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FEASIBILITY STUDY OF REAL-TIME IOT BASED EMERGENCY VEHICLE ALERT SYSTEM FOR ROAD SAFETY

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Abstract— Emergency vehicles such as police cars, fire trucks, and ambulances must reach their destinations quickly and safely. Sirens and warning lights are traditionally used to facilitate movement through traffic. However, some drivers unaware of their presence which leads to delays and hindering response times. To address this challenge, this study investigates the feasibility of an IoT-based emergency vehicle alert system that enhances driver awareness through real-time notifications and location information.

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Microcontroller, Real-Time Notification

The proposed system integrates a NodeMCU microcontroller, GPS module, and Firebase Realtime Database to transmit and store the emergency vehicle's coordinates. MIT App Inventor is utilized to develop a smartphone application to display the real-time location of the emergency vehicle on a map and provides notifications to drivers within a 3.0 km radius. Feasibility testing was conducted to evaluate the system's performance in terms of GPS data transmission, notification delivery, and location accuracy. The results show consistent data synchronization with Firebase, reliable notifications across the defined radius, and accurate representation of vehicle positions on the application interface. These findings confirm the practicality of the proposed approach in improving driver responsiveness and minimizing delays in emergency response.

I. Introduction

The Internet of Things (IoT) has significantly transformed the landscape of modern transportation systems, enabling real-time data exchange and decision-making processes. In the context of vehicular IoT systems, the development of intelligent networks to detect the presence of emergency vehicles represents a critical advancement. Emergency vehicle detection systems, using IoT-based sensors and communication technologies, can enhance the safety and efficiency of road networks by dynamically altering traffic patterns to give priority to ambulances, fire trucks, or police cars. These systems operate by deploying a series of interconnected sensors and

devices, which continuously monitor and relay information about nearby vehicles, such as their speed, location, and proximity. By integrating IoT with vehicle-to-everything (V2X) communication, these systems can instantly notify regular vehicles and traffic control infrastructure when an emergency vehicle is approaching. This technology helps reduce response times and mitigate risks of accidents by ensuring a clear path for emergency responders. The integration of IoT in this domain not only promotes smart mobility but also aligns with the broader vision of connected and autonomous vehicles, paving the way for more efficient and safer urban environments.

This paper is organized as follows. The next section provides a literature review that introduces the need for improved emergency vehicle detection systems, emphasizing the limitations of traditional sirens and warning lights. The methodology section describes the integration of NodeMCU, GPS, and Firebase Realtime Database in developing a prototype real-time alert system. The subsequent section presents the feasibility study results demonstrating the system's effectiveness across different radii in notifying nearby vehicles. This section also discusses the practical implications of the findings and potential to be implemented in real emergency vehicles as well as areas for further enhancement. Finally, the paper concludes with a summary of contributions and future research directions.

II. Literature Review

In recent years, the integration of Internet of Things (IoT) technology into smart cities has significantly enhanced the detection and prioritization of emergency vehicles in urban traffic systems. Reference [1] highlighted the role of IoT in smart cities, focusing on how interconnected sensors enable real-time detection of emergency vehicles, thereby improving traffic management. Similarly, [2] presented a framework for prioritizing emergency vehicles in

intelligent traffic systems, which aims to optimize traffic flow and reduce response times for emergency services. Furthermore, IoT-based systems have been instrumental in fusing various detection technologies, such as audio and vision. Reference [3] emphasized the importance of combining these two modalities to create more accurate emergency vehicle detection systems, while [4] proposed a real-time traffic surveillance system that incorporates acoustic signals to detect emergency vehicles in densely populated areas. This approach enhances the robustness of detection systems in noisy urban environments. On the other hand, Artificial Intelligence (AI) also plays a pivotal role in improving the efficacy of emergency vehicle detection. Reference [5] introduced an AI-based system that prioritizes emergency vehicles by automatically adjusting traffic signals, ensuring quicker passage through congested areas. Reference [6] further explored the use of IoT in vehicular emergency models, proposing a new framework that enhances the overall safety of road networks.

In addition to detection, the notification and tracking of accidents are crucial for emergency response. Reference [7] introduced a smart accident detection system that integrates GPS and GSM technology, enabling real-time notifications to emergency services. Reference [8] also discussed the role of IoT in monitoring vehicle speed and detecting accidents, which helps to prevent collisions. Meanwhile, [9] expanded on this by utilizing vehicle-to-vehicle (V2V) communication in IoT-based systems to detect and prevent potential collisions in vehicular ad hoc networks (VANETs). On the other hand, a smart vehicle monitoring system that not only tracks vehicle locations but also aids in accident prevention through IoT-based data analytics proposed in [10]. These systems collectively highlight the transformative impact of IoT in enhancing road safety and ensuring the rapid detection of

and response to emergency situations.

In this paper, an IoT-based emergency vehicle alert system is developed to enhance driver awareness of nearby emergency vehicles. The system utilizes a NodeMCU microcontroller and Firebase Realtime Database to gather and process location data. A dedicated smartphone application notifies drivers about the presence of an approaching emergency vehicle and displays its real-time location on a map. This system addresses a critical issue where drivers rely solely on the siren sound to detect emergency vehicles, often leading to delayed reactions. By providing precise location information, the system helps ensure safer and more efficient traffic management.

III. Methodology

A. System Architecture

The system architecture of the IoT based emergency vehicle alert system is designed to show how information moves from the emergency vehicle to the nearby drivers in real time. As shown in Figure 1, the emergency vehicle is equipped with a GPS module that communicates with the GPS satellite to obtain accurate location coordinates. These coordinates are then sent to the cloud through a NodeMCU microcontroller, which acts as the processing unit and communication gateway. The cloud database, supported by a server, stores and manages the incoming location data and makes it available for other users at the same time. From the cloud, the information is shared with the mobile application installed on the smartphones of nearby drivers. The application uses Google Maps API to display the exact location of the emergency vehicle and provides a notification when the vehicle enters a set radius. This allows drivers to be aware of approaching emergency vehicles, giving them time to respond safely by slowing down or giving way. The architecture is simple but effective, ensuring smooth data transmission, accurate location mapping, and timely alerts. This design is practical for feasibility testing

and shows strong potential for future use in real emergency vehicles.

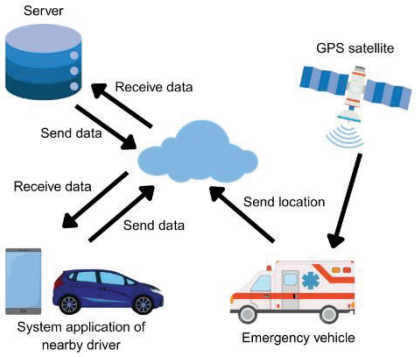


Figure 1: System Architecture

B. System Block Diagram

The IoT-based emergency vehicle alert system aims to improve road safety by providing real-time location updates of emergency vehicles to nearby drivers. The system architecture of this work is demonstrated in Figure 2. This work integrates a GPS module, NodeMCU microcontroller, Firebase Realtime Database, and a smartphone application. When the emergency vehicle is in operation, the system is activated through a switch, which powers the GPS module to continuously capture the vehicle's location coordinates. These coordinates are then transmitted to the NodeMCU, which functions as the core processing unit of the system. The NodeMCU is equipped with Wi-Fi capabilities, allowing it to transmit data to the Firebase Realtime Database, where the coordinates are stored. Firebase serves as a cloud-based platform for storing and synchronizing data in real-time.

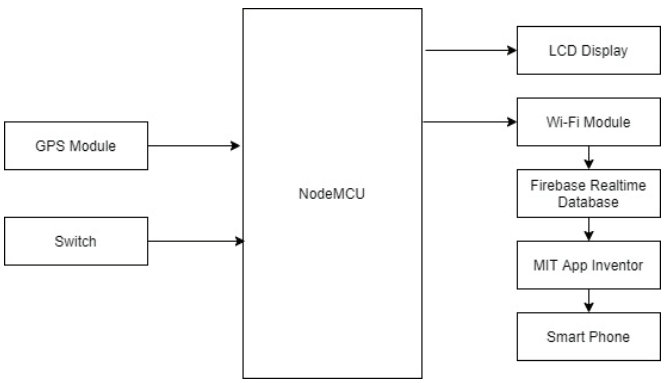


Figure 2: System Block Diagram

C. System Flowchart

Figure 3 illustrates the systematic architectural flow of the implemented emergency vehicle alert system, delineating the key operational components and their interconnections.

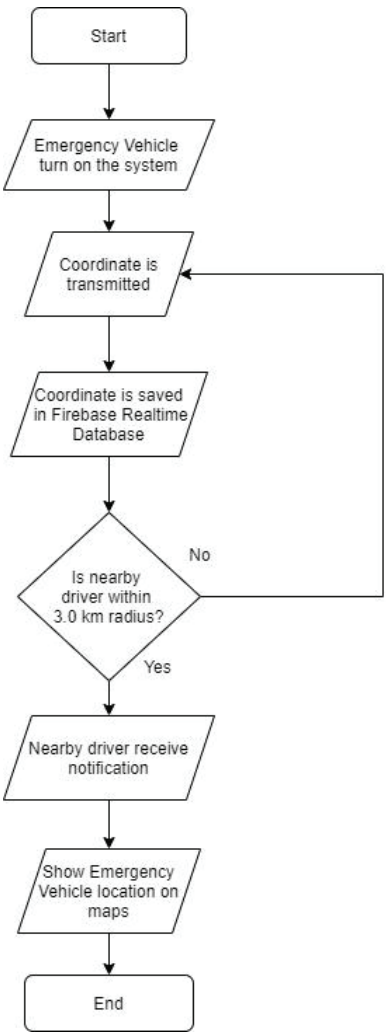


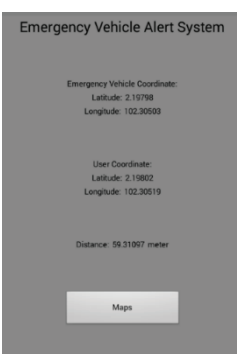
Figure 3: System Flowchart

The system is set to constantly monitors the location of surrounding vehicles within a 3.0km radius. If a nearby vehicle is detected within this range, the system immediately sends a notification to the driver's smartphone via the Firebase platform. The smartphone application, developed by using MIT App Inventor, displays a map with the real-time location of the emergency vehicle, allowing drivers to adjust their course or pull over to give way. The system also includes an LCD display for outputting relevant information within the emergency vehicle, ensuring the vehicle operator is aware of the system's functionality. This real-time notification system addresses the common issue where drivers only rely on the sound of sirens, often struggling to determine the exact location of an emergency vehicle, especially in congested or noisy environments. By offering a visual representation of the emergency vehicle's location through the mobile application, drivers can react more efficiently, enhancing traffic

management and reducing delays for emergency responders. Therefore, the used of NodeMCU, Firebase, and smartphone integration makes this system an efficient and scalable solution for modern smart cities, contributing to safer and more responsive traffic systems.

IV. Results and Discussion

The feasibility testing of the proposed IoT based emergency vehicle alert system was conducted to evaluate its performance in real-world scenarios. The prototype system, built upon a NodeMCU microcontroller, GPS module, and Firebase Realtime Database was assessed for its ability to provide reliable notifications and accurate spatial awareness. The results demonstrate that the system prototype can successfully transmit GPS data and deliver notifications to nearby drivers within the defined proximity radius. As shown in Figure 4, the application interface reliably displayed real-time coordinate tracking with latitude of 2.19798 and longitude of 102.30503. Furthermore, the distance calculation algorithm demonstrated dependable operation which producing separation distances with sub-meter precision ranging from 10.12863 to 59.31097m. These findings validate the technical feasibility of continuous monitoring for both emergency vehicles and nearby drivers.



(a) Main screen of system apps

(b) Pop up notification

Figure 4: Interface of System Apps

In addition, feasibility testing highlighted the system's real-time alert mechanism as a key feature. Notifications were triggered when emergency vehicles entered a defined proximity threshold while the integration of Google Maps API provided clear geographic contextualization as illustrated in Figure 5.

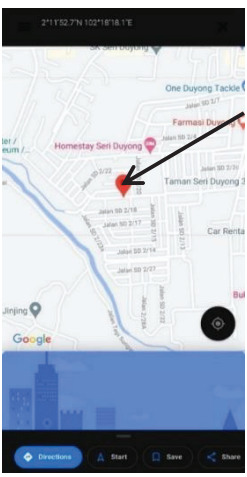


Figure 5: Location of Simulated Emergency Vehicle by Google Maps

The ability of the prototype to transform raw coordinate data into actionable spatial awareness indicates practicality compared to traditional audio only siren systems. These results suggest that the system has potential to improve both emergency vehicle navigation efficiency and nearby driver responsiveness.

Further analysis of notification latency provided additional insights into system performance. As illustrated in Figure 6, response times showed a modest linear increase with larger radii, progressing from a mean of 5.18s at 1.0km to 5.77s at 3.0km. Standard deviations remained consistent between 0.39s and 0.43s across all test configurations which reflects a stable system behaviour. Notably, sub-6-second average response times were maintained even at the maximum tested radius, indicating strong scalability for urban environments. The minimal performance degradation across different ranges highlights the robustness of the prototype while consistent variance demonstrates its reliability under diverse conditions.

Overall, the feasibility testing results validate the practicality of the proposed system and provide valuable insights for refinement. The findings confirm that the prototype offers a viable pathway toward

enhancing emergency response effectiveness and improving road safety while laying the groundwork for future implementation in real emergency vehicles.

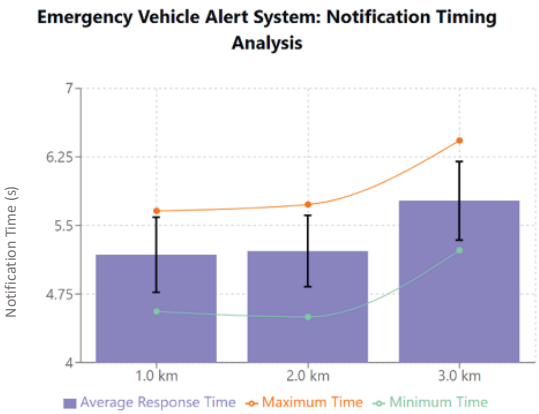


Figure 6: Notification of Timing Response

V. Conclusion

As a conclusion, this work presented the feasibility study of an IoT based emergency vehicle alert system designed to enhance nearby driver awareness through real-time notifications and location information. The integration of a NodeMCU microcontroller with GPS and Firebase Realtime Database enabled the smooth collection, transmission, and storage of emergency vehicle coordinates, while the mobile application developed using MIT App Inventor facilitated real-time mapping and user notifications. The feasibility results demonstrated that the system effectively addressed the limitations of relying solely on sirens, improving nearby driver reaction times within a 3.0km radius. Consistent notification performance across varying distances further validated the reliability and scalability of the prototype. The findings confirm the technical feasibility of the proposed system and its potential for the implementation toward a real emergency vehicle. Future work will focus on expanding detection range, refining system efficiency, and

exploring additional IoT technologies to strengthen the practicality and coverage of this approach.

VI. Acknowledgement

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