SEMARAK ILMU PUBLISHING
202103268166(003316878-P)

Journal of Advanced Research in Applied Sciences and Engineering Technology

Journal homepage:
https://semarakilmu.com.my/journals/index.php/applied_sciences_eng_tech/index
ISSN: 2462-1943

Vehicle Tracking System Based on Internet of Things Utilizing TTGO T-CALL ESP32 SIM800l

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ARTICLE INFO

Article history:
Received 28 March 2023
Received in revised form 17 October 2023
Accepted 3 April 2024
Available online 22 May 2024

Keywords:
GPS module; TTGO T-CALL ESP32 SIM800l; Internet of Things; latitude; longitude

ABSTRACT

Nowadays, cases of stolen vehicles are increasing rapidly, particularly in urban areas. The stolen vehicle is difficult for the owner to trace since the GPS system is rarely used due to its expensive cost. Thus, the purpose of this research is to analyze the accuracy of the real-time monitoring provided by the Blynk application using information obtained from GPS modules and to design a simple and compact smart vehicle monitoring anti-theft system utilizing the TTGO T-CALL ESP32 SIM800l with the Blynk application. Next, a tracking system is configured and developed by utilizing the Arduino IDE software to flash the code into the microcontroller and the Internet of Things platform as the connectivity to the Blynk App. Furthermore, the usability and functionality of the Global Positioning System (GPS) and TTGO T-CALL ESP32 SIM800l are essential in determining the vehicle's location. The use of TTGO T-CALL ESP32 SIM800l is to make the device more compact than previous research. The data has been obtained using a comparison of two microcontrollers; TTGO T-Call ESP32 SIM800l and the Arduino Mega connected to the GSM SIM800l. The data will be analyzed under two different parameters; the accuracy of altitude and speed. It can be seen that the TTGO T-Call ESP32 SIM800l has a lower percentage of latitude and longitude errors. It also has great performance in terms of speed accuracy, which is 88.5%.

1. Introduction

The Global Positioning System (GPS) is a navigation system using satellites, a receiver and algorithms to synchronize location, velocity and time data for air, sea and land travel as stated by Milner [1]. GPS can be used to track and trace some locations around the world, and it is widely used, particularly in urban areas, to assist users in determining their location in a specific place. For example, GPS was used in the Waze application, and Waze was used among drivers to help them reach their desired location. GPS was also used to determine the location of various objects via

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https://doi.org/10.37934/araset.45.2.118127

Bluetooth connections, such as iTag, which can trace the whereabouts of an item if it is lost or stolen. The iTag is a Bluetooth 4.0 low-energy device that communicates with the iTracing app. After being attached to any user's easily misplaced and valuable belonging, the location of an iTag can be tracked using a smart phone as mentioned by Irawan *et al.,* [2]. Aside from iTag, Zigbee is one of the modules that can be used to trace the location of an object with the help of GPS. Based on research by Ramvani [3], Zigbee allows users to have many end devices where they can monitor many items within a range while consuming less power energy. Despite having many advantages, the Zigbee provides short-range detection which means it is only suitable for small areas and not efficient as a theft security system.

Furthermore, in addition to using a Bluetooth module or Zigbee, internet can also be used to trace the location of items equipped with GPS. Patel *et al.,* [4] concluded that the Internet of Things, or IoT, has become increasingly popular in industry, particularly in the development of new technologies. NodeMCU is a component with a built-in 2.4 GHz Wi-Fi module that allows it to connect to the internet. It has GPIOs, a 3.3V operational voltage range, and a USB micro-B connector for power and serial connection based on data from JoyIT [5]. NodeMCU is compatible with the Blynk application. Blynk is an application that allows users to control, set up, and monitor a project remotely. In this example, it is used to keep track of the user's valuables. When the project moves out of internet range, the Esp32 or Wi-Fi module will continue to work as long as the internet is connected, resulting in a limited range. The Short Messaging Service (SMS) module of the Global System for Mobile Communication (GSM) is developed for wireless radiation monitoring (SMS). Abd Rahman *et al.,* [6] discussed in their research that this module can receive serial data from radiation monitoring devices like survey meters and area monitors and send it to a host server as text SMS. Because Bluetooth, Zigbee, and internet Wi-Fi have restricted ranges, GSM allows projects to communicate information to users even if they are out of range, as long as the SIM card has credit. In this project, GSM was used to send the location in the form of longitude and latitude to trace the lost or stolen item.

Table 1 shows the comparison of modules that were used in previous research for the development of a tracking system. The majority of the researchers have conducted extensive research to improve the current system and ensure that a new system is more reliable [7-9]. Most of it used a Neo 6m GPS module to obtain the location from the satellite. The main objective of this research is to identify the optimum module that can be used in tracking system projects in terms of accuracy of altitude and speed. Based on Table 1, Hashim *et al.,* [10] utilized Lora GPS for their system, while the other researchers have been applying GPS Neo 6m. Systems in Zohari and Mohd [7], and Hashim *et al.,* [10] all use Arduino as their microcontroller whereas system for Pranay *et al.,* [9] employs two microcontrollers, Arduino and NodeMCU. Juwairiyah *et al.,* [8] applied NodeMCU as the microcontroller in the system. Moreover, the tracking system used by Zohari and Mohd [7] was designed to be large, causing the project to take up a lot of space when mounted to the vehicle. The proposed system employs two unique modules ESP32 and SIM800l in a single component that is referred to as TTGO T- CALL ESP32 SIM800l. Other than that, the proposed system also uses the Blynk app as a monitoring system for latitude, longitude, and real-time monitoring. The proposed system will be very reliable since it uses new technology compared to previous research and also allows users to access the information via an application on their smart phones.

Table 1
Comparison of Modules for Development of Tracking System

Research	Arduino	NodeMCU	TTGO T-CALL ESP32 SIM800l	GSM Module	LoRa	GPS Type
GPS Based Vehicle Tracking System [7]	√	X	X	√	X	NEO 6M
Geolocation Using NodeMCU [8]	X	√	X	X	X	NEO 6M
Location Tracking Using Lora [10]	√	X	X	X	√	LoRa GPS
Security Assistance Device Using Wireless Technology for Women [9]	√	√	X	√	X	NEO 6M
Vehicle Tracking System Based on Internet of Things Utilizing TTGO T-CALL ESP32 SIM800l	X	X	√	X	X	NEO 6M

This research will resolve the deficiencies that were present in the previous projects. The past project employed NodeMCU to develop a tracking system, where the clock speed (80MHz) for the component is less than the research project's (160Mhz) and it was also built with a single-core processor, making the transmitting of data slower. Additionally, the previous research had a limited range because it relied on internet Wi-Fi to deliver information to the Blynk app. The use of TTGO T-Call ESP32 SIM800L in this project makes the data process faster and more precise. Furthermore, the GPRS system was used in the research project to ensure that the user's and device's range was unlimited.

2. Methodology

There were two parts for this research; hardware operation and software operation using Blynk application.

(i) Hardware Part

For this project, it used two components to create the vehicle tracking system, including the TTGO T-CALL ESP32 SIM 800l and the GPS module. The TTGO T-Call ESP32 SIM800L is a combination of two components, which are the ESP32 and the SIM800l module as stated by Sathyasri *et al.,* [11] and Crisgar *et al.,* [12]. Rathnayaka *et al.,* [13] also mentioned that it only supports 2G nano sim cards, which might not work in countries that do not have a 2G signal. The NEO-6M GPS module was used to produce the altitude from the satellite to trace the vehicle. The C language was used to flash the code into the component using the open-source Arduino (IDE) software since it is easy to write the code and upload it to the board.

Figure 1 illustrates the block diagram for this project as well as the components and applications that have been utilized. Based on Figure 1, there are three inputs that connect to the microcontroller: a power bank, a SimCard (which contains internet data and credit), and a NEO 6M GPS Module. The outputs for this project are the Blynk application and SMS. When the microcontroller gains sufficient power from the power bank, it will process the data that has been coded. After the GPS module is online, it will start to receive signals from the satellite, and the received data will be transferred to the microcontroller. Next, the microcontroller will produce data from the inputs; it will process the data and send it to the Blynk application, which contains a map widget and an altitude label. Finally, the user may request the coordinates by sending the keyword "Get Location" via SMS to the microcontroller. Then it will process the data and transmit the coordinates back to the user by replying to the SMS with a Google Map that shows the coordinates.

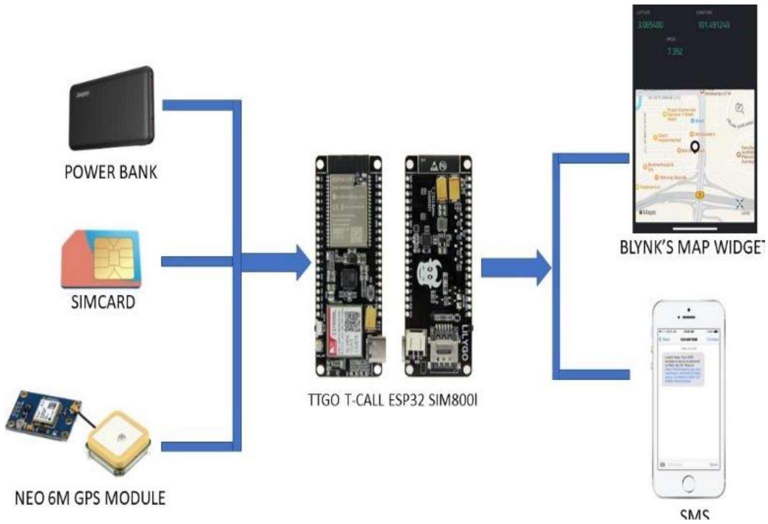

Fig. 1. Research Block Diagram

(ii) Software Part

Figure 2 shows the interface for the Blynk application, which contains a map widget and three label widgets. The Internet of Things, also known as IoT, is a popular term in the field of information technology. The Internet of Things is a combination of the real world and the digital world. Gubbi *et al.,* [14] and Gillis [15] mentioned that IoT helps people live and work smarter, as well as gain complete control over their lives. This study makes use of the Internet of Things to make people's lives easier. The Blynk application is one of the best applications that can work with IoT systems. This project operated through the Blynk application, allowing the user to download it from the Google Play store without any charge. However, it does include in-app purchases, particularly for users who wish to obtain extra features such as widgets. Durani *et al.,* [16] wrote that the variety of monitoring and remote-control widgets provided by the Blynk application makes the work more efficient. Noar and Kamal [17] said the Blynk application implements a drag-and-drop system, resulting in a user-friendly mode that is simple to manage. Among the application's most notable features is its connectivity. To ensure that the system connects to the Blynk application, this project uses GSM connectivity via the GPRS system, which requires a SIM card data plan. According to the Blynx App system flowchart, the user must log into the application before it displays the map widget, latitude, longitude, and vehicle speed. The Map widget enables users to track the vehicle's coordinates in real time.

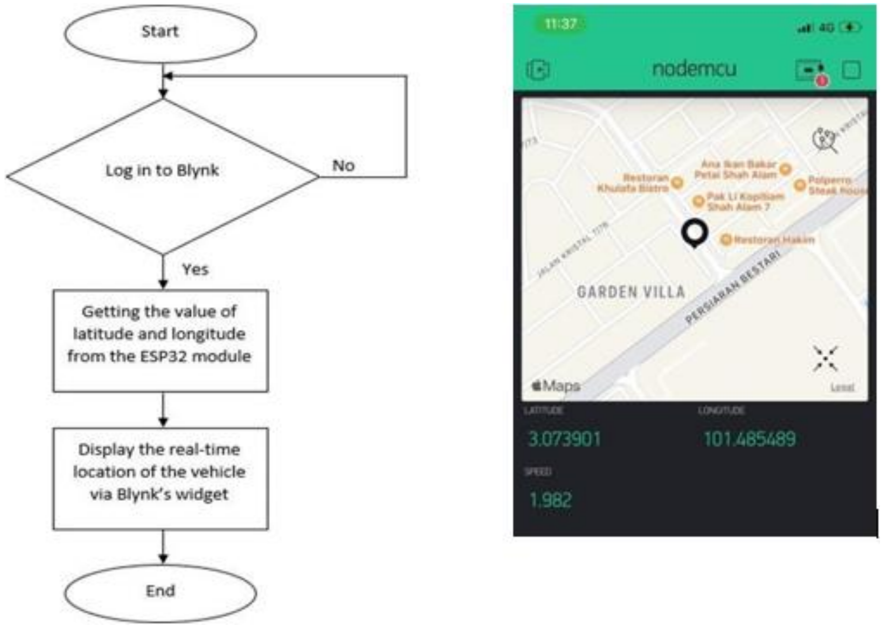

Fig. 2. Blynx Application with System Flowchart

Figure 3 depicts the operating system flowchart for this project. This project will be built into a vehicle. Prior to that, the user must insert the SIM card into the microcontroller. To connect to the Blynk application and send SMS to users, the SIM card requires an internet data plan and a credit card. After connecting the microcontroller to the power source, the user should wait for the GPS module to come online, which indicates it will receive data from the satellite, including latitude, longitude, and speed. If the module is outside, the waiting period is less than one minute, and it tends to take about ten minutes if the module is inside the house. It should be noted that if the GPS module is positioned underground or in a building, like an apartment, it is unlikely to function. Multipath is one of the reasons that can affect the transmitted signal, potentially cause it to exhibit a different delay time than the received signal as mentioned by Han *et al.,* [18], Idris *et al.,* [19], and Wang *et al.,* [20]. The GPS module's received data will then be transmitted into the microcontroller. Following that, the microcontroller will process the data and prepare it for transmission to the Blynk application as well as via SMS. The coordinates will be displayed in the Blynk application, or the user can request for them to be sent via SMS. Users can also request the vehicle's speed while the vehicle is moving.

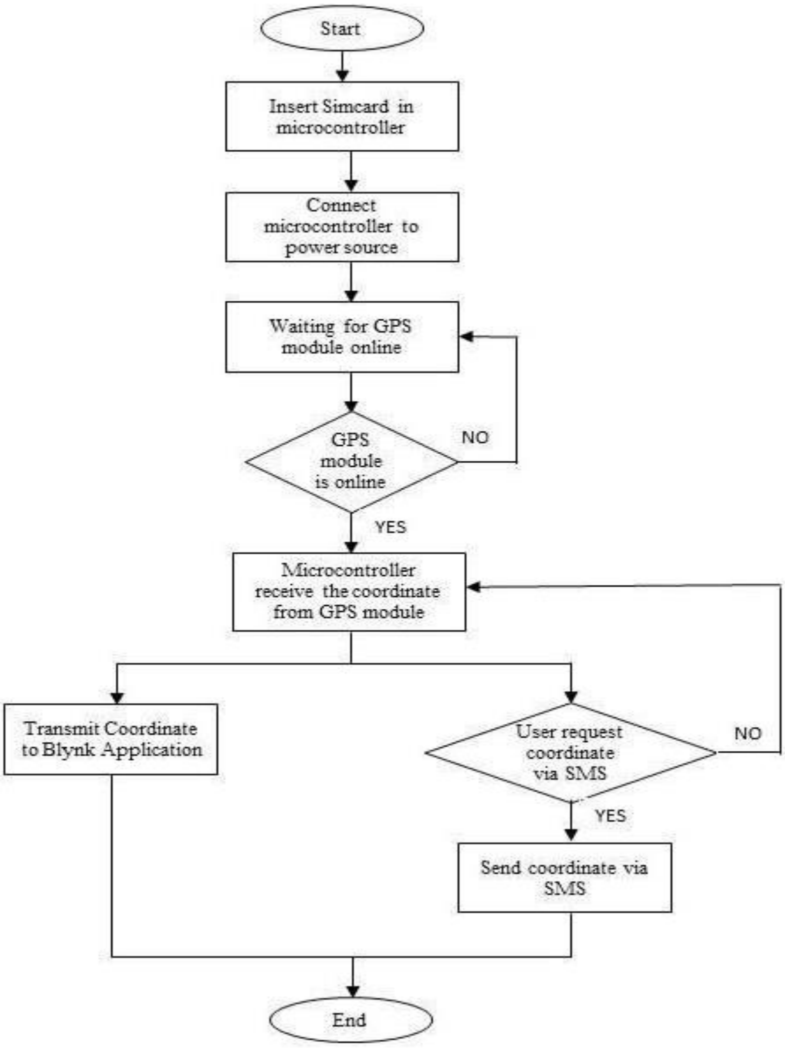

Fig. 3. Flowchart of system operation

3. Results and Discussion

3.1 Tracking System Using NEO-6M GPS Module

Two microcontrollers were evaluated for compatibility with tracking system projects. Project A is a proposed project that will employ the TTGO T- CALL ESP32 SIM800l and GPS NEO-6M modules. The previous project, Project B, implements NodeMCU and GPS NEO-6M. In addition, the obtained results were analyzed in terms of altitude and speed.

Table 2 identifies six different locations marked for this experiment in and around Shah Alam, Selangor, Malaysia. The table included the real coordinate altitude values as well as the altitude produced by two modules. The purpose of this experiment is to determine the accuracy of both modules, Project A and Project B. The generated data is then compared to the real coordinates obtained via Google Map on a smartphone to identify the percentage of error for both modules. The lower the percentage of error, greater efficient the tracking system module.

Table 2
Latitude and Longitude Obtained from Project A and Project B

Places	Real Coordinate	TTGO T-CALL ESP32 SIM800l	NodeMCU
Pangsapuri Rimba 2 blok C (section 16)	3.054456 101.482882	3.054243 101.482239	3.053707 101.482994
Restaurant Hakim (section 7)	3.074368 101.485444	3.074076 101.485672	3.073901 101.485489
Decathlon Shah Alam (section 14)	3.070199 101.524491	3.069826 101.524147	3.068281 101.518869
Padang Jawa’s KTM (section 16)	3.052743 101.489998	3.053010 101.489398	3.052742 101.488991
School of Electrical UiTM (section 7)	3.069769 101.503678	3.072613 101.497757	3.072600 101.497581
Taco Bell Plaza Shah Alam (section 9)	3.084692 101.522919	3.085005 101.522814	3.085000 101.523651
Stadium Shah Alam (section 13)	3.082538 101.543717	3.082444 101.543699	3.082528 101.544001

Figure 4 shows a graph comparison of the percentage of error for latitude, while Figure 5 is based on the longitude of Project A and B. According to both graphs, some of the coordinates delivered by Project B are less accurate than those provided by Project A, which can have a minor effect on tracking systems. Note that all percentages are in the form of 10^{-3}. From Figure 5, Project B has a larger error at Padang Jawa's KTM than Project A, with 0.992216% for Project B and 0.591191% for Project A. However, for latitude at Padang Jawa's KTM, Project A has a slightly higher error compared to Project B. For latitude at Restaurant Hakim, Project A, with 9.49789%, has a lower error percentage compared to 15.1901% for Project B. Meanwhile, at longitude, both projects almost delivered the same coordinate as the targeted location. At Taco Bell, it can be seen that Project B has a large error for latitude and longitude, 9.98479% and 0.721019%, respectively, whereas Project A's longitude has only 0.103425% of error. Furthermore, the percentage of error for Project B at the targeted point Decathlon is also higher than Project A, which is 62.4715%, while Project A has 12.149% at latitude. Nevertheless, both have a minor error at longitude, which is 0.338834% for Project A and 5.53758% for Project B. It happens due to a lot of building around the targeted point, affecting the signal from the antenna. The transmitting signal is weak and the delivered data will be less accurate. Next, both microcontrollers at the school of engineering have a significant rate of errors. Project B generated the highest percentage of errors at latitude when compared to Project A, 92.2219% and 92.6454%, respectively. This is due to the fact that poor internet coverage and rainy weather during data collection cause data processing to be slightly disrupted during information delivery. Project A has a lower total percentage of errors than Project B. Project A, the current research, is built with a 160 MHz clock speed and a dual core processor, which allows for faster and more accurate data processing than previous research. This experiment demonstrates how faster clock speeds and a greater number of processors lead to improved data reading and information delivery accuracy.

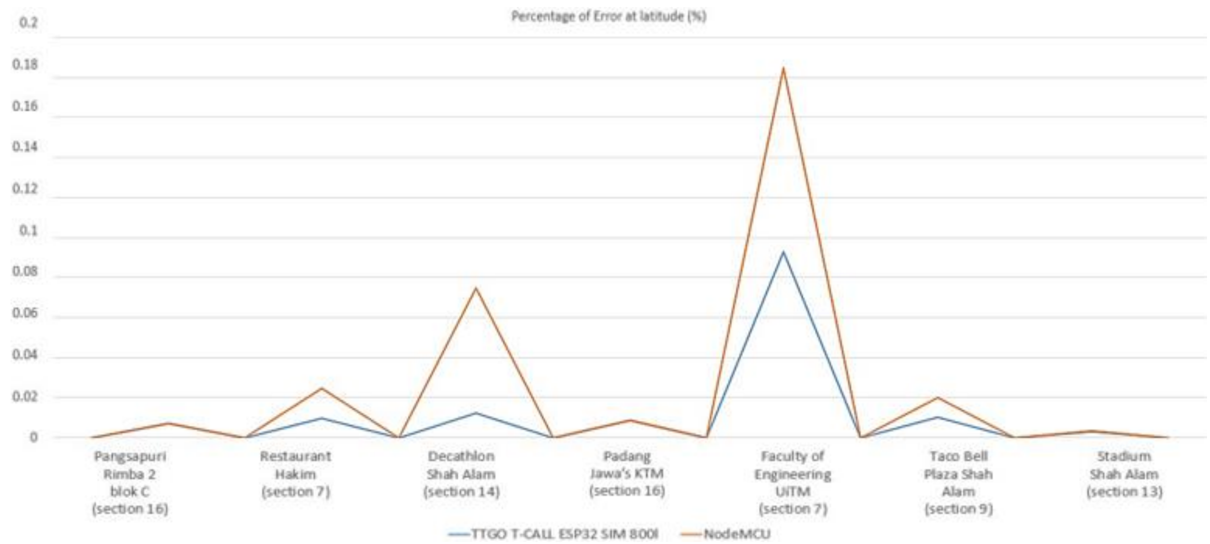

Fig. 4. Latitude Obtained from Project A and Project B

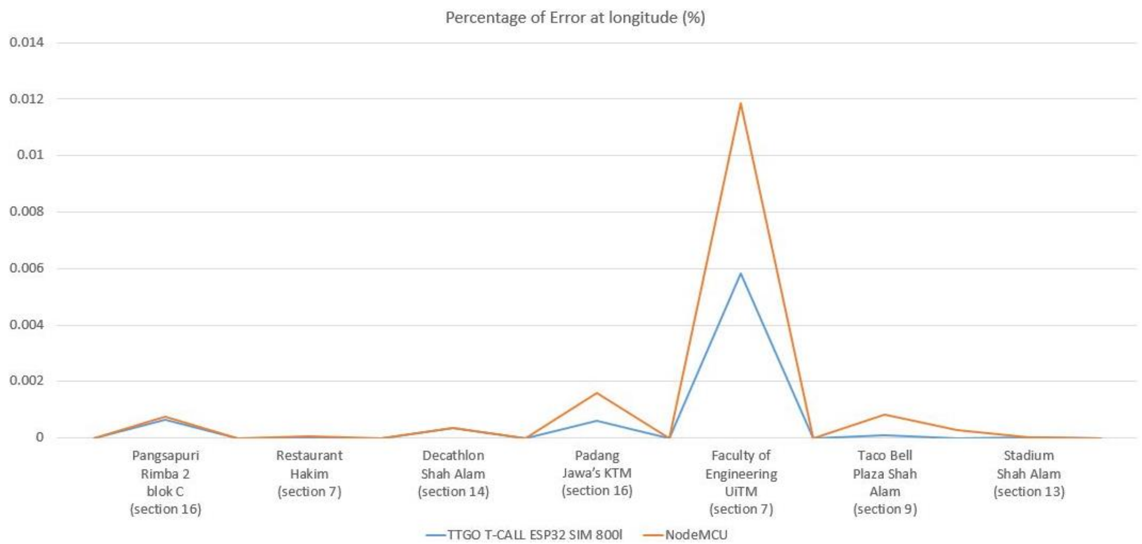

Fig. 5. Longitude Obtained from Project A and Project B

3.2 Speed Monitoring System

Figure 6 depicts a graph comparing speed via two modules. The speed has been determined, which is 20 to 60 km/h, with an increase of 10 km/h. A motorcycle was employed in the experiment to gather speed data. When the motorcycle reached a speed of 20 km/h, both projects had a slight error in terms of accuracy, where Project A produced 90.00% of the exact speed while Project B delivered 75.00% of the accuracy. Next, Project B obtained the worst accuracy (63.33%), and Project A managed to get 73.33% of accuracy at a speed of 30 km/h. Further, there is a big difference between projects A and B when the speed of a motorcycle reaches 40 km/h, with project A nearly reaching the necessary speed while project B's speed accuracy is far from precise, where Project A gained 92.50% and Project B gained 70.00%. Furthermore, there was a minor difference in speed accuracy between Project A (90.00%) and Project B (80.00%) after the motorcycle reached 50 km/h. Lastly, Project A nearly delivers the same result as the exact speed, especially when the speed reaches 60 km/h (96.67% accuracy), but Project B has a little different result with the proper speed (83.33% accuracy at 60 km/h). Based on the results, it can be concluded that Project A (88.5%) can outperform

Project B in terms of accuracy of speed. This result shows that clock speeds and the number of cores will affect the accuracy of the data processing.

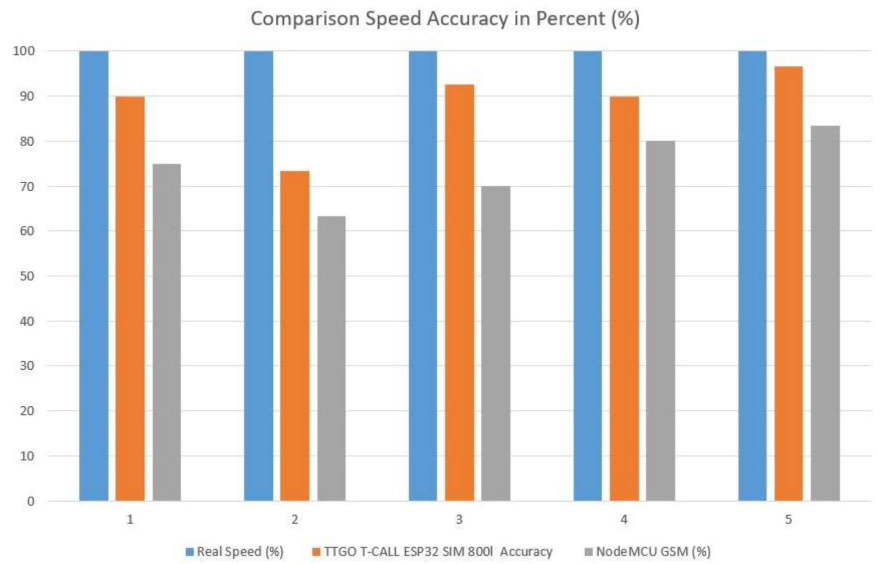

Fig. 6. Comparison of Speed via Two Modules

4. Conclusions

This research is to develop a tracking system using a new microcontroller called the TTGO T-CALL ESP32 SIM800l while testing its reliability in monitoring data processes and its stability for the proposed project. Based on the result that was obtained, it achieved the main objective, which was to build the tracking system with high-speed data processing while producing accurate data. This can be seen from the result, with TTGO T-CALL ESP32 SIM800l having the lower percentage of error for latitude and longitude at 0.150951% compared to the previous project's 0.217546%. The research project also produced 88.5% accuracy, compared to 74.33% accuracy in a previous project. Despite being quite expensive in comparison to the previous project, this microcontroller may continue to provide information to the user even when the device is travelling far away, since it uses GPRS, which uses a SIM card internet data plan. Finally, by exploiting this technology, future research into vehicle tracking systems may be enhanced.

Acknowledgement
This research was funded by Fundamental Research Grant (FRGS/1/2018/TK04/UITM/02/29) from Ministry of Higher Education. Profound appreciation and gratitude to the College of Engineering Universiti Teknologi MARA Shah Alam for permitting us to perform this study.

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