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D-Tags Design by Combining Bluetooth Router, IoT, and Mobile Phone to Track Personal Items

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***Abstract* – Losing personal items such as a wallet or room keys is disturbing. Problems arise when clues to find the item are lacking or even non-existent. Of one hundred-two people who filled out the questionnaire about how often losing their belongings, 76% had experienced it. Because of that, it must be hard to remember where the last they put the stuff. Therefore people need tools that can help them easily find their item with a transmitter and connect to a mobile phone. Previous research showed that the transmitter with a frequency system had a detection distance of only 5 meters. From this weakness, the authors propose the development of a tracking items device that combines an Internet of Things-based Bluetooth transmitter and receiver system approach called D-Tags by combining Bluetooth routers, IoT, and mobile phones. The system is designed for both indoor and outdoor areas. Bluetooth testing allows the device to detect items up to 7.43 meters without wall obstacles. The system provided location information such as Living Room or Bedroom and the coordinates when outside the room. Regarding time, a single detection item is faster in the range of 15.13 seconds to 15.60 seconds than searching for two things simultaneously. From the tracking radius of the outdoor area, the device can track items up to 31.8 meters from the last item's position. All information tracking history can be seen on the web application. The experiment results prove that D-Tags can be used to track items by indicating their location ~~and~~ with a relatively short search duration.**

Keywords: Bluetooth Receiver, Bluetooth Transmitter, Internet of Things, Location, Timestamp

I. INTRODUCTION

People cannot separate the growing productivity of their work from the existence of personal items. When they engage in outdoor activities, they always carry items such as keys, wallets, and mobile phones and use them frequently. However, they may often be careless in storing these items because they forget them due to their hectic activities throughout the day.

Referring to the questionnaire data on the forgetfulness of items conducted by the authors on January 3-16, 2022, from 102 people aged 13 to 48, approximately 76.5% admitted that respondents often experience loss or forgetfulness of personal items such as wallets and keys. Around 38.2% of respondents searched for items more often by remembering where the lost items were last located, without knowing the exact position. If it occurs repeatedly, it will drain energy and is time-consuming [1]. Moreover, one survey reported that people waste 2.5 days a year looking for misplaced objects [2]. If the issues are taken lightly, there is the worst possible threat. Irresponsible people can misuse the data if the items are not found immediately, which is another trouble besides interfering with daily activities [3].

Referring to the main problem and the questionnaire results, the authors want to design a personal item-tracking system device called D-Tags. The architecture will be combined with an Internet of Things-based Bluetooth transmitter and receiver through a mobile web application. The device utilizes a BLE protocol as a communication intermediary between components (ESP32 Microcontroller, Buzzer, and 9 Volt battery) to handle inside the room and Global Positioning System (GPS) for outside purposes. This method allows the tracking device to be developed with a broader range and more effectively in a better real-time environment than the previous research [4,5].

The personal items tracking system is a large-scale innovation that needs improvements. The paper by [6] described another way to accomplish how a tracking system works with a camera-based hand-held system. Moreover, the researchers could obtain Bluetooth communication through various topics such as object tracking, child monitoring, and location detection [7-9]. Existing research [10-13] has shown how GPS could be interpreted through various aspects and combine multiple systems [14,15]. The following subsection explains the tracking system from previous research that has been done.

"Gantungan Anti Lali" in Bahasa is designed to find small items [16]. This tool works by emitting radio waves to be sent to the speakers. Then, the user can hear the sound produced by the buzzer included in this tool. The system can detect an object within a maximum distance of 5 meters. The disadvantage of this tool is that if the distance between the object and the remote control is too far, the sound produced will be slower.

Research by [17] aims to create an IoT-based sustainable wallet tracking system. The IoT device used is the user interface from Ubidot. That is a web interface that is integrated with Google Maps. Testing the tool's accuracy is carried out in different places, producing an average percentage of coordinate point accuracy of

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95.32%. However, the prototype receiver is quite large, which is considered inappropriate.

In previous research, it is a low-cost tracking system tested short and long-range [1]. The system consists of Global Positioning System (GPS) for long-range and a Bluetooth module for short-range. The paper aims to fetch GPS data, store it in Mobile Object Database (M.O.D.) in MySQL, then map the data to google maps through the mobile application to find the object that is misplaced from a specified range. On the other hand, even though it is reliable, the paper lacks information about the developed mobile application.

The study from [18-19] is a GPS-enabled device placed together within a wallet as a security measure. This paper is about designing an android application to monitor and track the wallet. The result of the functionality and usability indicates that the mobile app has the potential to be used as a tracking tool. Unfortunately, since the system needs to be embedded into a device, it becomes an unflexible platform if the smartphone does not meet the minimum specification. Moreover, the GPS tracker device is still too big to be placed in a wallet.

The system will work in two areas which are indoor and outdoor. Furthermore, D-Tags is also equipped with a web user interface to make it easier for users to interact with the device. However, the flexibility behind this interface requires the internet to be accessed on any device so that people do not need any minimum specification of gadgets to use the web user interface.

The paper is organized as follows. Section I is the brief of the problem's urgency that the authors want to tackle. Section II is about the methodology proposed in the system. Next, clarify how the device works well in final testing in Section III. Last, section IV concludes the paper.

II. METHODOLOGY

This study has used three phases, as illustrated in Figure 1. It begins with Phase 1 as Preparation, which focuses on reviewing literature and then gathering the data that aligns with the problem. Then, Phase 2 focuses on the prototype development of hardware and software. Finally, phase 3 contains an evaluation step to determine how the prototype works proven with a certain data amount from the implementation process.

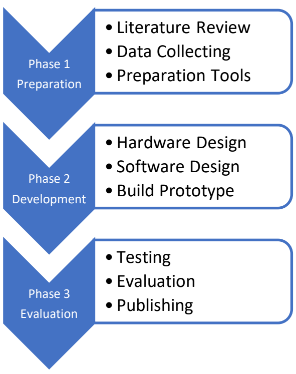

Figure 1. Research Methodology

A. Design System

The proposed system works in both indoor and outdoor areas, as shown in Figure 2. Indoors and connected to the internet, the ESP32 scans for a particular ID among available receivers. When the receiver is successfully connected, the transmitter sends data with HTTP POST protocol to the web server. The home.php page catches the transferred data, then stores all data in the MySQL database. From this point, the history page can fetch all the data, such as location and timestamp. Meanwhile, in an outdoor area, it only needs communication with the receiver. When the receiver is found and sends the feedback communication, the web server sends coordinates that Google Maps API gives to the database. When the interface shows the location, whether it is room location or coordinates, the buzzer is already activated. Finally, the user could interact and see the location in real-time with the tracking items device.

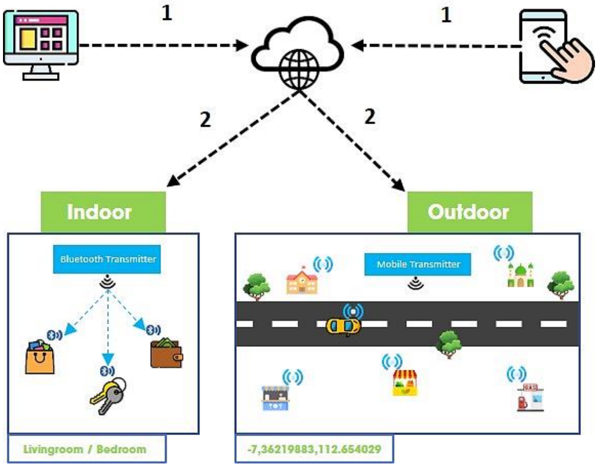

Figure 2. System Architecture

B. Hardware and Software

The proposed hardware design is arranged as in Figure 3. A board containing ESP32 serves as the main component for navigating data transfer in the project. The second is a buzzer as sound clues to find items, and the third is a 9 Volt battery as a power supply. This study made two receivers and two transmitters for testing purposes, but both transmitters do not need a buzzer or battery for power supply. The transmitter is not designed for movement purposes and is just a station to look around any available receivers in rooms that the user wants to find. The rooms initialized for this study are the Living room (LR) and the bedroom (BR) for the indoor area.

Figure 3. Hardware Design

This section displays some of the important interfaces and features available in the web application prototype. On the top in Figure 4 is home page, and on the bottom is ~~a~~ history page.

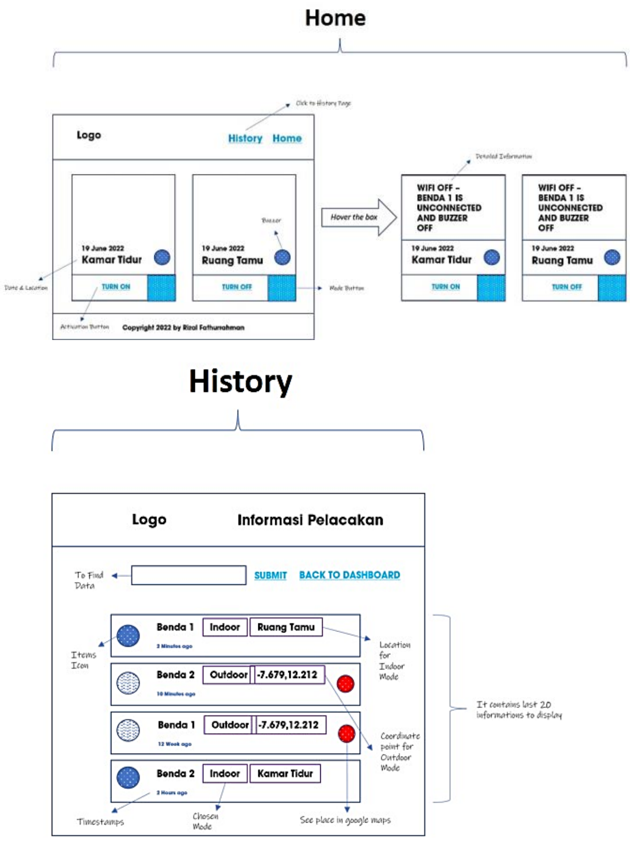

Figure 4. Web Application Design

Homepage manages any data sent from the transmitter or receiver, for instance, wifi connectivity, location to display, device, and buzzer activation. On the history page, users can view information about the last known location or time of the item's discovery during the day. Furthermore, especially for the outdoor area, the user can see the exact position of the item by clicking the red button as shown on the history page directly on Google Maps.

C. Implementation Methods

This study aims to summarize three main results; maximum Bluetooth range, time, and location accuracy. First is the maximum Bluetooth range. The purpose is to determine how far Bluetooth communication can be done in an indoor area with the maximum range the receiver can listen to. The method of data collection uses both a transmitter and a receiver. There are two conditions shown in Figure 5, with a red dashed line to measure Bluetooth range through a wall obstacle and a blue dashed line to measure Bluetooth range without a wall obstacle. After placing the transmitter in starting point on a full-colored circle and turning on the buzzer, then slowly move away until the buzzer stops ringing.

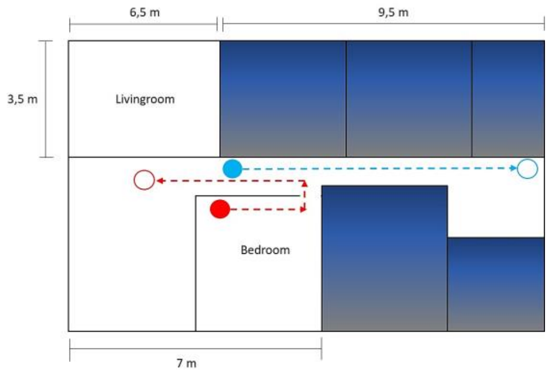

Figure 5. Implementation Sketch

Secondly, Figure 6 shows to determine whether the device is working correctly in indoor areas.

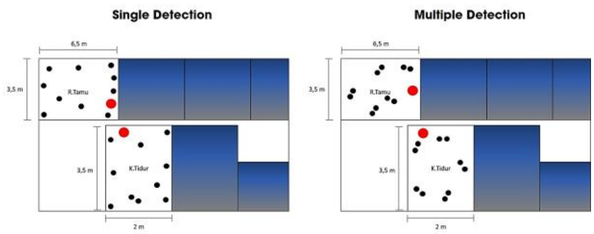

Figure 6. Indoor Testing Location

They are tested two conditions; single and multiple detection items. This also aims to collect the average time from an unknown location until it gets the real-time location. Red circles illustrate transmitters, and black circles illustrate the receivers' placement.

Lastly, determine whether the device works accurately in the outdoor area. Figure 7 shows how the prototype interacts with the web application system on the flowchart.

This experiment also aims to measure the possible distance user can track items from the last position using the exact coordinates in Google Maps. Tested in ten different places, it will show the average distance. In addition, measure features from Google Maps are used to count the difference between two coordinates, as shown in Figure 8.

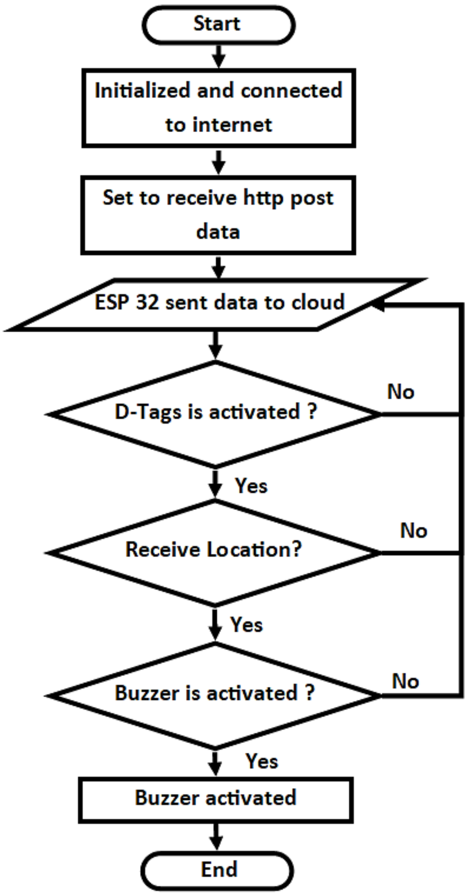

Figure 7. Flowchart System

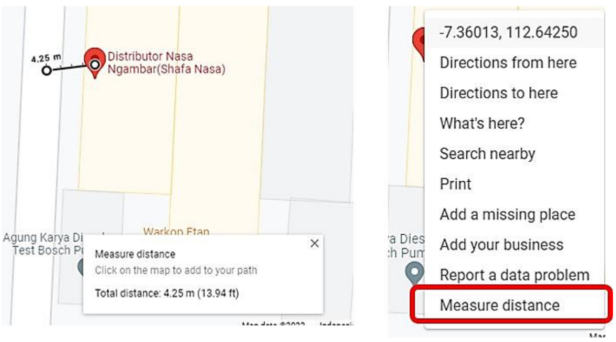

Figure 8. Measure Distance Features in Google Maps

III. Results and Discussion

The proposed system is conducted by a real-task experiment in indoor and outdoor areas. Therefore, all the results have been verified to ensure it meets the requirement.

Figure 9 shows that these testing results indicate that Bluetooth can communicate better without wall obstacles within a maximum average of 7.43 meters. On the other side, Bluetooth with a wall obstacle has a maximum average range of 1.82 meters.

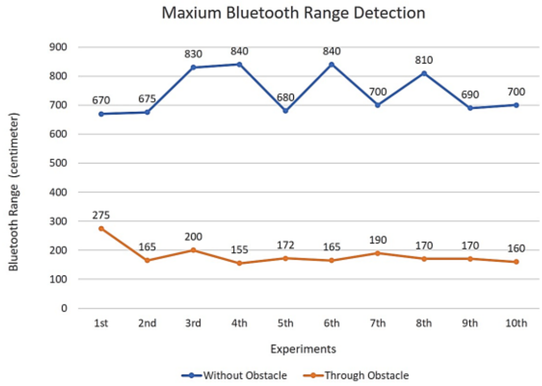

Figure 9. Graph of Two Conditions of Bluetooth Range Experiment

Single Condition Testing is carried out to determine whether the device can find items in a room with the transmitter looking for only one receiver and how quickly the device finds the location. The data shown in Table 1 shows an average time of 15.13 seconds for receiver 1 and 15.60 seconds for receiver 2. In addition, the locations represent two rooms the Living room (LR) and the Bedroom (BR). Buzzers also work properly with all receivers in each initialization test.

Table 1. Single Condition Testing

No.	Receiver 1			Receiver 2		
	Location	**Buzzer**	**Time**	**Location**	**Buzzer**	**Time**
1	*LR*	On	12.32	*BR*	On	16.31
2	*LR*	On	13.18	*BR*	On	17.90
3	*LR*	On	16.19	*BR*	On	21.88
4	*LR*	On	13.62	*BR*	On	10.44
5	*LR*	On	16.88	*BR*	On	10.50
6	*LR*	On	13.17	*BR*	On	18.16
7	*LR*	On	17.22	*BR*	On	15.47
8	*LR*	On	12.58	*BR*	On	15.18
9	*LR*	On	16.63	*BR*	On	15.43
10	*LR*	On	19.52	*BR*	On	14.29
	Average Time		15.13	Average Time		15.60

Multiple Condition Testing is conducted to determine whether the device can find items in a room with the transmitter looking at two receivers simultaneously and how quickly the device can find the location. From the data shown in Table 2, it gets an average time of 30.49 seconds for receiver 1 and 27.92 seconds for receiver 2. In addition, as in single-condition testing, the location could get to the location of the closest room. Unfortunately, the buzzer has unstable conditions in experiments 6 and 7 because could not make a sound.

Table 2. Multiple Condition Testing

No.	Receiver 1			Receiver 2		
	Location	**Buzzer**	**Time**	**Location**	**Buzzer**	**Time**
1	*LR*	On	24.50	*BR*	On	12.56
2	*LR*	On	12.61	*BR*	On	23.59
3	*LR*	On	24.05	*BR*	On	31.40
4	*LR*	On	65.05	*BR*	On	31.11
5	*LR*	On	28.41	*BR*	On	28.31
6	*LR*	On	24.86	*BR*	Off	28.56
7	*LR*	Off	16.17	*BR*	Off	26.17
8	*LR*	On	33.41	*BR*	On	31.94
9	*LR*	On	48.50	*BR*	On	32.11
10	*LR*	On	27.39	*BR*	On	33.50
	Average Time		30.49	Average Time		27.92

This experiment measures the average possible distance to find lost items. Two measurements can show how far an object might be: the first one is the object's last known location (shown in the Object Coordinates Left column), and the second one is the last place where the object was able to send data to the web server (shown in the Object Coordinates Lost column).

Table 3. Outdoor Condition Testing

Places	Object Coordinates Left	Object Coordinates Lost	Difference (m)
Room	-7.36, 112.64	-7.36, 112.64	28
Mosque	-7.36, 112.64	-7.36, 112.64	17
Factory Industry	-7.3655, 112.64	-7.36, 112.64	45
Supermarket	-7.36, 112.63	-7.365, 112.63	44
Traditional Market	-7.37, 112.63	-7.37, 112.63	33
Bank	-7.36, 112.62	-7.36, 112.63	23
Shopping Complex	-7.35, 112.63	-7.35, 112.63	46
School	-7.33, 112.63	-7.33, 112.63	41
Gas Station	-7.33, 112.63	-7.34, 112.64	24
Food Court	-7.36, 112.64	-7.36, 112.64	33
	Average Distance		31.8

In this experiment, the device was tested over ten different places to determine the average from all of the places. Table 3 shows the average distance is 31.8 meters.

IV. Conclusion

The proposed system-based personal items tracking has been implemented. The study is an improvement to the related systems in terms of software application, data communication, and design prototype. The design has been developed as an item-tracking device consisting of an ESP32 microcontroller, buzzer, and a 9V battery as a power supply. The maximum distance the Bluetooth communication system can reach is 7.43 meters in conditions without wall obstacles and 1.82 meters in conditions with wall obstacles. In terms of time, the single detection in an indoor area could communicate better from 15.33 to 15.60 seconds to get the real-time location. However, it takes longer for multiple detections, around 27.92 to 30.49 seconds. In terms of distance radius, the device in the outdoor area could have the possibility to track lost items within 31.8 meters. However, outside the radius, the user rarely found the items. From the web application, the system can display the location and the items placed. The history of tracking item data can be shown in the previous section, such as user interface, be it room location, timestamp, or coordinates. This research is expected to help develop smaller D-tags and has more use time.

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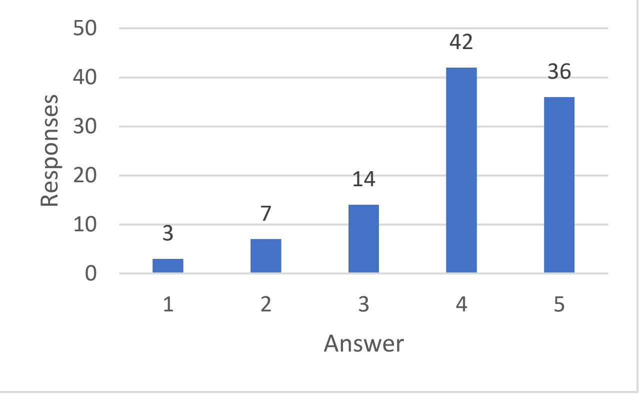
APPENDIX

Questionnaire Survey Questions and Results

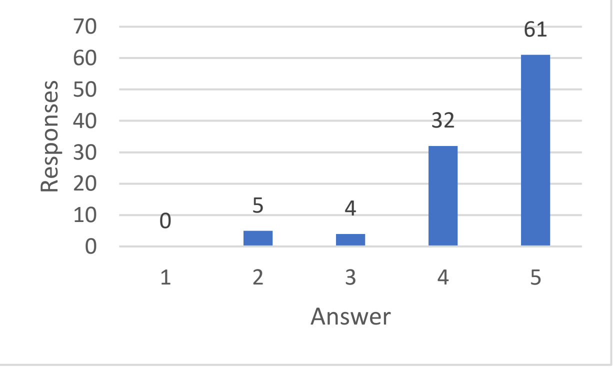
1. How often do you lose or forget personal items? (102 Responses)

1= can't remember.
2= never have.
3= Several times.
4= often.
5= every day.



2. Do you think this solution is important if you have a tool that allows you to find these items? (102 Responses)

1= do not know.
2= Not at all.
3= all ok.
4= important.
5= Very important.



More complete details of the survey results in excel form can be seen in the link below:

https://docs.google.com/spreadsheets/d/1audcQocQiGgQVbUKpVaY4P-xV_goEdytYy1_UsHCxjQ/edit#gid=433468902