IoT Based Smart Traffic Enforcement System Using RFID GSM and ESP32 CAM for Automated E Challan Generation

Kumati Durga Prasad[1*], Keerthi Gowthami[2], Bommineni Sindhu[2], Madipoju Srianjun[2], Rampelli Rajesh[2]

[1]Assistant Professor, [2]UG Student, [1,2]Department of Electronics & Communication Engineering

[1,2]Vaagdevi Engineering College, Bollikunta, Warangal, 506005, Telangana, India.

*Correspondence: Kumati Durga Prasad (kommati.prasad427@gmail.com)

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Abstract

The rapid increase in vehicular traffic and urbanization has significantly raised concerns about road safety, with over 1.3 million fatalities reported annually due to traffic accidents and overspeeding contributing to nearly 30% of these incidents, while smart traffic enforcement systems are projected to grow at over 16% annually. Traditional traffic policing relies heavily on manual observation and intervention, which is prone to human error, delays, and corruption, while also lacking real-time tracking and automated penalty mechanisms. Furthermore, conventional systems do not provide seamless integration of identification, evidence collection, and instant notification, reducing their effectiveness in modern traffic management. To address these challenges, the proposed RFID-GSM Based Signal Jump E-Challan System with Auto Alert utilizes the ESP32-CAM to develop an intelligent and automated traffic enforcement solution. The system integrates IR sensors to measure vehicle speed by calculating travel time between fixed points, while RFID technology uniquely identifies each vehicle. When a violation such as overspeeding or signal jumping is detected, the ESP32-CAM captures an image as evidence, and the system automatically generates a digital e-challan. A GSM module then sends the violation details and penalty notification directly to the registered mobile number of the vehicle owner. This IoT-enabled system ensures accurate, transparent, and real-time enforcement, reduces human intervention, minimizes corruption, and supports the development of efficient and scalable smart traffic management systems.

Keywords: Automatic Traffic Enforcement, E-Challan System, GSM Communication, Intelligent Transportation System, Smart City Infrastructure, Speed Detection, Traffic Violation Monitoring

1. Introduction

The rapid growth of vehicular traffic and urbanization has significantly intensified concerns regarding road safety across the globe. It is estimated that over 1.3 million fatalities occur annually due to road accidents, with overspeeding contributing to nearly 30%

of these incidents [1], making it one of the leading causes of traffic-related deaths. Additionally, the increasing adoption of intelligent transportation technologies has led to the growth of smart traffic enforcement systems, which are projected to expand at a rate exceeding 16% annually [2]. In modern environments such as urban intersections, highways, school zones, and smart city corridors, there is a critical need for automated systems capable of detecting violations [3], identifying vehicles, and enforcing penalties in real time to improve road safety and regulatory compliance.

Traditional traffic monitoring and enforcement systems rely heavily on manual observation by traffic personnel and basic surveillance infrastructure. These systems are often inefficient due to limited manpower, inconsistent monitoring, and dependence on human judgment [4]. Manual enforcement methods are prone to errors, delays, and even malpractice, reducing their reliability and effectiveness. Furthermore, conventional systems lack integration between violation detection, vehicle identification, evidence collection, and penalty enforcement, making the process time-consuming and less transparent [5]. The absence of automated communication mechanisms also delays notifying offenders, weakening the impact of enforcement.

In real-time scenarios, these limitations lead to several critical challenges affecting traffic management and safety. Violations such as signal jumping and overspeeding often go undetected or unpunished [6], encouraging reckless driving behavior. Delays in identifying offenders and issuing penalties reduce accountability and fail to act as effective deterrents.

Additionally, the lack of real-time monitoring and automated systems increases dependency on manual processes, which can result in inconsistencies and potential corruption. The absence of immediate alerts and digital record-keeping further limits transparency and traceability [7]. These challenges highlight the need for an intelligent, IoT-based traffic enforcement solution that can automatically detect violations, generate evidence, and issue instant notifications, thereby improving compliance, enhancing road safety, and supporting the development of smart and efficient traffic management systems.

2. Literature Survey

Rudomanenko et al. [8] proposed an adaptive control system for industrial robotic manipulators that adjusted control parameters based on system dynamics and operational conditions. Karatzinis et al. [9] proposed a coordination framework for heterogeneous mobile sensing platforms to monitor dispersed gas plumes using distributed sensing and data fusion techniques.

Salavasidis et al. [10] proposed an autonomous trajectory design system for mapping unknown seafloors using a team of Autonomous Underwater Vehicles (AUVs). Keroglou et al. [11] proposed a survey on technical challenges in assistive robotics for elderly people in domestic environments, focusing on perception, navigation, and human-robot interaction.

Van der Pol et al. [12] proposed coordinated deep reinforcement learning for traffic light control that enabled multiple agents to optimize signal timing collaboratively. Zhang et al. [13] proposed a survey of reinforcement learning-based control methods for signalized intersections with connected automated vehicles. The study analyzed various algorithms for improving traffic efficiency.

Hashmi et al. [14] proposed a traffic flow optimization system at toll plazas using proactive deep learning strategies to predict traffic patterns and reduce congestion. Guerrieri et al. [15] proposed a deep learning-based approach using You Only Look Once version 3 (YOLOv3) for automatic traffic data measurement through moving vehicle observation.

El-Tantawy et al. [16] proposed a multi-agent reinforcement learning-based adaptive traffic signal control system that optimized signal timings across a network of intersections. Zhao et al. [17] proposed a survey on computational intelligence techniques for urban traffic signal control, analyzing methods such as fuzzy logic, neural networks, and evolutionary algorithms.

Efthymiou et al. [18] proposed an overview of Artificial Intelligence (AI) applications for sustainable smart cities, focusing on traffic management, resource optimization, and urban planning. Choosakun et al. [19] proposed a framework for developing cooperative intelligent transport systems in Thailand, focusing on communication, coordination, and infrastructure integration. Qadri et al. [20] proposed a state-of-the-art review of traffic signal control methods, analyzing challenges and opportunities in modern traffic management systems.

3. Proposed System

Figure 1 illustrates the architecture of an IoT-based intelligent traffic policing system centered on the ESP32, which serves as the core processing and decision-making unit. The system integrates multiple input modules such as ESP32-CAM for image capturing, IR sensors for speed detection, and RFID for vehicle identification. A regulated power supply ensures stable operation of all components. The ESP32 processes sensor data using embedded software to detect speed violations, capture evidence, and trigger communication modules. Output devices such as LCD, buzzer, GSM, and IoT modules provide user feedback, alert mechanisms, and remote monitoring capabilities. This system enables automated, accurate, and real-time enforcement of traffic rules with minimal human intervention.

Step 1: Power Supply Initialization: The regulated power supply provides stable DC voltage to the ESP32 and all peripheral components, ensuring reliable system operation in roadside environments.

Step 2: Vehicle Detection Using IR Sensors: Two IR sensors (IR1 and IR2) are placed at a fixed distance to detect vehicle movement. When a vehicle crosses IR1 and IR2, timestamps are recorded, enabling the system to calculate speed using the time difference.

Step 3: Speed Calculation and Analysis: The ESP32 computes vehicle speed using the formula Distance/Time and compares it with a predefined speed limit. If the speed exceeds the threshold, it is identified as a violation.

Step 4: Vehicle Identification via RFID: When a violation is detected, the RFID module reads the vehicle's unique tag. This allows the system to retrieve vehicle and owner details from the database for further processing.

Step 5: Image Capture Using ESP32-CAM: The ESP32-CAM module is activated to capture a real-time image of the violating vehicle. This provides visual evidence, ensuring transparency and reducing disputes.

Step 6: Alert and Display System: The LCD displays system status, detected speed, and violation messages, while the buzzer generates an audible alert to indicate a traffic rule violation.

Step 7: GSM-Based Notification System: The GSM module sends an SMS (e-challan) to the registered vehicle owner. The message includes violation details such as speed, time, and vehicle ID, ensuring immediate notification.

Step 8: IoT Integration and Data Logging: The IoT module enables real-time data transmission to a cloud server. Violation records, images, and logs are stored for monitoring, analysis, and future reference by traffic authorities.

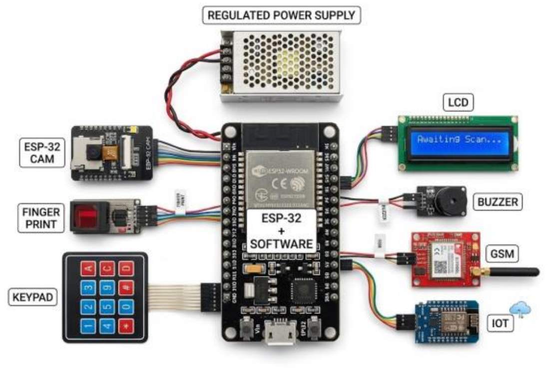

Figure 1. Proposed System

3.1 Working Procedure

The system functions through the following sequence of operations as shown in Figure 2. As the vehicle approaches, the first IR sensor detects its presence and records the timestamp (T1). The vehicle passes the second IR sensor, and the second timestamp (T2) is recorded.

The system calculates speed using the known distance between the IR sensors and the time difference. The calculated speed is compared against a preset threshold.

Violation Trigger:

- If within the limit: No action taken.
- If exceeded:
  - RFID tag is read to identify the vehicle.
  - ESP32-CAM is triggered to capture the image.
  - GSM module sends SMS to the vehicle owner with challan details.

Logging: The violation details are logged in a local database or sent to a cloud server for future analysis. This process is fully automated and does not require human supervision once the system is deployed and operational.

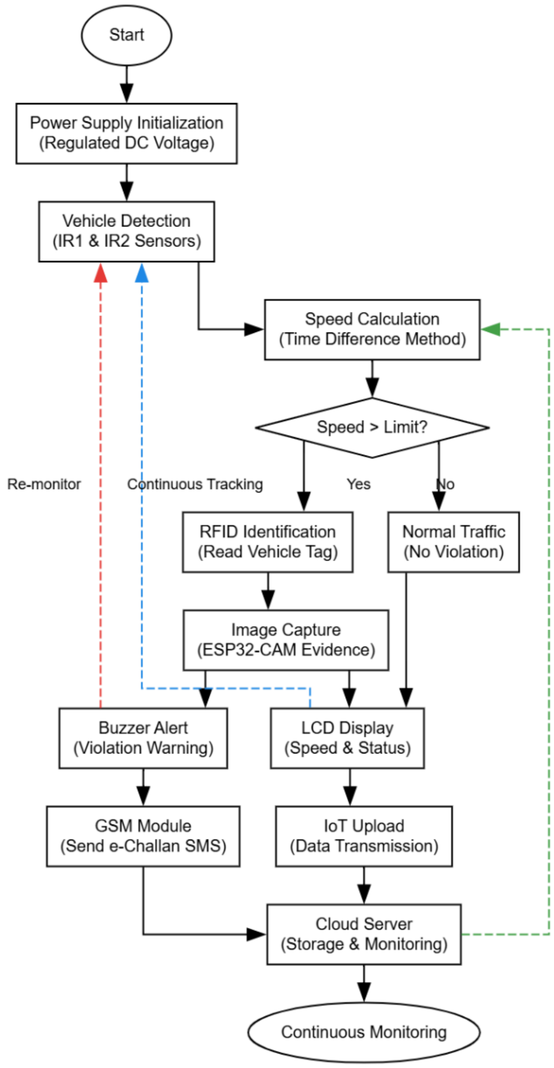

Figure 2. Working Flowchart.

4. Results and Discussion

Figure 3 illustrates the complete hardware implementation of the proposed RFID-GSM based signal jump detection system. The system consists of a regulated power supply unit, microcontroller board, RFID reader, GSM module, ESP32-CAM module, LCD display, buzzer, and associated circuitry. Initially, a 12V regulated power supply is provided, which is stepped down to 5V DC using a voltage regulator circuit. This 5V supply is distributed across all hardware components to ensure stable operation. The glowing LED indicates the presence of the regulated 5V supply. The interconnected modules enable real-time detection, processing, and communication of traffic violations within the system.

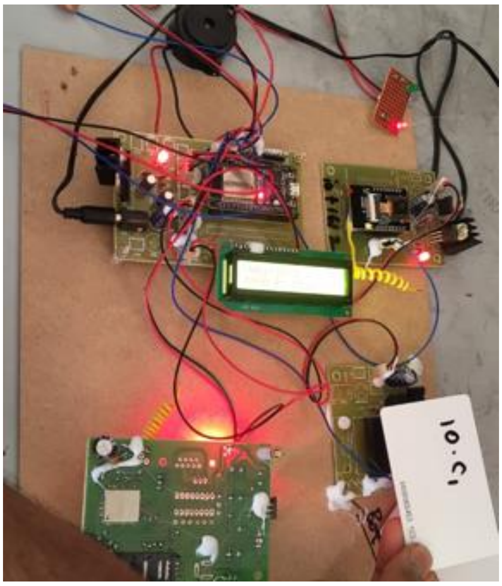

Figure 3. Hardware Setup of RFID-GSM Based Signal Jump Detection System.

Figure 4 shows the output displayed on the LCD screen after the system initialization. Once the regulated power supply is provided and the reset button is pressed, the microcontroller begins execution and displays the message “Speed Violation Signal Jump” on the 16x2 LCD module. This indicates that the system has successfully detected a traffic rule violation. The LCD acts as a real-time visual feedback unit, providing immediate information about the detected event to the user or operator.

Figure 4. LCD Display Showing Signal Jump and Speed Violation Alert.

Figure 5 presents the email notification generated by the system after detecting a violation. The ESP32-CAM module captures an image of the violating vehicle or scene and sends it via Wi-Fi to a predefined email address. The email contains a subject indicating the type of violation (e.g., signal crossing or overspeeding) along with the captured image as an attachment. This automated communication ensures remote monitoring and evidence collection without human intervention.

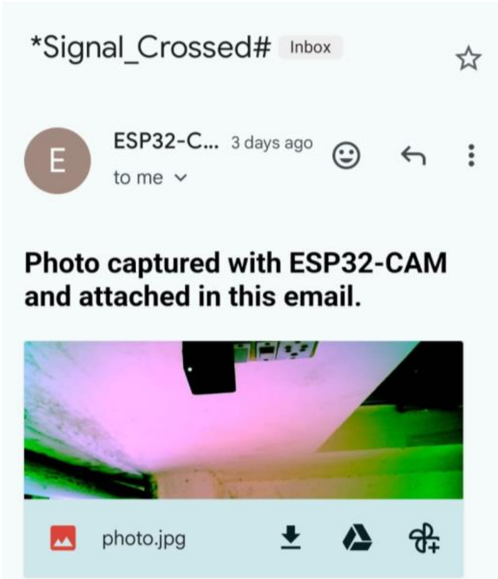

Figure 5. Email Notification with Captured Image from ESP32-CAM.

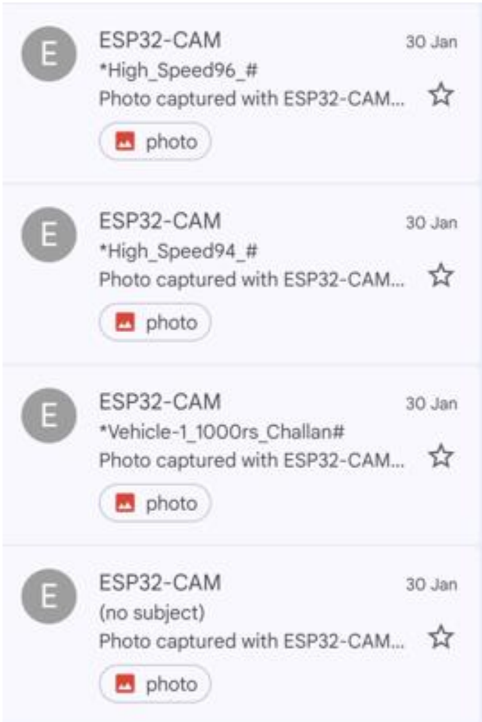

Figure 6. Email Inbox Showing Multiple Violation Alerts

Figure 6 shows the email inbox containing multiple alerts generated by the system for different traffic violations. Each email corresponds to a specific event, such as high-speed detection or signal jumping, and includes an attached image captured by the ESP32-CAM. The repeated entries demonstrate the system's capability to continuously monitor and log violations in real time. This feature enhances accountability and provides a digital record for further analysis and enforcement actions.

5. Conclusion

The proposed RFID-GSM Based Signal Jump E-Challan System with Auto Alert offers an efficient and intelligent approach to modern traffic enforcement by integrating automation, real-time monitoring, and IoT connectivity. By utilizing IR sensors for accurate speed detection and RFID technology for vehicle identification, the system ensures precise detection of violations such as overspeeding and signal jumping. The ESP32-CAM enhances transparency by capturing visual evidence, while the automatic generation of e-challans and GSM-based notifications enables instant communication with vehicle owners. This reduces dependency on manual policing, minimizes human errors and corruption, and ensures timely penalty enforcement. Furthermore, the system's ability to integrate identification, evidence collection, and communication into a single framework makes it highly effective for smart city applications. Finally, it improves road discipline, enhances safety, and contributes to the development of reliable, scalable, and intelligent traffic management systems.

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