

IoT-Enabled Bus Tracking System for Real-Time Campus Transportation

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Abstract

Transportation is a utilitarian means by which individuals may move from one location to another. In the present epoch of globalisation, transport plays a vital role in the economic development of a country. The statutory basis for accountability of a public service corporation is now ensuring the delivery of excellent and high-quality service. Currently, students, particularly those who do not have their own means of mobility, rely on school transportation to navigate the campus. However, an issue emerged when students were unable to retrieve the position and location while the bus was in motion. Users have difficulty due to the uncertainty of the bus's arrival schedule, which necessitates an indefinite waiting period. We developed an Internet of Things (IoT) based bus tracking system for Universiti Tun Hussein Onn Malaysia (UTHM) to resolve the problem. This system enables users to conveniently receive real-time information about the bus's current position, location, and estimated arrival time at each stop. The researcher used the Design Thinking Process (DTP) paradigm in this study. The process consists of five steps: empathy, deciding, ideation, prototyping, and testing. The analysis's results validate the successful development and planned operation of the system. Furthermore, the system has the capability to display the precise position and location of the bus, in addition to providing consumers with useful information. The accompanying questionnaire supports this claim, indicating that 32 students, which accounts for 95% of the target audience, have confidence in the product's ability to work well. Ultimately, the IoT-enabled bus tracking system implemented at UTHM effectively accomplished all of its predetermined objectives.

1. Introduction

Large-scale mobility, such as in tourism and education, necessitates the implementation of transportation services (Litman, 2021). Most universities in the country provide bus transportation as a service for students or citizens who lack a private vehicle to attend lectures or university activities. Universiti Tun Hussein Onn Malaysia (UTHM) students expressed their support for this initiative in a survey, where 86%, or 36 out of 42 respondents, strongly agreed that university students require bus transportation services. Six respondents, or 14.30%, concur with this

statement. Technological progress has now begun to shift to an era of automation, where current technological trends lead to IoT (Rahmatulloh, 2019). IoT introduces the concept of connecting all devices, sensors, machines, and devices to the Internet through data collection and transmission over a network. We also use the GPS system as a communication medium to understand the condition and location of a person or thing (Wardhany, 2020).

Although campus bus services are provided to assist students without private vehicles, there are still major constraints that affect the effectiveness of this system. Among the main problems encountered is the lack of current bus location information and estimated time of arrival (ETA). This situation causes students to have to wait for the bus for an uncertain period, especially during hot or rainy weather, which further affects punctuality to class. In addition, there is no user-friendly real-time display system for trip monitoring. Therefore, this study was conducted to develop a bus tracking system based on Internet of Things (IoT) technology that allows users to monitor the position of the bus in real time via a mobile application and receive notifications via the WhatsApp application. This system aims to improve the efficiency of campus transportation management and provide comfort to users.

2. Literature Review

Previous research on the environment of Malaysia's public transport system and the Internet of Things and is presented in this section.

2.1 Public Transport Environment in Malaysia

Transport plays a very important role in the economic growth of the country. Sakaran & Noor (2020), in Malaysia the quality of services is highly emphasized in order to convince consumers to use public transport. As such, the role played by public transport in the country is very important as it is the most realistic way to be used by the public community especially for those in the city and students (Hashim, 2019). Arina Ishak (2019) stated that the level of consumer satisfaction with bus services in Penang was at a moderate level according to consumer perceptions. While consumers were not satisfied with the service quality was at a low level. . This is supported by the percentage of users using bus transport services which decreased by 50.46% from the previous year, a report through Transport Malaysia 2020 statistics. Ibrahim (2020) stated that among the causes that the lack of consumer will to use public transport is due to the failure to provide quality services as expected by consumers. The consumers have considered that the public transport system is not reliable in terms of punctuality (Shelat et al, 2020). According to Isaac (2019), public transport delays such as buses, LRT, taxis and airplanes occur frequently and do not take time.

2.2 GPS Technology in Vehicle Monitoring

Information sources related to past studies must be taken into account and applied in developing this project. Several past and existing studies and developments were taken to obtain additional information and improve the product to be developed. Table 1 comparison of GPS technology in vehicle monitoring obtained through past studies.

Table 1 Comparison of GPS technology in vehicle monitoring

Research	Finding research
Sonawane, A., Bhanushali, A., Gogri, K., & Khairnar, M. (2020). Real time bus tracking system. <i>Int J Eng Res Technol (IJERT)</i> , 9(06), 2278-0181.	Cities that experience congestion and high population density using bus services cause congestion, causing long waiting times. Therefore, this system was developed using GPS as the basis and an android application. Future improvements will be to use a location map on the application to make it easier for users to see the position of the bus more clearly.
Priya, S., Prabhavathi, B., Priya, P. S., Shanthini, B., & Scholar, U. (2015). An android application for tracking college bus using google map. <i>International Journal of Computer Science and Engineering Communications</i> , 3(3), 1057-1061.	The project used a GPS-enabled mobile phone instead of a GPS device to track the location of the college bus and combined it with of Google Maps Application. However, the developed system does not provide estimated vehicle arrival times.
Ramadan, M. N., Al-Khedher, M. A., & Al-Kheder, S. A. (2012). Intelligent anti-theft and tracking system for automobiles. <i>International Journal of Machine Learning and Computing</i> , 2(1), 83.	This project is a vehicle tracking and security system that uses GPS and GSM to track vehicle locations and control vehicles remotely. This system does not use mobile applications like Blynk, but instead sends location data via SMS and displays it on Google Earth.

Although all three studies show the great potential of using GPS in vehicle tracking systems, there are still some significant weaknesses. The study by Gogri (2020) does not provide interactive map display and needs improvement in terms of bus location visualization. The second project does not provide estimated time of arrival (ETA), which is important for user convenience (Priya et al., 2015). Meanwhile, the system by Ramadan et al. (2012) uses SMS and Google Earth methods without a mobile application, making it less user-friendly and not real-time. Overall, all three systems lack interactive features, user-friendliness, and comprehensive real-time capabilities, making it less suitable for modern applications in efficient public transportation.

2.3 Internet of Thing (IoT)

The Internet of Things (IoT) is a concept in which devices can be transformed to IoT devices via internet connectivity. The technology aims to provide convenience for users by connecting devices used daily to the internet. The essential core within the IoT can be divided into 3 categories namely collecting information and sharing, receiving information and responding to it as well as the norm. It is, IoT devices that carry out the function of collecting and sharing information in relation to correlations with sensors (McClelland, 2020). Transmission and processing of information can be performed either wired or wireless. Generally, IoT devices will be connected to computing as data can be accessed from anywhere at any time from the communication aspect, IoT devices communicate using a wide variety of protocols such as Wi-Fi and Bluetooth. There are six types of wireless IoT technology each of which has advantages and disadvantages. The technologies are Low Power Wide Area Network (LPWANS), cellular, Zigbee, Bluetooth and BLE, Wi-Fi and RFID (Behr Technology Inc, 2020).

3. Methodology

This section provides a comprehensive explanation of the project process. Researchers use this section as a point of reference to formulate, gather, and examine information. The section explores the implementation of an IoT-based bus tracking system for UTHM, covering the whole development process from initial planning and requirement analysis to design, development, testing, and finalization. This technique allows researchers to get a more profound comprehension of the process of selecting appropriate methodologies for their subject. By according to the prescribed sequence, you may successfully do the assignment without encountering any complications.

3.1 Research Design

Project design refers to a systematic approach or methodology used throughout the whole project development process (Jin, 2010). The choice of the project design is vital for assuring the seamless advancement of the project development. The developers have opted for the Design Thinking Process approach as a framework and point of reference for the development of a bus tracking system for UTHM using IoT technologies. The Design Thinking Process model has five essential steps that must be taken into account throughout the system development process. These stages include empathy, define, ideate, prototype, and test. Figure 1 depicts the phase of the Design Thinking Process model that is used in system development.

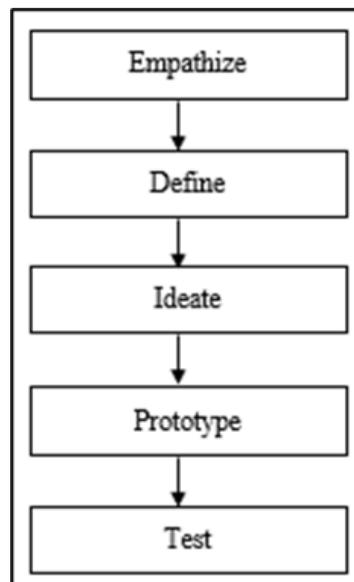


Fig. 1 Design thinking process (Improvasi, 2019)

3.1.1 Empathize Phase

At this phase, the researcher conducts an in-depth evaluation of the application's requirements and goals. Data pertaining to bus transport is gathered through surveys distributed to the intended audience of students and drivers as well as interviews with the university's transport department.

3.1.2 Define Phase

The researchers have synthesized the problem at its initial stage, explored the genuine needs of the target group, defined the questions, and identified reasonable actions. This phase necessitates a thorough and detailed analysis of the primary user needs to guide the product development design. We also interpret the collected information from surveys, scientific readings, articles, journals, and other sources to gain a clearer picture.

3.1.3 Ideate Phase

By devising and developing solutions to the target group problem, the researcher will gain a realistic understanding of the problems at hand. This will involve evaluating the solutions that are deemed most suitable for solving the target group problem. The process encompasses concepts related to the design of hardware and systems, the use of software and applications, the components involved in bus detection systems, and the operations that result from the combination of hardware, software and application. Before initiating the actual product development process, the researcher utilized Tinkercad software to design the prototype means process was done. Additionally, as this phase progresses, the researcher will identify the most effective final solution method for prototyping. Figure 2 shows the final product design using Tinkercad software.

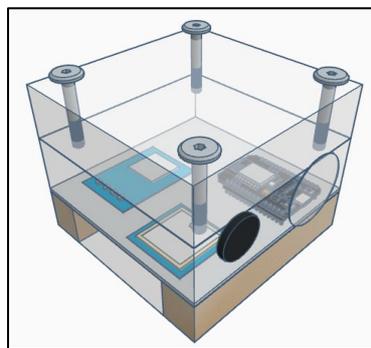


Fig. 2 Product design using TinkerCad software

3.1.4 Prototype Phase

After analysing the needs, the development moves to the prototype building phase. Here, the researcher focuses on hardware development for the Neo-6m GPS module components, the ESP8266 NodeMCU and the buzzer, the creation of a New Tracking Bus template on the Blynk app, and notification of the WhatsApp app. The researcher meticulously arranges the components on the junction box, employs widgets for the bus movement display on the maps, shows the longitude and latitude values, and determines the requirements for the Blynk application. The researchers have also developed a programming programme specifically designed for this system, which ensures optimal output. This phase also prioritizes application usability to ensure a seamless and secure user experience. Figure 3 shows the operation block of an IoT-based bus tracking system for UTHM.

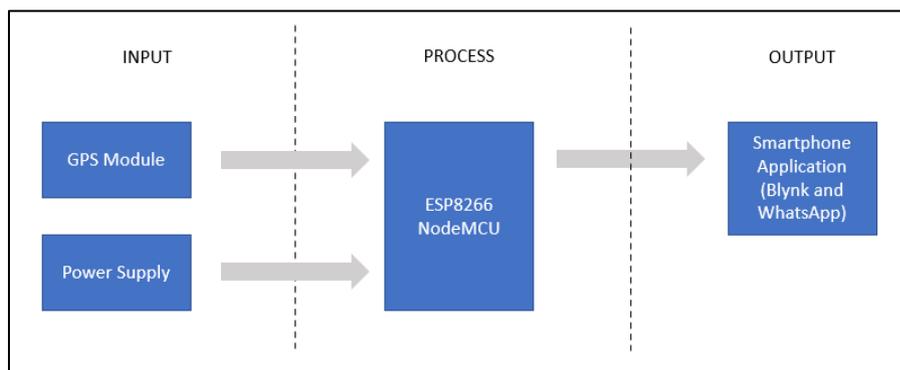


Fig. 3 Operation block of a bus tracking system based on IoT technology

We connected the ESP8266 NodeMCU to the 5V power supply to enable it to function as a microcontroller. We will first connect the ESP8266 NodeMCU to the Internet to enable the microcontroller's operation. This connection uses a hotspot as an internet source. Next, the GPS module tracks the latitude and longitude of the bus position and sends this information to the ESP8266 NodeMCU. The Blynk application develops the Bus Tracking New template, which allows users to view location data, longitude, and latitude from the ESP8266 NodeMCU. Through the WhatsApp application, users receive notifications about bus transport locations and expected arrival times. Figure 4 illustrates the UTHM bus tracking system's workflow.

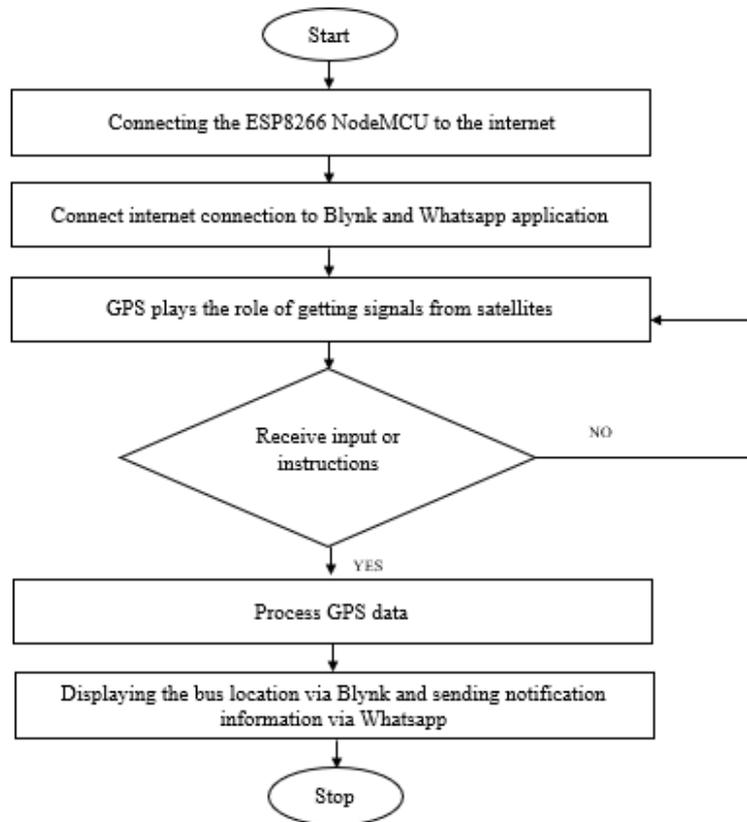


Fig. 4 Operation flowchart of bus tracking system for UTHM based on IoT technology

a. Hardware Development

A key component of the bus monitoring system is the ESP 8266 NodeMCU. The primary functions of this system are data storage, transmission, and reception. The ESP8266 NodeMCU will be informed of the bus's location by use of the GPS module, which will receive signals from a stationary satellite and record them. As a microcontroller, the ESP8266 NodeMCU will be powered by a 5V source using a type C connector. Table 2 and Figure 5 display the ESP8266 NodeMCU's circuit connections.

Table 2 Component pin connection

Component	Connection at microcontroller	Connection at component
GPS Neo-6m module	D1	RX
	D2	TX
	3.3V	VCC
	GND	GND
Buzzer	D3	Positive(+)
	GND	Negative(-)

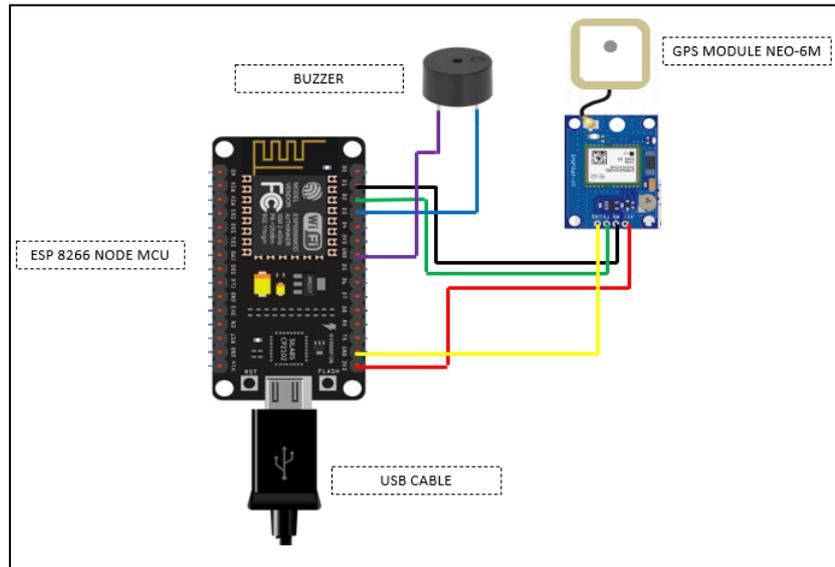


Fig. 5 Connection for ESP8266 NodeMCU circuit

b. Software Development

IDE software is used for programming. The program is implemented as the flow chart in Figure 4.

c. Application Development

Several widgets were used in the construction of the Blynk app. One of them is the speed gauge widget, and another is the map widget, which displays the value of longitude, latitude, and satellite data. Included in this package is the WhatsApp app as well. Users may get updates on the whereabouts and anticipated arrival time of their bus via the app.

For the Blynk application, students need to download the Blynk IoT application via the Google Play Store or Apple App Store and register a new account. After that, the system developer will share the Template ID, Device Name, and Auth Token required to connect their device to the template that has been built. By entering this information, students will be able to access the same interface as the original system, including the display of the current location of the bus, latitude and longitude information, and map display. Meanwhile, for the WhatsApp notification system, students need to activate their numbers first with a service like CallMeBot. This is done by sending the message “I allow callmebot to send me messages” to the WhatsApp bot number provided. After that, students will receive a personal API Key which is then inserted into the system code running on the ESP8266 microcontroller. With this configuration, students will automatically receive notification messages via WhatsApp when the bus reaches a certain stop or is within a designated geofencing zone. Figure 6 shows the Blynk app's user interface, whereas Figure 7 shows the WhatsApp app's user interface.

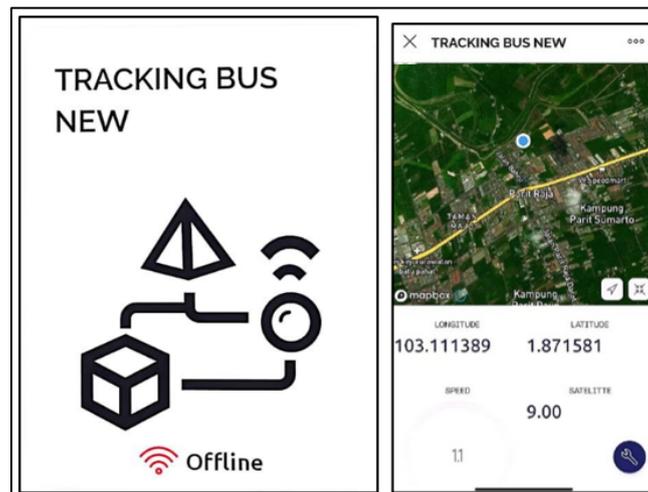


Fig. 6 Blynk application interface board

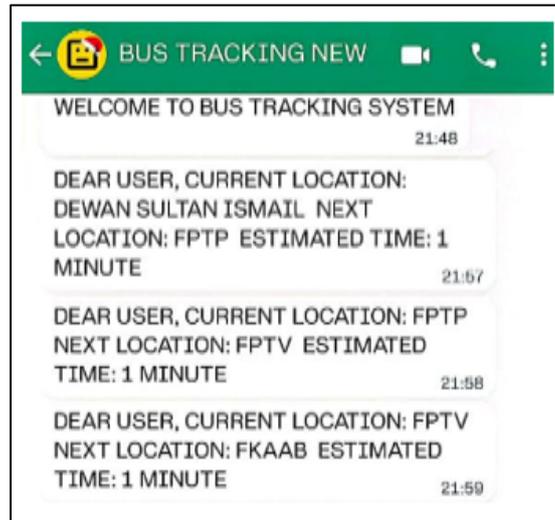


Fig. 7 WhatsApp application interface board

Finally, the combination of hardware and software was installed on the junction box as shown in Figure 8.

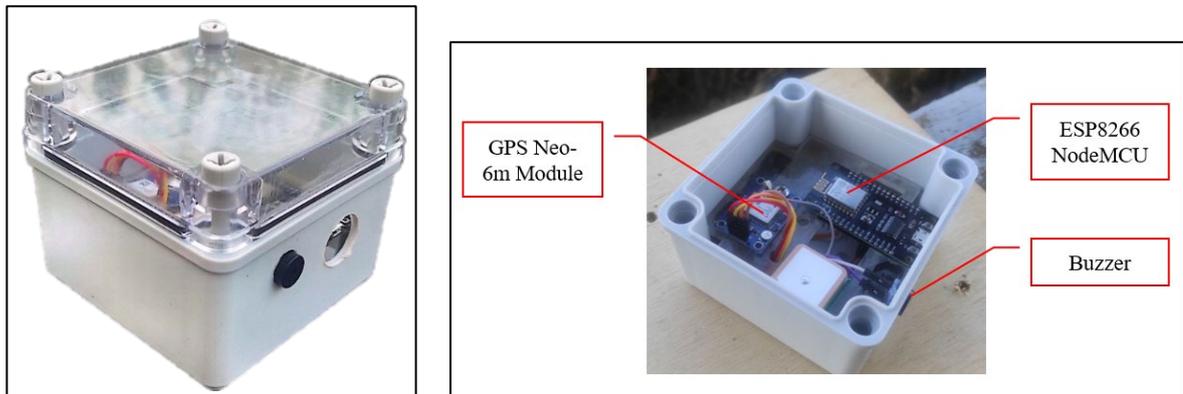


Fig. 8 Final product of bus tracking system for UTHM based on IoT technology

3.1.5 Testing Phase

The ready-to-develop product will go through the final phase of testing. These tests are essential to ensuring that the product developed works properly as a whole. Furthermore, we conduct testing to guarantee the accomplishment of the overarching goal that guided the product's development. Hardware testing entails evaluating the installation of various components within the circuit. The tester conducts important hardware testing, ensuring the built circuit functions properly and without any issues. The overall test is a test that is carried out as a whole when the main framework and hardware are combined. This test step focuses on the entire product's operation. We conduct this test to verify the proper operation of the entire product and its alignment with the desired outcome.

4. Result and Discussion

4.1 Geo Fencing

Findings in Table 3 show longitude and latitude readings for each bus stop. We take these readings both before and after the bus stop. In order to get a good read, the researcher has used a range of measurements of 12 m long and 6 m wide per bus stop. The university evaluates the measurements using data from buses and 2-lane roads.

Table 3 *Longitude and latitude through Blynk using the Geo Fencing method*

Location	Before		After	
	Longitude	Latitude	Longitude	Latitude
KKP	103.097725	1.862424	103.097908	1.862390
G3 BACK	103.087044	1.857805	103.087303	1.857761
FKEE	103.089081	1.859863	103.089127	1.860080
KKDK	103.088242	1.862774	103.088326	1.863041
G3 FRONT	103.086449	1.859692	103.086655	1.859740
PTTA	103.083496	1.858104	103.083138	1.857985
DSI	103.081345	1.858239	103.081573	1.858415
FPTP	103.081390	1.861198	103.081566	1.861388
FPTV	103.081512	1.862232	103.086161	1.862437
FKAAB	103.083145	1.864337	103.083389	1.864318
FKEE NB	103.086411	1.861406	103.086571	1.861660
FKMP	103.087860	1.861294	103.088081	1.861131
ARKED	103.087563	1.857225	103.087746	1.857158
ATM	103.086273	1.854500	103.086258	1.854169

4.2 Latency

Latency is the time delay or length of time required for data to travel between the sender and the recipient. The high amount of latency can result in poor website performance. This affects the Blynk app's ability to display visuals and the WhatsApp application's speed to send notifications. Latency is obtained from the readings shown via the Blynk app by calculating the time sent by the device minus the time received by the app. Table 4 shows the latency findings the researcher received.

Table 4 *Latency of bus stop*

Location	Latency
KKP	47ms
G3 BACK	41ms
FKEE	59ms
KKDK	62ms
G3 FRONT	50ms
PTTA	46ms
DSI	43ms
FPTP	47ms
FPTV	38ms
FKAAB	60ms
FKEE NB	51ms
FKMP	41ms
ARKED	55ms
ATM	37ms

4.3 ESP8266 NodeMCU Microcontroller

The ESP8266 microcontroller, the main tool controlling the entire operation of the bus tracking system for UTHM based on IoT technology, was part of the developed circuit. The Arduino IDE software preprogrammes this microcontroller. We conducted a test on the ESP8266, measuring the power supply voltage at 3.3 V at pin 3V3. We conduct this test using a multimeter, positioning a positive probe on the 3V3 ESP 8266 pin and a negative probe on the earth pin, also known as pin Gnd on the ESP8266. The results are in Table 5.

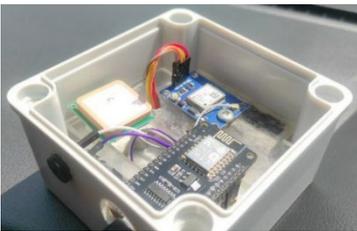
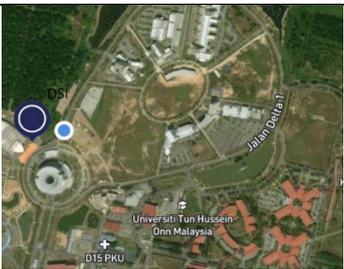
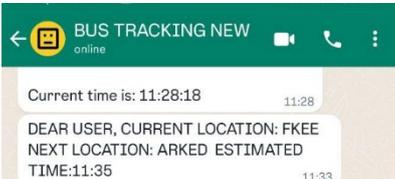
Table 5 Input and output power for circuit

	Input	Output
Current (Amp)	0.1A	45mA
Voltage (V)	5.1V	3.28V
Power (W)	0.5W	0.15W

4.4 GPS Neo-6m Module

The ESP8266 NodeMCU will receive longitude and latitude readings from the Neo-6m GPS module, which will then be displayed on the Blynk application. Blynk will display the current location of the bus movement via a map widget and LCD widget. The WhatsApp application will receive notifications containing information about the bus movement schedule and the duration of the bus journey to reach the next location. Table 6 shows the operation of the hardware and application on the smartphone.

Table 6 Operation of the GPS Neo-6m module and the display on the application

Operation	Explanation
	<ol style="list-style-type: none"> 1. Hardware connected with power supply. 2. GPS Neo-6m module in a fix position shown blue blink. 3. The buzzer sounds when the hotspot connection is successful and the bus moves within the geofencing area.
	<ol style="list-style-type: none"> 1. The LCD widget at Blynk app displays the template status when supply connection and hotspot connection success.
	<ol style="list-style-type: none"> 1. The LCD widget at Blynk app displays GPS connected when the module is in a fix position state.
	<ol style="list-style-type: none"> 1. The widget displays longitude and latitude current location of the bus.
	<ol style="list-style-type: none"> 1. The bus stop will be pinned when the bus reaches the bus stop. 2. The users can see the bus movement directly through the map widget
	<p>WhatsApp app will receive notification of information related to bus movement.</p>

4.5 Discussion

In summary, the implementation of the Internet of Things (IoT)-based bus tracking system for UTHM has been a success. The researcher carries out many initial processes and procedures, such as doing a thorough search for previous studies and gathering information from the target population. The researcher conducted a visit to the Transportation Division of the institution and administered a questionnaire to the students in order to gather information about bus transportation. The results facilitated the development of systems that can tackle issues such as limited availability of bus traffic locations and predicted journey and arrival times. In order to tackle this issue, scientists have devised an IoT-based bus tracking system specifically for UTHM. The researchers successfully completed the prototype phase of the DTP model by creating the system. It encompasses the advancement of programming software, hardware, and applications. The researcher used the Blynk application and the WhatsApp application. The hardware development entails the integration of various crucial components to construct the circuit, including the ESP8266 NodeMCU, the Neo-6m GPS module, and the buzzer. The last stage of the DTP included amalgamating all of these advancements to assess functionality. The test process includes all elements of design, component functionality, internet connection, and power supply. The researchers used geofencing technology to collect precise longitude and latitude data at every bus stop. The researchers conducted tests and examined the data from the university bus transport's moving vehicles by monitoring each bus stop and seeing the results on the Blynk and WhatsApp applications. Once the researchers verified that the complete circuit was working correctly, they proceeded to undertake expert authentication and user questions in order to get feedback on the new device. In conclusion, the bus tracking system using UTHM-based IoT technology has met the desired performance standards.

4.6 Conclusion

All things considered, the product that was made contains the required features to complete the target need, and it also incorporates modifications that were suggested by experts to guarantee that it would function correctly and effectively. The creation of this product may be of assistance to consumers by monitoring their position and location while they are travelling by bus and providing them with information about the expected travelling time of the bus. In addition to this, the programme provides customers with simple access to information in the form of graphics, which enables them to keep track of public transit sources. For the purpose of boosting efficiency and finding solutions to problems, future researchers might utilise the components that were described in this study as a reference to recommend and implement changes.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

*The authors confirm contribution to the paper as follows: **study conception and design:** Ikhwan Hafiz Bahrum; **data collection:** Ikhwan Hafiz Bahrum; **analysis and interpretation of results:** Ikhwan Hafiz Bahrum; **draft manuscript preparation:** Ikhwan Hafiz Bahrum. All authors reviewed the results and approved the final version of the manuscript.*

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