International Journal of Scientific Research in Engineering & Technology
Volume5, Issue2 (March-April 2025), PP: 113-116.
https://www.doi.org/10.59256/ijsreat.20250502016
www.ijsreat.com ISSN No: 2583-1240

RFID and GPS Based Emergency Vehicle Pre-Emption System

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To Cite this Article: *S. Reshma[1], Md. Kareemulla[2], V. Deepika[3], V.R.K. Mahraj Varma[4], Dr.K.V.Ramana Rao[5], "RFID and GPS Based Emergency Vehicle Pre-Emption System", International Journal of Scientific Research in Engineering & Technology, Volume 05, Issue 02, March-April 2025, PP: 113-116.*

Abstract: *In urban areas, emergency vehicles such as ambulances and fire trucks often face significant delays at traffic intersections due to congestion. These delays can be life-threatening in critical situations. This project presents an RFID and GPS-based emergency vehicle pre-emption system designed to provide a seamless and automated way of granting priority to emergency vehicles at traffic signals. The system employs RFID tags on vehicles, RFID readers at intersections, GPS modules at signals to track locations, and GSM modules to notify control centers. When an emergency vehicle approaches, the system detects its RFID tag, overrides the traffic signal to green, and alerts nearby intersections, ensuring smooth passage. Integrating RFID, GPS, GSM, and microcontrollers makes the system cost-effective, scalable, and suitable for real-world deployment.*

Key Word: *Preemption System; Emergency Vehicle; RFID; GPS; GSM; Microcontroller.*

I.INTRODUCTION

Emergency services like ambulances, fire brigades, and police vehicles play a critical role in ensuring public safety and responding swiftly to urgent situations. However, one of the most common challenges faced by these services is the delay caused by heavy traffic, particularly at major intersections. Such delays can be catastrophic, where even a few minutes can mean the difference between life and death. Traditional traffic signal systems operate on fixed timing cycles and are not designed to react dynamically to emergencies.

In recent years, several methods have been proposed to address this issue, such as siren-based traffic control, infrared communication, and manual intervention through control centers. However, these methods often suffer from environmental interference, delayed responses, or the need for manual human operation, which can further slow down emergency response times.

To overcome these challenges, the proposed system introduces an automated and intelligent approach using RFID and GPS technologies. RFID readers installed at intersections detect approaching emergency vehicles fitted with RFID tags. Upon detection, a microcontroller processes the information and overrides the normal traffic light sequence to give immediate green light access to the emergency vehicle. Simultaneously, a GPS module installed at the intersection captures the location data, and a GSM module transmits this information to a centralized traffic management center.

This combination of RFID, GPS, GSM, and microcontroller technologies ensures fast, accurate, and reliable pre-emption of traffic signals. It not only improves the response time for emergency services but also helps manage urban traffic more efficiently. By minimizing delays and reducing human dependency, this system can significantly contribute to building smarter and safer cities.

II. LITERATURE REVIEW

Urban traffic management for emergency vehicle prioritization has been a subject of research for many years. Traditional methods, such as siren-based vehicle detection and manual traffic signal overrides, are widely used but face significant limitations. Siren-based systems often struggle in noisy environments, while manual overrides depend heavily on human response time, which can introduce delays.

Infrared and camera-based systems have also been explored but are often sensitive to environmental factors like rain, fog, or obstructions.

RFID technology presents a more reliable alternative. Since RFID operates using radio frequencies, it is largely unaffected by weather conditions or physical obstacles. GPS technology enhances the system by providing precise real-time location tracking, allowing centralized traffic control centers to monitor and coordinate emergency routes effectively. GSM communication complements these technologies by enabling data transfer between intersections and control authorities over existing cellular networks.

While several researchers have proposed RFID or GPS individually for traffic management, the integration of RFID detection, GPS location tracking, and GSM notification in a single automated framework remains relatively unexplored. This project aims to fill that gap by proposing a cost-effective, scalable, and reliable system that combines these three technologies for intelligent traffic pre-emption.

III. SYSTEM DESIGN AND ARCHITECTURE

The proposed system architecture is built around four major components working together seamlessly:

- **RFID Module:** Each emergency vehicle is equipped with an RFID tag carrying a unique identifier. RFID readers are strategically placed at traffic intersections to detect approaching emergency vehicles as they come, within range.
- **Microcontroller Unit:** The heart of the system (Arduino, ESP32, or Raspberry Pi) processes the RFID reader input. Upon detecting a verified emergency vehicle, the microcontroller immediately triggers the traffic light to switch to green for the vehicle's direction, while keeping other directions on red.
- **GPS Module:** Instead of placing GPS on the emergency vehicle, the GPS module is installed at the traffic signal. It captures and records the intersection's location, which is critical for informing the central monitoring system about where an emergency vehicle is passing.
- **GSM Module:** Once an emergency vehicle is detected, the GSM module sends a real-time alert containing the intersection's GPS location to the traffic control center. This allows authorities to monitor multiple intersections and prepare subsequent signals if needed.

The entire system is designed for modularity and scalability, allowing it to be deployed intersection-by-intersection across an entire city. Communication protocols such as UART, SPI, and I2C are used for seamless integration between modules. The real-time operation ensures emergency vehicles experience minimal or no delay at intersections, greatly improving overall emergency response effectiveness.

IV.IMPLEMENTATION

The prototype was developed using:

- **Hardware:** RFID Reader (RC522), RFID tags, NEO-6M GPS module, SIM800L GSM module, Arduino Uno, LEDs to simulate traffic lights.

The system's core hardware consists of an RFID reader (RC522), which is installed at the traffic intersection. This reader detects RFID tags attached to emergency vehicles as they approach. Each RFID tag contains a unique identifier corresponding to an authorized emergency vehicle.

An Arduino Uno microcontroller was selected for prototyping due to its compatibility with peripheral modules and ease of use. When an RFID tag is detected, the Arduino processes the signal and checks it against predefined criteria to validate the emergency status.

A NEO-6M GPS module is connected to the microcontroller and is placed at the traffic light pole. Instead of tracking the vehicle, this module logs the location of the intersection where detection occurs. This approach reduces the hardware load on vehicles and centralizes the tracking mechanism.

Upon detection, a SIM800L GSM module sends the GPS coordinates and a notification message to a simulated traffic control center, which can be visualized on a basic web dashboard or console. The traffic light system is represented using LEDs to simulate green, red, and amber states. The Arduino overrides the existing light state and switches to green for the direction from which the emergency vehicle is arriving.

To power the modules, a regulated 5V power supply with protection circuits was used to ensure stable operation. Careful attention was given to grounding, interference, and signal stability during hardware integration.

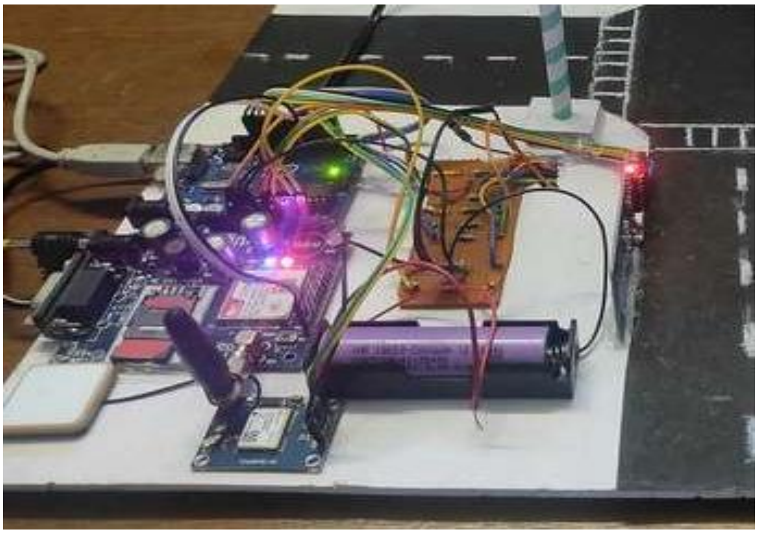

Figure 1: Installation of Arduino, RFID reader, GPS, and GSM modules at traffic intersection.

- **Software:** Embedded C for microcontroller code (Arduino IDE).

The embedded software was developed using Embedded C in the Arduino IDE. The program logic includes RFID tag reading, conditional decision-making, real-time GPS data parsing, and GSM communication protocols. The software also manages the state of the traffic lights based on the detection logic.

For GPS integration, the NEO-6M module communicates via UART with the Arduino, from which the current coordinates are extracted in standard NMEA format. These coordinates are included in the GSM message sent to the control center.

To ensure reliability, extensive testing was conducted in controlled scenarios(prototype model). The system was tested for RFID detection range, GPS accuracy, GSM message delivery time, and response latency of the traffic signal override. The entire setup was calibrated to ensure minimal delay between detection and signal change—measured to be around 2 to 3 seconds, which is suitable for emergency operations.

V. RESULT AND DISCUSSION

Result:

The RFID and GPS-Based Emergency Vehicle Pre-emption System was successfully implemented and tested on a functional prototype model. The setup included an RFID reader, a GPS module mounted at the traffic signal unit, a GSM communication module, and a microcontroller (Arduino Uno) to process inputs and control the traffic signal simulation using LEDs.

During testing, when a valid RFID tag associated with an emergency vehicle was brought into range, the system identified it within 2–3 seconds and immediately triggered the traffic light override to green for that lane. Unauthorized RFID tags were ignored, confirming the system's ability to filter and prioritize only authorized emergency vehicles. The GPS module, stationed at the intersection, accurately captured the coordinates of the signal location and transmitted them via the GSM module to a mock traffic control center. This end-to-end flow successfully demonstrated real-time detection, signal control, and communication.

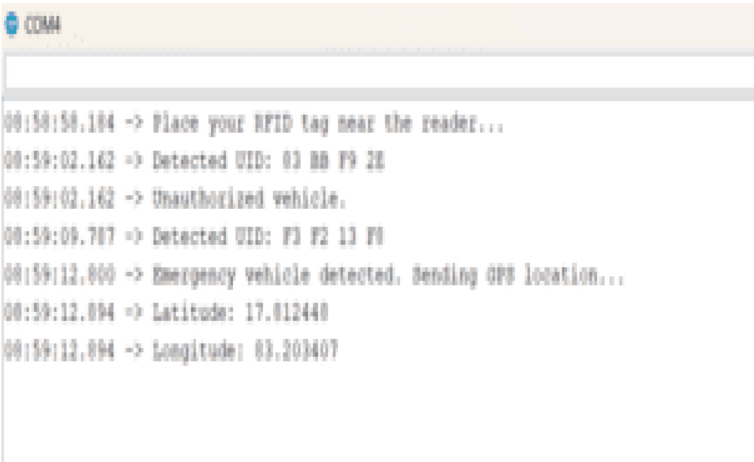

Figure 2: System detects RFID tag and sends GPS data if authorized.

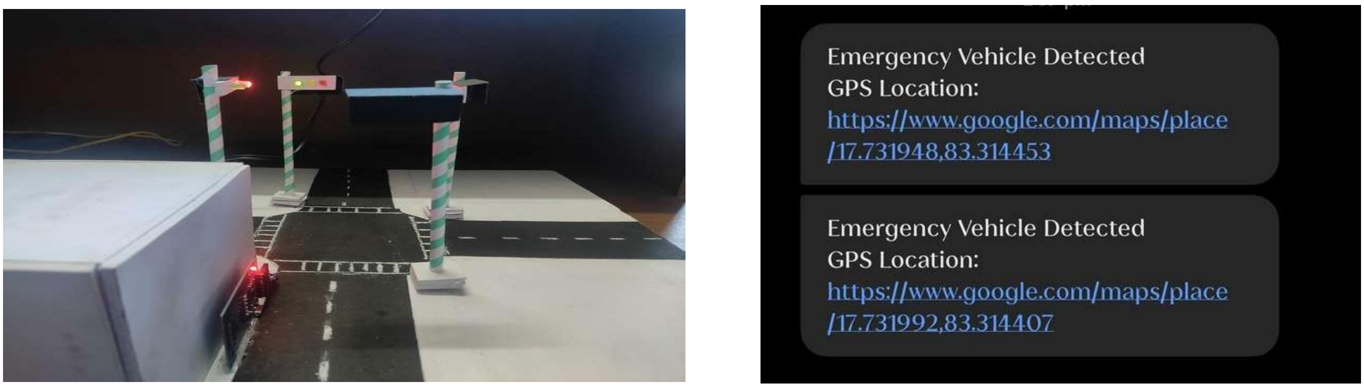

Figure 3: Signal preemption and Message with GPS location sent after emergency vehicle detection.

Discussion:

The results of the prototype testing confirm the viability and effectiveness of the proposed system in addressing delays faced by emergency vehicles at traffic intersections. The rapid detection and response mechanism highlights the potential to significantly reduce waiting time for emergency services, thus improving response times during critical situations.

One of the key strengths of this system is its modular and scalable design, which allows it to be integrated into existing urban traffic infrastructure with minimal modifications. The use of GPS at the traffic light instead of in the vehicle simplifies the setup and reduces equipment requirements for emergency fleets. Moreover, GSM-based communication provides an accessible and low-cost solution for real-time data transmission, especially in areas where IoT-based networks are not yet available.

However, since the testing was conducted on a small-scale prototype model, real-world deployment would require consideration of additional factors such as environmental robustness, vehicle speed variations, network latency, and integration with city-wide traffic management systems. Despite these limitations, the prototype demonstrated strong foundational performance, laying the groundwork for further development and field trials.

VI.CONCLUSION

This project successfully demonstrates the design and implementation of an RFID and GPS-based emergency vehicle pre-emption system aimed at reducing delays caused by traffic congestion. By identifying emergency vehicles through RFID tags and automatically prioritizing their passage at intersections, the system ensures faster and safer transit during critical situations. The inclusion of a GPS module at the traffic signal, which forwards location data to a control center via GSM, adds a layer of real-time tracking and centralized coordination.

The prototype model testing confirmed the system's reliability, responsiveness, and potential effectiveness in real-world applications. With a rapid response time of 2–3 seconds and accurate data transmission, the system proved to be efficient in detecting authorized emergency vehicles and adjusting traffic signals accordingly. The results indicate that this solution is both cost-effective and scalable, making it a promising addition to future smart traffic management and urban mobility systems.

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