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Vehicle Safety Application through the Integration of Flood Detection and Safe Overtaking in Vehicular Communication

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Abstract

Road safety in Malaysia is a major concern due to frequent floods and accidents caused by overtaking. These issues result in significant injuries and losses. In this paper, we introduce a new system called the Safe Driving Tool (SDT). The SDT integrates a Flood Detection System (FDS) and a Vehicle Overtaking System (VOS) using Long-Range (LoRa) communication technology. The FDS continuously monitors water levels in flood-prone areas. It alerts drivers about potential hazards through vehicle-to-infrastructure (V2I) communication. Simultaneously, the VOS enables safe overtaking maneuvers. It does this by exchanging information with nearby vehicles through vehicle-to-vehicle (V2V) communication. Through testing and experimentation, we have shown that the SDT system effectively reduces accident risks and losses associated with floods and overtaking. The system's performance under various conditions confirms the reliability and effectiveness of LoRa communication technology in enhancing vehicular safety. This study represents a significant advancement in road safety. It combines flood detection and overtaking assistance into a single unified system, addressing two major causes of road accidents in Malaysia. The integration of V2I and V2V communication provides a comprehensive solution that improves driver awareness and decision-making. This ultimately leads to safer driving environments and enhanced driver convenience.

Keywords: Connected Vehicle; Flood; Internet of Things; Long-Range; Vehicle Overtaking; Vehicle-to-Infrastructure; Vehicle-to-Vehicle.

1. Introduction

Vehicle-to-Infrastructure (V2I) technology enables the exchange of information between vehicles and road infrastructures, providing real-time access to critical road data. In Malaysia, recurring flooding is a natural disaster that affects both the east coast and the western part of the Peninsular [1]. Urbanization and climate change have worsened the situation, leading to property damage, infrastructure failure, and loss of life [2, 3]. Roads can become impassable during a flood due to blockages or being submerged in water, which poses a significant risk as it prevents individuals from reaching safety. Vehicles can get damaged or stranded by floodwaters, leading to increased danger because they may overturn easily and result in severe injury or even death for the driver [4, 5]. To effectively manage floods, continuous monitoring of water levels is necessary to mitigate the impact on lives and properties. Furthermore, adoption of the latest technology, which facilitates better decision-making towards disasters, is a necessity [2].

To tackle these challenges, the integration of modern vehicle safety applications becomes crucial [6]. Vehicle manufacturers are equipping vehicles with both passive and active safety systems, taking advantage of advancements in Internet of Things (IoT) technologies. As a proactive solution, the development of a Flood Detection System (FDS) using V2I communication has emerged. This system, categorized as an active safety system, utilizes V2I communication

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to gather real-time flood information from road infrastructure and promptly alert drivers of potential hazards. By communicating with flood detection nodes, the FDS module detects flood risks in real-time, enabling drivers to avoid affected areas and reducing the risk of accidents on waterlogged roads. Various FDS employ sensors to obtain and monitor environmental parameters from several water sources or regions prone to flooding. Based on the existing works (Table 1), systems often use multiple sensors to detect floods by setting environmental parameter thresholds [4, 7–12]. Advanced approaches trained detection models such as fuzzy logic to reduce the system's complexity; however, a significant model required historical data for training, which is unsuitable for certain regions that do not have historical data [13, 14]. Some studies strive to minimize costs by using fewer sensors while maintaining effective flood detection [4, 7–9]. Table 1 summarizes previous studies related to FDS.

Table 1. Summary of previous studies (Flood Detection System)

Reference	Description	Tools	Medium
Groot & Dezfouli (2020) [7]	The authors developed a prototype of the flood warning system to display the sensor-measured water level to the driver.	16x2 Liquid Crystal Display, ESP32 Wi-Fi & Bluetooth MCU, LEDs and, Ultrasonic Sensor (HC-SR04),	WiFi
Baballe& Abbati (2022) [13]	The authors developed a flood detection system including consequence assessment using sensors measurement and local historical flood risk data. The information should be accessed through the internet in a Blynk application.	Arduino Pro Mini, LoRa Module (SX1278), Soil Moisture Sensor and, Ultrasonic Sensor.	LoRa
Meghana et al. (2020) [15]	The authors developed a travel mobile application which includes flood information. The application can monitor flood conditions and alert the drivers of the road condition on the route to allow them to change the route earlier, significantly reducing travel time.	N/A	N/A
Ragnoli et al. (2020) [8]	The authors mount sensors at three different heights to measure the water level when the water reaches a specific height and email the public if the water level reaches the threshold.	Li-Ion Battery, LoRa Gateway (Lorix One), LoRa Module (RFM95W), Microchip AtmelSAMD21, Real Time Clock (DS3231), Soil Moisture Sensor (Yl-69) and, Solar Cell with Charging Regulator Module (TP4056)	LoRaWan
Yogarayan et al. (2021) [4]	The authors developed a monitoring station that could install at the side of the road to detect floods and send information to the developed website or alert the relative authorities using the GMS service.	Arduino Yun and Water Level Sensors.	WiFi
Abd Majid et al. (2020) [10]	The authors propose a flood prediction system using environmental factors such as water flow, water level, and rain intensity. The authors also provide several ways to alert affected people using networking such as SMS, social media, and visual alerts using LED lights and hooters.	Arduino Nano (Atmega328), Node MCU (Tensilica Xtensa LX106), LoRa Module, Rain Gauge Sensor, Water Level Sensor, Hooter, Strobe Lights, Solar Charge Controller and, Solar Panel.	LoRa
Yassin et al. (2021) [11]	The authors detect floods by defining thresholds to the environmental parameters, including temperature, pressure, water level, and humidity from the river or dams. An Android application is developed to display the sources' status and alert the public if necessary. The application also integrates valuable information such as safety tips and local safe places.	Arduino Uno (tmega328p), Temperature and Humidity Sensor (DHT11), Ultrasonic Sensor (HC-SR04), Water Float Sensor and, WiFi Module (EPS8266),	WiFi
Sung, Devi & Hsiao (2022) [12]	The author proposed AIoT-based system aims to provide real-time flood analysis, enabling authorities to monitor residents in mountainous areas and issue early warnings.	Heltec LoRa32, GSM SIM900, rain gauge sensor, water flow meter sensor, tilt (inclinometer) sensor	LoRa and SIM900
Leon et al. (2018) [14]	The author utilizes an artificial neural network model to train and analyze historical data collected from the Ing River in Thailand during flood events. Predictions regarding future floods are generated by considering the river's current parameters as detected by sensors. The valuable information will be shared using the LINE application.	Arduino Mega 2560, NB-IoT Module (Devio NB-Shield I), GPS Module (NEO-6M), Water Detection Sensor, Solar Panel, Ultrasonic Module (JSN-SR04T) and, Water Flow Sensor (DN40),	NB-IoT

However, the effectiveness of V2I communication depends on the availability of communication methods, which may be limited in remote areas, limited to certain road infrastructure [13], and require high power consumption [15]. To address this, alternative communication technologies such as Long-Range communication (LoRa) are proposed. LoRa offers wide-range coverage and low power consumption despite its ability to transmit over 100 days using on-battery power, transmitting within 15 km radius [8, 13, 16]. Additionally, various methods, including mobile apps [11, 12, 15], Google Mobile Services (GMS) [17, 18], and social media alerts, are explored to enhance flood detection and management strategies, providing real-time updates and guidance during floods. Mobile apps also cater to drivers, providing flood information for navigation [15]. In sum, flood detection and management strategies encompass sensor-based systems, AI methods, effective information dissemination, and user-friendly applications, contributing to enhanced flood preparedness and response. It allows drivers to be more prepared for facing unpredictable environmental challenges, such as flooded roadways.

Similarly, overtaking remains a challenging task, especially in non-line-of-sight (NLOS) conditions. Drivers need to have adequate perception range to perform safe overtaking [19], including visibility of the road, traffic conditions, and vehicle positions. The driver’s perception may also be extended based on driving experience and driving behaviors. To address this challenge, IoT technologies have led to the development of the Vehicle Overtaking System (VOS) to assist drivers in performing safe overtaking maneuvers [20, 21]. Approaches utilizing cameras, sensors, and AI-based systems have been proposed to detect and identify vehicle surroundings before overtaking [22–24]. Table 2 provides a summary of previous studies related to VOS.

Table 2. Comparison of previous studies (Vehicle Overtaking System)

Reference	Description	Tools	Medium
Chen et al. (2021) [21]	The authors employ a method to determine a safety distance for two vehicles by factoring in the driver's emergency brake reaction time, braking distance, and upper and lower bounds, as well as human response and reaction time.	N/A	N/A
Athree & Jayasiri (2020) [22]	The authors proposed a vision-based overtaking system by utilizing a dashboard camera to assess the feasibility of overtaking on the road under local traffic rules. The techniques employed lane line detection, traffic sign recognition, and vehicle detection and used the information to calculate the distance to ensure safe overtaking.	Dashcams	N/A
Saji et al. (2019) [24]	The authors proposed a low computational power system which utilizes image processing and convolutional neural network (CNN) based on the vision provided by the front vehicle via a vehicle dashcam to predict a safe overtaking.	Camera, Raspberry Pi	4G
Rahim et al. (2019) [25]	The authors proposed an overtaking approach where the overtaking vehicle utilizes the view from a preceding vehicle's camera using a QR code to enable connection while overtaking.	Camera Module v2 (Sony IMX2019), Raspberry Pi, Raspberry Pi 3 Model B (ARMv8), and DSI Display.	WiFi
Razak et al. (2021) [26]	The authors developed an in-vehicle safety warning system for aiding drivers in safe overtaking, utilizing ultrasonic sensors placed at the vehicle's corners to detect obstacles and vehicles based on ISO17387:2008 standard.	Arduino Uno, Buzzer, LED, and Slide Switch. Ultrasonic Sensor (HC-SR04),	N/A
Abdelkader & Elgazzar (2021) [27]	The authors developed a cehicle overtaking system to address limit visibility issue caused by large vehicles at the front by utilizing ad-hoc connection in 5G. It allows the driver able to communicate with each other to ensure a safe overtaking maneuver.	Arduino Leonardo (ATmega32u4), Buttons, and LED.	5G
Aldulaimi & Hamed (2022) [28]	The authors proposed an overtaking method by utilizing V2V and V2X communication to allow the vehicle to exchange data and use those data to calculate time to collision and overtaking time.	N/A	N/A
Aldulaime & Hamed (2022) [29]	The authors created a lane change system that utilizes vehicle speed recommendations. This system includes an algorithm that produces overtaking advice, incorporating suggestions on vehicle speed, timing, appropriate lane changes, and overtaking decisions based on data from surrounding vehicles.	Simulator (C++ and SQL server 2012)	Direct Short Distance Communication (DSRC)
AASHITO (2018) [30]	The authors utilize an algorithm to classify overtaking on highways, which makes overtaking decisions using information received from nearby vehicles, local traffic regulations, and the current navigation of the route.	Simulator	IEEE 802.11p/WAVE
Zhao et al. (2024) [31]	The authors integrate lane change warning with collision warning, curve speed warning, emergency event notification, car-following guidance, identification of variable speed limits, and information services in a connected vehicle environment.	Testbed, GNSS and PC	DSRC
Song et al. (2024) [32]	The authors propose a model that detects driver lane change maneuvers by utilizing real-time vehicle dynamic features transmitted through Vehicle to Everything (V2X) communication. The model showcases high accuracy in both lane keep and lane change scenarios, and it also exhibits robustness in zigzag driving situations. These findings have been validated through tests conducted using the NGSIM real traffic dataset.	N/A	N/A

In response to the challenges of comprehensive overtaking solutions, the integration of V2V communication holds promise. By exchanging information between vehicles, VOS can provide additional details to the driver, improving the safety and effectiveness of overtaking maneuvers. Several AI-based systems also use convolutional neural networks (CNN), YOLOv3 (You Only Look Once, Version 3) etc. to detect lane lines, recognize traffic signs and predict the distance of an object [22, 23]. However, relying on comprehensive datasets can be challenging in situations where the applicability of such datasets may be limited, especially due to variations in traffic signs and rules across different regions.

Hence, this paper presents a novel Safe Driving Tool (SDT) system that integrates two vehicle safety applications: FDS and VOS. Utilizing LoRa communication technology, the system enables long-range and low-power data transmission between vehicles and infrastructure to detect floods. A mobile application is developed to provide real-time flood alerts and overtaking decisions to drivers. Various studies allow the system to provide additional details to the driver, including perspectives like the front vehicle's view or the distance between vehicles [24, 25] or require the surrounding driver's participation to make an overtaking decision [26]. However, this kind of approach might not be suitable for adverse weather, and potential inaccuracies in driver judgments. Other approaches allow the vehicles to transmit their information such as vehicle speed, acceleration and position while overtaking. By utilizing these exchanged data, the system can calculate the overtaking decision in the form of time to collision or safe overtaking time and pass back to the driver as advice while overtaking [27-29]. Various tests were conducted to evaluate the performance, reliability, and functionality of the integrated system. This integrated system offers a comprehensive approach to address challenges related to flood detection and safe overtaking, ultimately enhancing road safety and disaster preparedness. The following sections describe the materials and methods, system testing, results and analysis and conclusion of this study.

2. Material and Methods

The development of the Safe Driving Tool system (SDT), which uses an embedded system method to combine the Vehicle Overtaking System (VOS) and Flood Detection System (FDS), followed a specific conceptual design framework, as shown in Figure 1. Server nodes placed in flood-prone areas are equipped with ultrasonic sensors to monitor water levels continuously. These collected data from server nodes are transmitted to nearby vehicle nodes along with relevant coordination details. The vehicle nodes have sensors that measure distances between vehicles, speed and position which will exchange with each other. During the overtaking maneuver, this information will be used to generate overtaking decisions for the driver to ensure a safe overtaking. Moreover, an integrated Android application (SDT Android) allows drivers to receive information such as overtaking decisions and flood alerts. Furthermore, a web-based monitoring tool (SDT Monitor) has been developed for performance tracking of the SDT system.

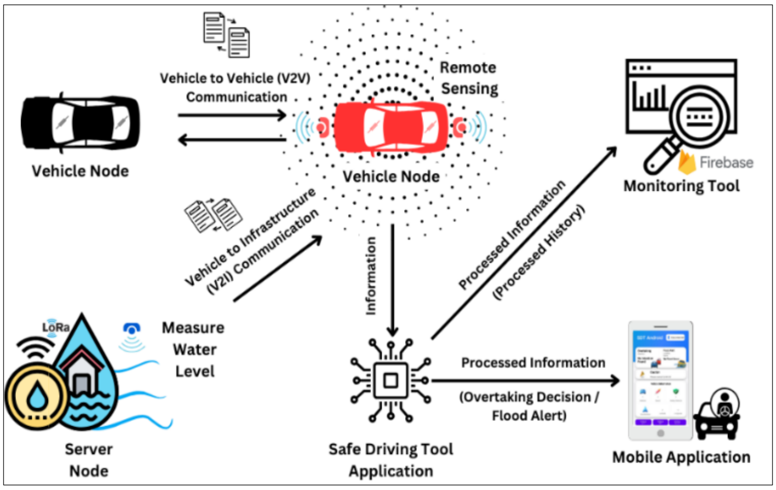

Figure 1. Safe Driving Tool System Conceptual Design Framework

Figures 2 and 3 show the flowchart and block diagram of the server node. The server node is equipped with an ultrasonic sensor to measure the water level continuously. Additionally, it obtains coordinate information (latitude and longitude) from a GPS module. Once these parameters are obtained, they are stored in a microcontroller and transmitted to nearby vehicle nodes using LoRa communication.

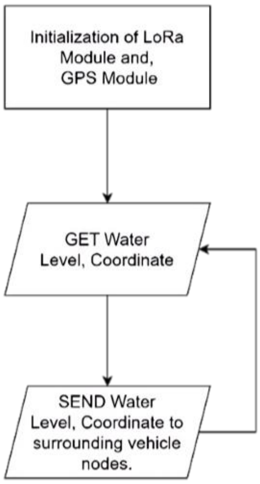

Figure 2. Architecture of the Server Node

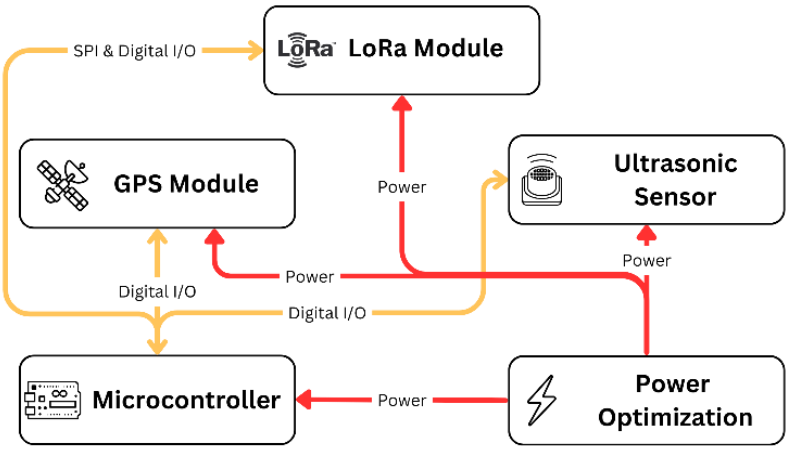

Figure 3. Block Diagram of the Server Node

Figures 4 and 5 show the block diagram and flowchart of the vehicle node. The vehicle node consists of two computational components: a microcontroller and a microcomputer. A microcontroller is responsible for collecting and transmitting data from various external modules, such as the GPS module, LoRa module, compass module and four ultrasonic sensors. The four ultrasonic sensors are placed at four corners of the vehicle. The microcomputer is responsible for storing and processing data, as well as making decisions based on the data. The microcomputer can communicate with the microcontroller and receive information from it, such as the data from other vehicle nodes and server nodes via LoRa communication or the self-information from the external modules. The vehicle node also uses LoRa communication to transmit its data to other vehicle nodes. The vehicle node can perform various tasks, such as flood alerts and vehicle overtaking assistance, depending on the data and the decision made by the microcomputer.

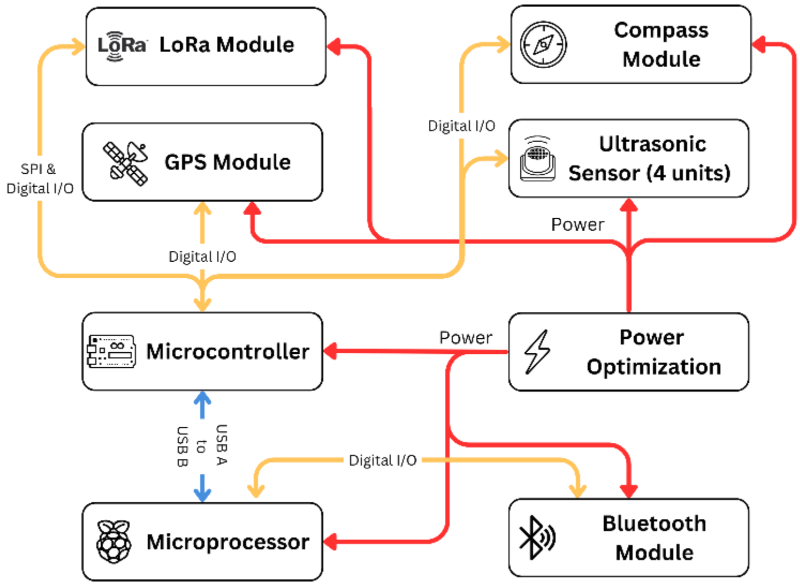

Figure 4. Block Diagram of the Server Node

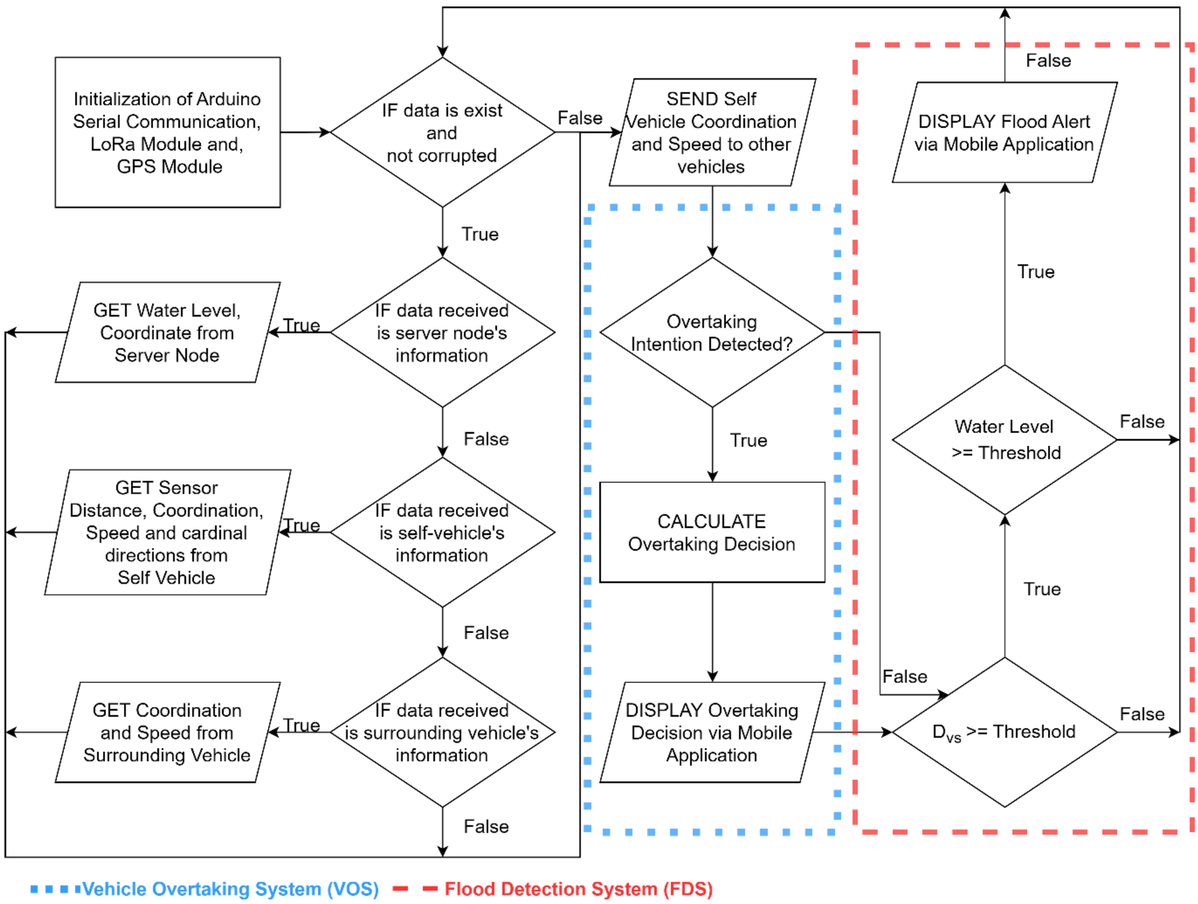

Figure 5. Architecture of the Vehicle Node

The overtaking decision, D is calculated based on the Haversine formula which includes latitude and longitude values of the host vehicle, h and surrounding vehicle, s as shown in Equation 1. In this equation, the φ refers to the vehicle latitude values and the λ refers to the vehicle longitude values. The value 6371.009 is the Earth's radius based on the WGS84 ellipsoid.

$$D = 2\,(6371.009)\,\mathrm{asin}\left(\sqrt{sin^2\left(\frac{\varphi_s-\varphi_h}{2}\right) + cos(\varphi_1) * cos(\varphi_2) * sin^2\left(\frac{\lambda_s-\lambda_h}{2}\right)}\right) \tag{1}$$

Moreover, FDS serves to ascertain water levels in flood-prone areas, determining whether they surpass predefined thresholds. Given the wide communication range of LoRa, a vehicle node receives information from a distant server node. To prioritize pertinent data for the driver, a threshold distance value is established. When a vehicle node receives flood information from server node, the system processes it only if the distance between the vehicle node and server node (D_{VS}) is within the predefined threshold. Suppose D_{VS} is greater than the predefined threshold distance. In that case, the system will continue to detect the flood occurrence by examining whether received water level from the server node exceeds the predefined threshold.

The server node and vehicle node prototypes were developed for experimental purposes using embedded system development methodology. Additionally, a mobile application, called SDT Android, was developed for the driver to receive information from the vehicle node. SDT Android is written in Kotlin programming language and can be installed on any phone with Android version 5.0 (Lollipop) or above. The application is connected to the vehicle node through Bluetooth communication. Figure 6 shows the main screen of SDT Android, which displays the connection status between the vehicle node, overtaking information panel, flood occurrence information panel, and vehicle motion information. Due to constraints of applying the prototype in actual vehicle, three buttons that act as vehicle signals: Left Signal, Right Signal, and Signal Off were provided at the bottom of the screen to simulate the overtaking intention of drivers and demonstrate the functionalities of the prototype.

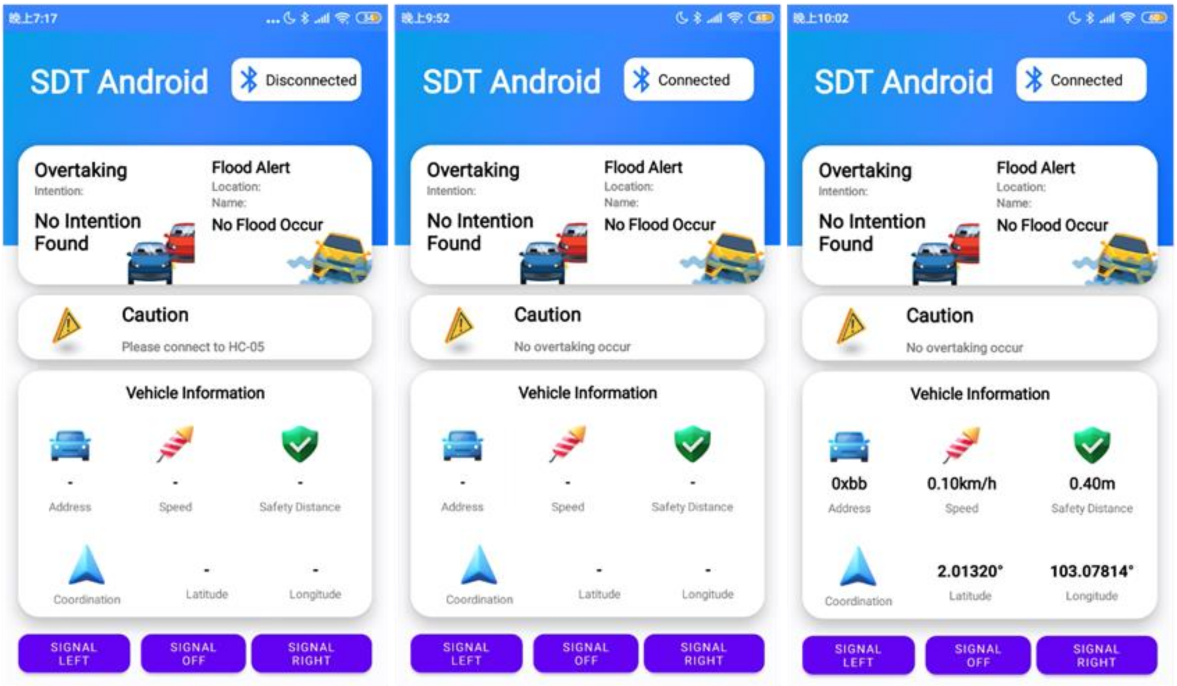

Figure 6. Main Screen of the SDT Android

The SDT Android will alert the driver through the Bluetooth module if a flood occurrence is detected. According to JPS Selangor's flood gauge thresholds, water levels ranging from 30 cm to 60 cm are classified as "Warning Level," while levels exceeding 60 cm are considered "Danger Level" [33]. Rapidly flowing water poses distinct risks; for instance, a water level of 12 inches (30 cm) can carry away small vehicles, while a level of 18 inches (45 cm) or more can transport larger vehicles [34]. In the proposed system, the water level less than 28cm is considered “Safe”. Otherwise, it is considered “Danger”.

Moreover, to evaluate the performance of the developed SDT Android, a web-based monitoring tool (SDT Monitor) is developed to monitor any process occurred in the vehicle node in real time. The vehicle node will upload any interaction made to the Firebase’s Realtime database through Wireless Fidelity (WiFi) communication. Real-time information of the connected vehicle as well as the information received from other nodes can be viewed using the SDT monitor, as shown in Figure 7.

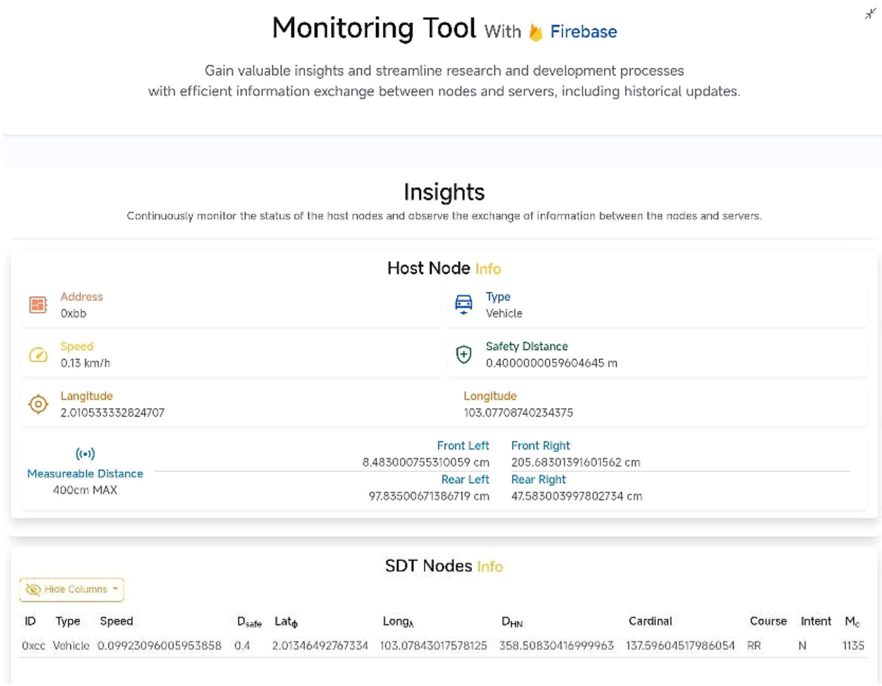

Figure 7. SDT Monitor – Real-Time Information Display

Besides, the SDT Monitor is also able to display the connected vehicle status, the measured distance, and the historical updates of the sensors. It can monitor the LoRa transmission rate, update rate between the microcontroller and microcomputer, error information, and distance in meters. It can also show the monitored and safety distance in a graph. Additionally, it also includes a filtering feature to visualize the vehicle information based on the specific period as shown in Figure 8.

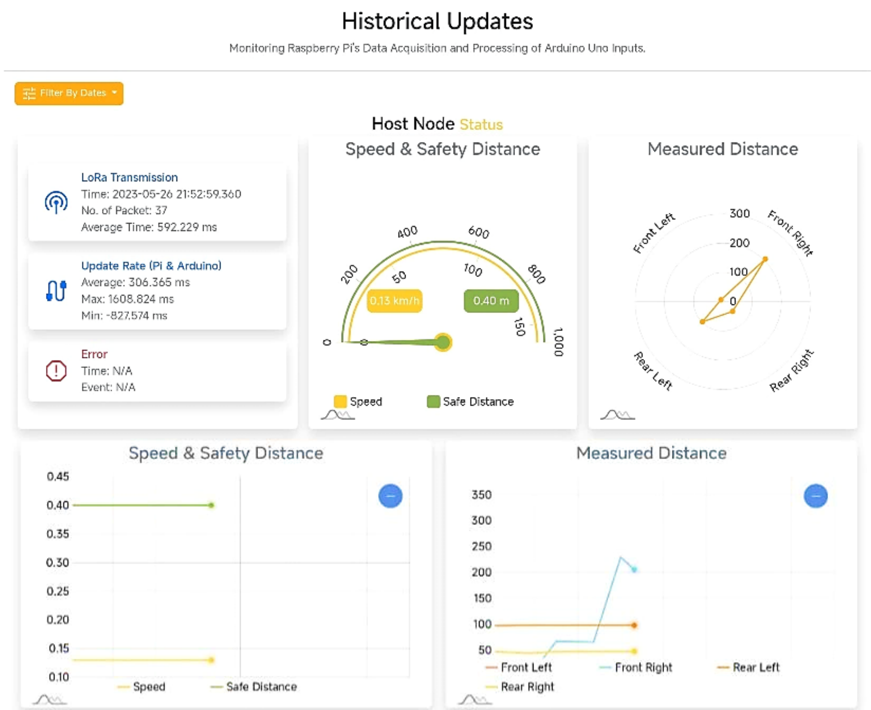

Figure 8. SDT Monitor – Detailed Vehicle Information Visualization

3. System Testing

The testing of the SDT system is divided into three sections: LoRa transmission inspection, FDS simulation, and VOS simulation. This comprehensive testing approach allows for a thorough evaluation of the reliability, integrity, and functionality of the proposed work. In the LoRa transmission inspection, the performance of the communication was assessed in transmitting and receiving data between two vehicle nodes for five minutes at various distances using SDT Monitor. This includes evaluating the received signal strength indicator (RSSI), signal-to-noise ratio (SNR) and packet losses. The testing was conducted in a town known as Yong Peng which is a significant locality within Johor, Malaysia in the district of Batu Pahat. During the communication, each vehicle node will send a packet at regular intervals every 200 to 400 milliseconds. The analysis distances include 50 meters, 100 meters, 150 meters and 200 meters, tested in two different locations, both characterized by a limited presence of surrounding buildings and expansive open areas, as shown using satellite images from Google Maps in Figures 9 and 10.

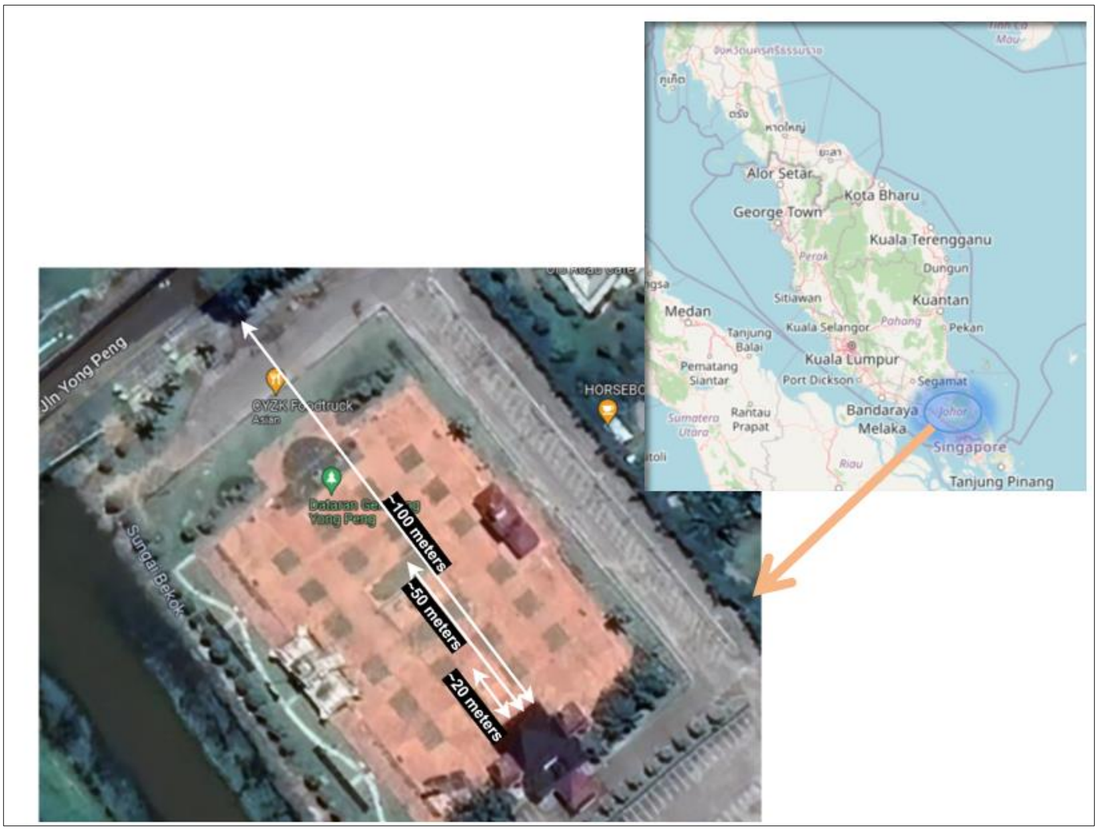

Figure 9. FDS Testing Location 1

Figure 10. FDS Testing Location 2

Before the testing, a server node is placed at the fixed location to act as the monitoring station. Adjacent to the server node is an approximately 46 centimeters deep container (D_c) which is filled with water to simulate different water levels. The ultrasonic sensor of the server node is placed at the top of the container to measure the distance of the water surface (D_{ws}). To obtain the actual water level of the container (D_w), a conversion is required using Equation 2. In the context of the server node as the focal point, two zones have been defined they are alert zone and non-alert zone. During this simulation, the alert zone spans a radius of 100 meters, while the non-alert zone extends beyond 100 meters from the server node, as shown in Figure 11. In case of a flood event, only vehicle nodes within the alert zone will receive an emergency notification from the mobile application. Various vehicle nodes are strategically positioned across different zones to assess the information reliability offered by the system. Details of different tests conducted on FDS based on flood occurrences and positions of vehicle nodes can be found in Table 3.

$$D_w = D_c - D_{ws} \tag{2}$$

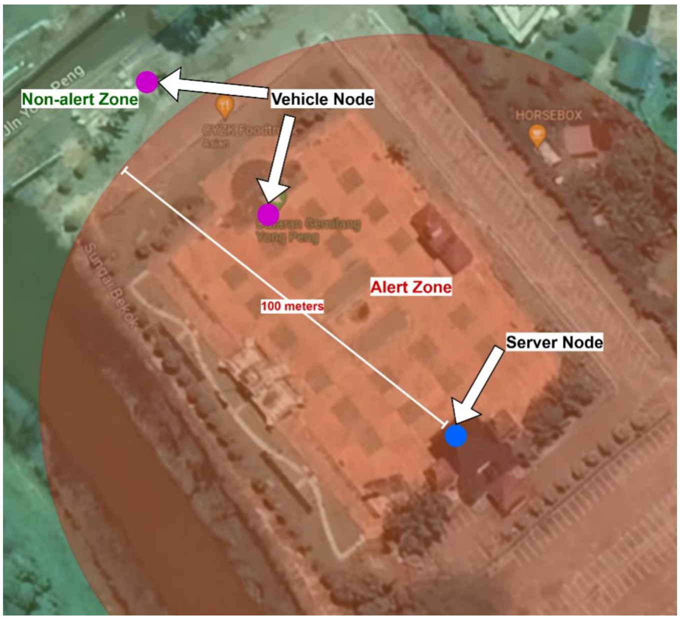

Figure 11. Alert and Non-Alert Zones in FDS Simulation

Table 3. Summary of FDS Tests: Flood Occurrences and Vehicle Node Positions

No. Test	Water Level (D_w)	Flood Occurrence	Position of Vehicle Node
1	~30 centimeters	Yes	At Alert Zone
2	~30 centimeters	Yes	At Non-Alert Zone
3	~20 centimeters	No	At Alert Zone

On the other hand, the simulation of the VOS was conducted by simulating a two-lane, one-way road using two vehicle nodes (represented by red and blue). Figure 12 illustrates this setup. In the simulation, the red vehicle node is not equipped with Raspberry Pi Model B as this node does not require computation for flood alert, caution, and generating overtaking decisions. The blue vehicle node will be connected to the SDT Android to visualize the information from the SDT system. Furthermore, both vehicle nodes were provided with a constant speed of 0.10 km/h, and the D_{safe} was computed as 0.40 meters (or 40 centimetres).

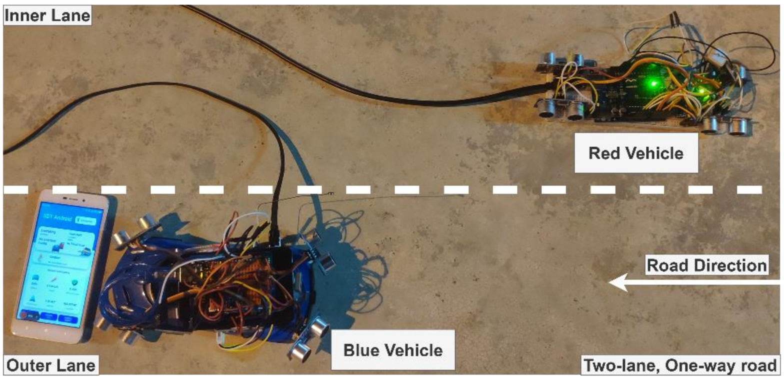

Figure 12. VOS Simulation Setup

In the first test, the blue vehicle will serve as an overtaking vehicle and signal its intention to change lanes to the inner lane through the application. By adjusting the distance between the red vehicle nodes, the system will then promptly assess whether it is safe for the maneuver to proceed. In the second test, when the red vehicle activates its left signal, indicating a lane change to the outer lane, this intention will be communicated via LoRa technology to alert the blue vehicle's mobile application, providing a warning about an upcoming overtaking maneuver.

4. Result and Discussion

The FDS was tested by simulating a flood event as described in Section 3. During the first and second tests, the water level in the container was approximately 30 centimeters. When the flooded area (container) is within a proximity of about 75 meters from the server node (referred to as the alert zone), an alert is generated for the driver through the SDT Android. This is illustrated in Figure 13.

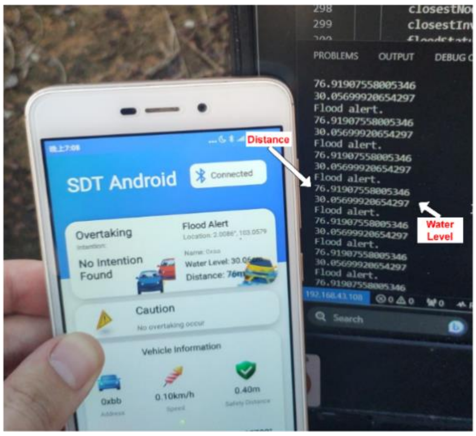

Figure 13. Result of Test 1 in FDS

On the other hand, if the flooded area is around 130 meters from the server node (known as a non-alert zone), even though it exceeds threshold levels, no flood alerts are sent to drivers. This can be seen in Figure 14 when water levels exceed thresholds, but no alert is triggered. In test three, with a lower water level of about 20 centimeters which falls below what qualifies as flooding events, illustrated in Figure 15, no flood event detection occurred when vehicles were located within the alert zone.

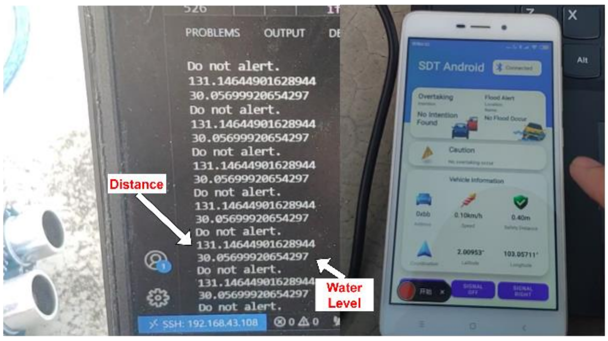

Figure 14. Result of Test 2 in FDS

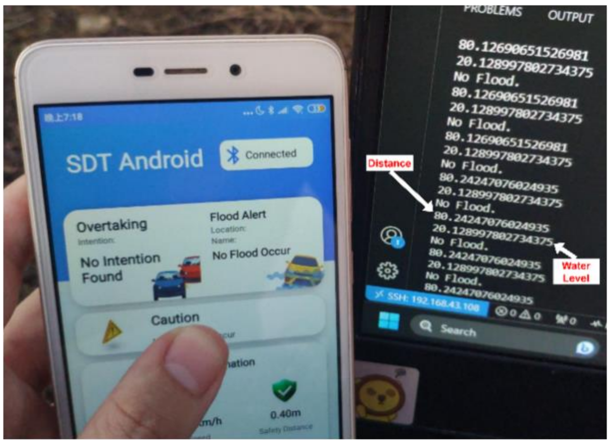

Figure 15. Result of Test 3 in FDS

The testing for VOS took place as described in Section 3. During the first test, when the blue vehicle node maintained a safe distance of around 45 centimeters from the red vehicle node, the system recommended the blue vehicle to overtake by showing the recommendation in SDT Android, as depicted in Figure 16. However, when the distance between the vehicles was reduced to approximately 37 centimeters, the system cautioned against the blue vehicle node's overtaking in Figure 17. In the second test scenario, while the red vehicle node attempted an overtake maneuver, the system alerted the blue vehicle node's driver of caution due to road conditions in Figure 18.

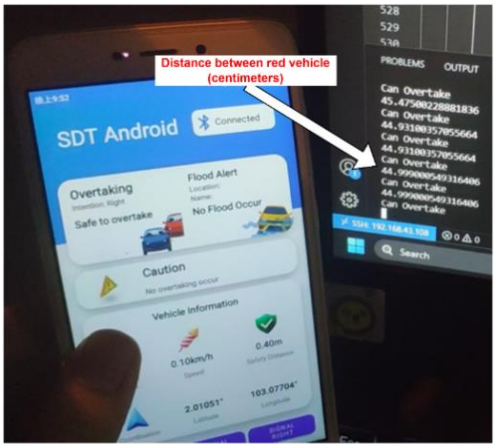

Figure 16. Result of Test 1 in VOS when Distance Between Vehicles is 45 centimetres

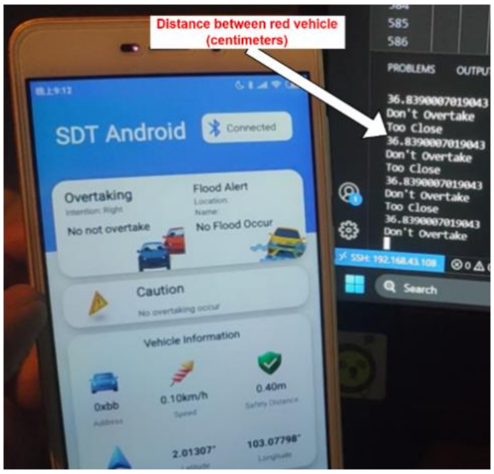

Figure 17. Result of Test 1 in VOS when Distance between Vehicles is 37 centimetres

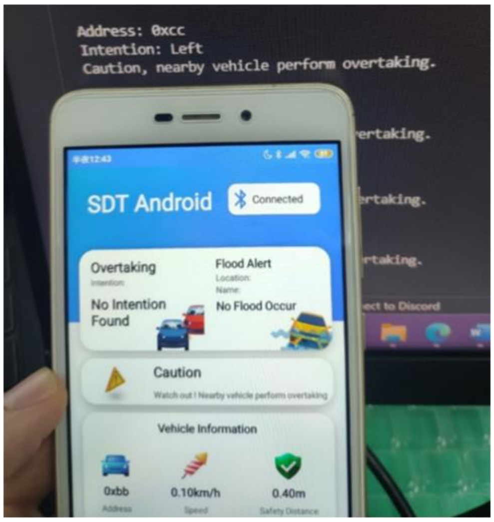

Figure 18. Result of Test 2 in VOS

5. Conclusion

In this study, a Safe Driving Tool (SDT) System is used to address the road safety issues in Malaysia. The SDT integrates Flood Detection System (FDS) and Vehicle Overtaking System (VOS) through Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) using LoRa communication technology. A mobile application known as SDT Android was developed to demonstrate the integration of FDS and VOS. SDT Android is able to provide real-time and relevant flood hazard information to alert the drivers on the road. It helps drivers avoid or reduce the risk of accidents caused by flooding. While performing overtaking, the SDT Android assists the driver to perform intentional overtaking by calculating the safe distance based on real-time information from the surrounding vehicles. It helps to overcome the limitations of human drivers in predicting safe overtaking situations, as they may be influenced by factors such as blind spots, driving experience, or weather conditions.

Several similar works have been discussed with regard to their strengths and limitations, and all of them do not integrate FDS and VOS into one complete system. Furthermore, the FDS and VOS related publications discussed limited testing on the reliability and functionality of their proposed work. This research also aims to conduct several tests for evaluating the performance of SDT systems in terms of reliability and functionality. A web-based monitoring system known as the SDT Monitor is developed to monitor the SDT system throughout the entire testing.

In conclusion, the SDT system consists of two nodes: the server node and the vehicle node. The server node aims to monitor the water level of the flood-prone area and transmit the information to the vehicle node by configuring and programming the Arduino Uno microcontroller and various external sensors or modules. On the other hand, the vehicle node aims to receive any information from the surrounding vehicle nodes or server nodes and process them to provide relevant, accurate information to the driver, such as flood alerts or overtaking decisions, while performing overtaking through mobile applications. Because of its capability, the vehicle node is equipped with a Raspberry Pi Model B microcomputer, which is connected to an Arduino Uno microcontroller to store and process huge amounts of information.

In future developments, the Lidar module is proposed to replace all the ultrasonic sensors on the vehicle node for wide measurement angles and measurement distances. Moreover, for more precise values, it is recommended to obtain the speed of the vehicle node from its existing hardware module rather than relying on a GPS module. Additionally, an LED light can be integrated into the side mirrors of the vehicle to reduce driving distraction. By utilizing the monitoring tool, the collected data, which includes driving behavior, could be analyzed to develop a more personalized VOS system, reckless driving detection system, etc.

6. Declarations

6.1. Author Contributions

Conceptualization, S.F.A.R. and S.Y.; methodology, K.C.S. and S.Y.; validation, K.C.S., S.F.A.R., and S.Y.; writing—original draft preparation, K.C.S.; writing—review and editing, S.F.A.R. and K.C.S.; visualization, K.C.S. All authors have read and agreed to the published version of the manuscript.

6.2. Data Availability Statement

The data presented in this study are available in the article.

6.3. Funding

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6.4. Acknowledgements

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6.5. Conflicts of Interest

The authors declare no conflict of interest.

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