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Creating Green Corridors for Emergency Vehicles Using ESP-32 and RFID Technology

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ABSTRACT
In urban areas, especially in countries with high population densities, traffic congestion poses a significant challenge for emergency vehicles, often inflating their response times. Timely response to any emergency situation ensures quick control over the situation and immediate medical attention to the victims, significantly improving their chances of survival. This project proposes a solution to the ever-increasing emergency response times in urban areas by creating a green corridor for emergency vehicles by dynamically controlling traffic signals using the ESP-32 microcontroller and RFID (Radio-Frequency Identification) technology. In this system, we propose to equip emergency vehicles with RFID tags and install RFID readers at junctions with traffic signals. The entire system will be controlled by a microcontroller. Once the RFID reader detects an emergency vehicle, it will inform the microcontroller and the controller will alter the sequence of the traffic signal to prioritize the emergency vehicle. The integration of RFID and ESP-32 provides a cost-effective, efficient, and real-time solution to reduce response times for emergency services. This project aims to save lives which are lost simply due to the loss of precious time waiting in traffic. This paper discusses the design, implementation, and potential impact of the system on urban traffic management.

Keywords – Traffic Signal, Emergency Vehicles, RFID, Urban Traffic Management, Response Time

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I. INTRODUCTION

With the rapid urbanization and increasing number of vehicles on the road, traffic congestion has become a critical issue, especially for emergency vehicles such as ambulances and fire trucks. Delays caused by traffic can lead to life-threatening situations, as emergency services struggle to reach their destinations on time. Traditional traffic management systems lack the flexibility to prioritize emergency vehicles, resulting in unnecessary delays. Many people succumb to their injuries due to this drawback of the conventional systems. A lot of lives can be saved and the situations can be brought under control much more efficiently just by responding to the emergency situation in time. Other proposed solutions to this problem follow complex methodologies such as calculating the path of the emergency vehicle and managing traffic accordingly. Such methods increase the complexity and cost of the system. This project aims to address this issue by creating a green corridor for emergency vehicles using the RFID technology. The system dynamically controls traffic signals to provide a clear path for emergency vehicles, ensuring their swift passage through congested areas. By integrating RFID for vehicle identification and ESP-32 for real-time communication with the traffic signal, the system offers a reliable and efficient solution for urban traffic management.

II. EXISTING SOLUTIONS

Several existing solutions have attempted to address traffic congestion and prioritize emergency vehicles. These include traditional traffic light systems, GPS-based tracking, and IoT-enabled traffic management systems. However, these solutions often lack real-time precision, seamless integration, and cost-effectiveness. For instance, GPS-based systems may suffer from signal delays, while IoT-based systems may require extensive infrastructure. This project attempts to overcome the drawbacks of these existing solutions by incorporating RFID technology and offers enhanced efficiency and reliability by considering only one traffic junction at a time and minimizing the factors affecting the system.

III. LIST OF FIGURES

IV. LITERATURE SURVEY

A thorough review of existing literature reveals various approaches to traffic management and emergency vehicle prioritization. Dr. Abdul Rahim a smart traffic light signalling strategy using embedded systems, focusing on emergency vehicle priority. Their system uses ultrasonic and infrared sensors to detect emergency vehicles and adjust traffic signals. However, the system lacks real-time precision and struggles with scalability in large urban areas due to its reliance on sensor-based detection, which can be affected by environmental factors such as weather and obstructions [1]. S. Javaid developed a smart traffic management system using IoT, which demonstrated the potential of real-time data processing for traffic control. While their system integrates GPS and cloud-based data processing, the reliance on GPS signals introduces latency, which can delay the system's response time during emergencies [2]. Arjun Chaudhari explored RFID-based smart traffic management, specifically for creating green corridors for emergency vehicles. Their system uses RFID tags and readers to identify emergency vehicles and adjust traffic signals dynamically. However, it lacks integration with modern IoT technologies, limiting its ability to handle complex traffic scenarios in real-time [3]. Rajak assessed the impact of dynamic real-time green corridors on normal traffic flow, highlighting the need for efficient integration. Their proposed solution relies heavily on centralized control systems, which can become a single point of failure [4]. Bhushan Gullapelli conducted a survey on intelligent traffic control systems for ambulances, emphasizing the importance of real-time decision-making. The survey highlighted that most systems fail to provide a seamless integration of technologies such as RFID, GPS, and IoT [5]. Chaudhari further elaborated on RFID-based systems for emergency vehicle prioritization. While the system is effective in identifying emergency vehicles, it does not account for the dynamic nature of urban traffic and lacks advanced features such as predictive analytics [6]. Naik proposed an RFID-based smart traffic control framework, focusing on reducing response times for emergency vehicles. However, the system's reliance on RFID alone limits its ability to handle multiple emergency vehicles simultaneously, leading to potential delays in high-traffic scenarios [7]. W. Wen introduced an intelligent traffic management expert system using RFID technology. The system uses RFID for vehicle identification and traffic flow optimization but lacks integration with modern IoT technologies, limiting its ability to handle real-time data processing [8]. Chattaraj discussed the use of RFID in intelligent traffic control systems, emphasizing its cost-effectiveness and reliability. However, the system's reliance on RFID alone limits its ability to handle complex traffic scenarios, such as intersections with multiple lanes and high traffic density [9]. Pawłowicz explored dynamic RFID identification in urban traffic management systems, highlighting its scalability and efficiency. However, the system's reliance on centralized control systems introduces potential vulnerabilities, such as single points of failure and latency in decision-making [10].

V. PROPOSED SOLUTION

The proposed system consists of the following components:
1. RFID Tags: Attached to emergency vehicles for identification.
2. RFID Reader: Detects the presence of emergency vehicles and communicates with the ESP-32 microcontroller.
3. ESP-32 Microcontroller: Processes the RFID data and controls traffic signals to create a green corridor.
4. Traffic Signal Unit: Used to communicate with the traffic at junctions.

1. 1 Working:
1. When an emergency vehicle equipped with an RFID tag approaches a traffic signal, the RFID reader detects the tag and sends an interrupt to the ESP-32 microcontroller.
2. The microcontroller processes the data and communicates with the traffic signal to change the signal to green, allowing the emergency vehicle to pass through.
3. Once the RFID reader placed on a different road of the junction detects the same vehicle, the system resumes its normal operation.

VI. METHODOLOGY

The methodology for this project involves the following steps:
1. System Design: Design the hardware and software architecture for the RFID and ESP-32-based system.

2. Component Selection: Choose appropriate components such as RFID tags, RFID readers, ESP-32 microcontrollers, and traffic signal units in accordance with the requirements of the project.
3. Integration: Integrate the RFID reader with the ESP-32 microcontroller and traffic signal control unit.
4. Testing: Test the system in a simulated environment to ensure real-time functionality and reliability.
5. Deployment: Deploy the system in real-world scenarios and evaluate its performance.

VII. COMPONENT SELECTION

The selection of components is critical to the smooth functioning of the system. The following components were chosen based on their cost, reliability, and compatibility:
1. ESP-32 Microcontroller: A 32 bit microcontroller chosen for its high speed I/O operations capability and sufficient number of GPIO pins.
2. RFID Reader and Tags: Selected for their ability to provide real-time vehicle identification and communication with the microcontroller.
3. Traffic Signal Unit: This unit consists of RGB LEDs which can glow in red, green, blue or any combination of these colours. Using a single LED for all three colours of the traffic signal reduces the number of I/O pins of the microcontroller required to be engaged.
4. Power Supply: A 5V power supply provided to the ESP-32 microcontroller.

VIII. COMPONENTS

7.1 ESP-32 Microcontroller: The core processing unit of the system, responsible for data processing and communication.

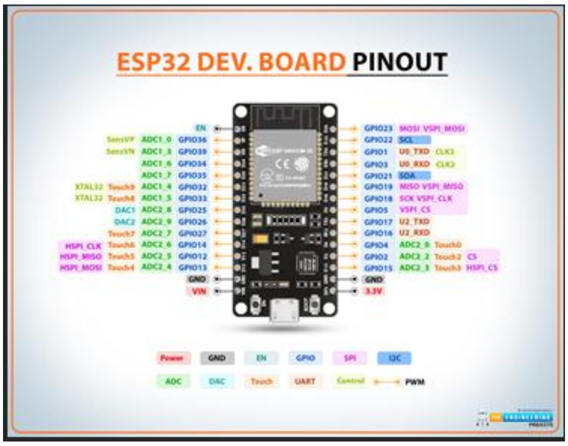

Fig. 7.1

7.2 RFID Reader (RC522): Detects RFID tags on emergency vehicles and sends data to the ESP-32.

Fig. 7.2

7.3 RFID Tags: Attached to emergency vehicles for identification.

Fig. 7.3

7.4 RGB LEDs – For simulating the traffic signal.

Fig. 7.4

IX. RFID AND ESP-32 IN THE SYSTEM

8.1 Role of RFID

RFID (Radio-Frequency Identification) technology is used for identifying and tracking emergency vehicles in real-time. Each emergency vehicle is equipped with a unique RFID tag, which transmits its identity to the RFID reader when it comes within range. The RFID reader captures this data and sends it to the ESP-32 microcontroller for processing. RFID is chosen for its reliability, low cost, and ability to operate in various environmental conditions. Unlike GPS, RFID does not rely on satellite signals, making it more suitable for urban environments where GPS signals may be weak or delayed.

8.2 Role of ESP-32

The ESP-32 microcontroller serves as the brain of the system, responsible for processing data from the RFID reader and controlling the traffic signal control unit. The ESP-32 is chosen for its dual-core processor, Wi-Fi, and Bluetooth capabilities, which enable seamless communication between the RFID reader and the traffic signal control unit. Its low power consumption and compact size make it ideal for integration into traffic management systems. Additionally, the ESP-32 supports real-time data processing, ensuring that the system can respond quickly to the presence of emergency vehicles.

8.3 Integration of RFID and ESP-32

The integration of RFID and ESP-32 forms the core of the proposed system. The RFID reader detects the presence of emergency vehicles and sends the data to the ESP-32, which processes the information and communicates with the traffic signal control unit. This integration ensures real-time detection and response, enabling the system to create a green corridor for emergency vehicles efficiently. The combination of RFID's reliability and ESP-32's processing power makes the system both cost-effective and scalable.

8.4 Block Diagram

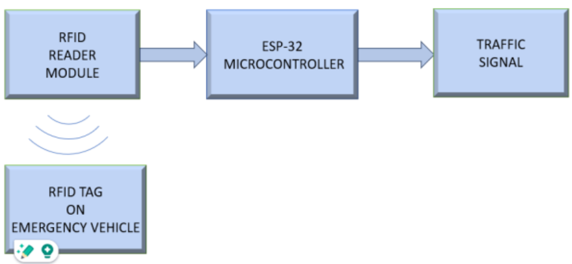

Fig 8.1

X. CONCLUSION

This project presents a cost-effective and efficient solution for creating green corridors for emergency vehicles using RFID and ESP-32 technology. By dynamically controlling traffic signals, the system ensures swift passage for emergency vehicles, reducing response times and saving lives. Future work can focus on integrating GPS and machine learning algorithms to further enhance the system's efficiency and scalability.

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