker for tourist bicycles has an accuracy rate of 9.8% and 4.4% for GPS tracking using conventional smartphones. The operator can still see this accuracy value whenever they check the tourist bicycle at a location where the visitor has left it.

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