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IoT-based automated case generation system for traffic rule violations

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ABSTRACT

This project presents a smart, economical, and accessible traffic control system that utilizes RFID technology, Node MicroController Unit (NodeMCU), internet connectivity, and Light Emitting Diode (LEDs) to effectively monitor and manage vehicle flow at road intersections. It is specifically designed to address the mounting urban traffic issues in Bangladesh, a densely populated and rapidly urbanizing country. The surge in the number of vehicles has overwhelmed conventional traffic management methods, often hampered by enforcement gaps and noncompliance with regulations, resulting in persistent congestion and inefficiencies. The proposed system uses RFID to detect vehicles and assess traffic density in real time, enabling dynamic and adaptive traffic signal control. With NodeMCU and internet connectivity, it facilitates streamlined communication and remote supervision, while LEDs provide clear instructions to drivers. By automating traffic regulation, the system reduces reliance on manual operations, mitigating corruption and enhancing enforcement effectiveness. Moreover, it fosters greater adherence to traffic laws by introducing a transparent, technology-driven framework. This innovative traffic management solution not only alleviates congestion but also cultivates a culture of compliance, contributing to the overall improvement of urban transportation networks. Its emphasis on integrating modern technology into traffic control aligns with the principles of sustainable urban development, offering a scalable and transformative approach to addressing Bangladesh's escalating traffic challenges.

Contribution/Originality: This study advances the field with an IoT-based smart traffic management system integrating RFID and NodeMCU to address congestion and violations. It features automated vehicle identification, real-time violation detection, fine issuance, and seamless communication with owners via SMS or email, offering an efficient and transparent approach to modern traffic challenges.

1. INTRODUCTION

An IoT-based traffic management system utilizes a network of interconnected devices, sensors, and actuators to monitor and control traffic conditions dynamically. By incorporating advanced technologies such as smart traffic lights, connected vehicles, and data analytics, these systems aim to optimize traffic flow, reduce congestion, and enhance overall transportation efficiency. Additionally, such systems provide mechanisms to identify and penalize individuals who violate traffic regulations. This project introduces a smart traffic control system that uses RFID technology to address issues like traffic congestion and traffic rule violations. The system employs an RFID receiver to detect vehicles and sends the RFID tag information to a Node MCU, which forwards it to a centralized database. The database cross-references the RFID tag with existing records. If no traffic violation is detected, the vehicle's information is securely stored. However, if a violation is identified, the system categorizes the vehicle as guilty and imposes a fine in accordance with traffic laws. The fine details are then communicated to the vehicle owner via Short Message Service (SMS) or email.

The system is built with a Node MCU mounted on a veroboard as per the circuit diagram, with the RFID receiver connected to the Node MCU. The Node MCU is linked to a server on a PC through a USB cable, enabling one or more administrators to monitor and control the system using secure login credentials.

Additionally, a mobile application has been developed to pro- vide users with access to information about their vehicles, including the ability to view fines and make payments directly through the app. By combining Internet of Things (IoT) technology with user-friendly features, this system offers a comprehensive solution for modern traffic management challenges.

2. LITERATURE REVIEW

This section will review the history of Traffic System studies, including such as the usage of various sensors, Wifi Modules, Android Apps, and Web Monitoring Facilities [1]. A comprehensive examination of agent technology applications in traffic and transportation systems is presented in this review. The authors highlight that traffic issues extend beyond individual countries and have global implications. They offer suggestions on leveraging new technologies to alleviate traffic congestion and manage traffic density. The importance of Intelligent Transportation Systems (ITS) and their diverse applications are also discussed in detail by the authors. Masek, et al. [2] A Unified Approach to Transportation Management in Smart Cities: The Innovative IoT-Driven Framework for Road Traffic Modeling proposes a system aimed at addressing the unprecedented urban growth and the resulting surge in vehicle numbers. This surge has brought forth fresh challenges for traffic management, including the need to reduce road congestion, accidents, and air pollution. Over the past decade, researchers have concentrated on leveraging advancements in sensing, communications, and dynamic adaptive technologies to equip road traffic management systems (TMS) [3] to address these pressing issues in future smart cities. Our solution endeavors to integrate advancements in Internet of Things (IoT) technologies, wherein low-power, embedded devices become integral components of the next-generation TMS [4]. This paper presents a priority signal control algorithm to tackle these issues. We have utilized Transit Signal Priority (TSP) techniques to enhance the Emergency Vehicle Priority (EVP) system. TSP is a proven strategy for improving public transit operations in urban areas. Our proposed algorithm adjusts signal phases using TSP techniques to prioritize emergency vehicles. These techniques help mitigate the impact of EVP on general traffic. Experiments conducted with the VISSIM microscopic traffic simulator show that the proposed traffic control algorithm reduces overall traffic delay by up to 8 percent compared to conventional EVP systems [5]. In order to reduce EV rescue delay, Savolainen, et al. [6] use LED equipment to display the signs of emergency vehicles [7]. When an emergency vehicle (EV) nears an intersection, its onboard unit (OBU) communicates with the traffic signal controller. This controller then activates the emergency vehicle LED flashing lights to alert passersby, enabling them to respond and prepare for the EV's approach. Despite this, EV drivers are still required to slow down when traversing the intersection, as the signal controller does not facilitate emergency vehicle signal preemption [8].

Al-Holou, et al. [7] they created a multi-dimensional model to assess the environmental effects, traffic congestion, and vehicle safety. The project, which started with a budget of $80,064 in 2010, was completed in 2012. The proposed adaptive sign control application targets two main goals: (1) improving traffic flow and reducing congestion; and (2) enhancing intersection safety. The adaptive traffic light control system, which employs V2V (Vehicle-to-Vehicle) and V2I (Vehicle-to-Infrastructure) communications, marks a major breakthrough in traffic management [9].

Neelakandan, et al. [5] increasing communication among vehicles can result in several negative consequences, including wasted time and fuel, environmental damage, and potential fatalities due to individuals being stuck in traffic jams. To tackle these issues, this paper proposes an efficient IoT-based traffic prediction system employing the OWENN algorithm. Additionally, it suggests integrating a traffic signal control system powered by an Intel 80,286 microprocessor for smart cities. The process begins with the extraction of traffic, weather, and directional data, which is then inputted into the OWENN classifier to identify areas with heavy traffic. If congestion is detected in a specific direction, the system adjusts IoT parameters using IBSO and regulates traffic flow through the Intel 80,286 microprocessor. This comprehensive approach aims to enhance traffic prediction accuracy and optimize traffic signal control, thereby improving efficiency within smart city environments [5]. As urban populations expand rapidly, managing and alleviating traffic congestion has become increasingly challenging. The proliferation of vehicles exacerbates several issues, including wasted time and fuel, as well as air and noise pollution. Additionally, it can lead to delays for emergency vehicles. This paper presents a real-time Traffic Management System (TMS) leveraging the Internet of Things (IoT) and data analytics. Ultrasonic sensors are utilized to measure traffic density, and upon analysis of the sensor data, the system controller adjusts traffic signal timing using a traffic management algorithm. Furthermore, it transmits data to a cloud server via a Wi-Fi module. \cite{lanke2013smart} The proposed system can predict potential traffic congestion at intersection points. In the event of an emergency vehicle detection, priority is given by extending the signal duration for passage through the intersection. Additionally, the system is capable of identifying signal violators and issuing fines, payable through a mobile app named Traffic Wallet. This system is praised for its cost-effectiveness, easy installation, and maintenance.

2.1 Related Works

The authors discussed an intelligent transmission control system [10] that utilizes cloud-based technology and machine learning methods. In this setup, images of approaching intersections are captured and stored in a cloud database. A cloud image Application programming interface (API) processes these images to identify vehicle density and characteristics, which is then relayed to the subsequent traffic signal in real-time [1]. The previous signal, now the active signal, monitors the next intersection's state and adjusts based on the updated conditions. These approaches improve the safety and effectiveness of intelligent traffic management (ITM) by predicting traffic flow, automating signal control, detecting driveways, and recognizing surrounding objects or vehicles. While many researchers are working on intelligent transportation systems, achieving optimal traffic management continues to pose challenges [11]. The authors emphasized that comprehensive traffic surveillance systems play a key role in transforming smart cities, with numerous studies exploring IoT- based intelligent traffic control solutions.

Researchers introduced an IoT-enabled intelligent traffic management approach [12] designed to alleviate severe congestion through both centralized and de- centralized domain controllers. This approach includes a data collection component that employs sensors, camera networks, and radio frequency identification (RFID) technology. The ap- plication layer regulates traffic signals and notifications based on real-time vehicle density on the road, providing regular up- dates via a software system [9]. The authors proposed a method to minimize inaccurate predictions by utilizing the "Rankine-Hugoniot" principle and an origin destination traffic model. To verify the effectiveness of the proposed system, they developed a model [10] with testing results demonstrating the method's capability to efficiently manage traffic congestion, accuracy, and system latency.

The authors introduced a method for forecasting traffic volume, vehicle concentration at specific developmental stages, and lane dimensions. Researchers further optimized traffic signal cycle durations and processing times at isolated, signal- controlled intersections using vehicle-generated data. They also proposed a decentralized, reinforcement learning-based management framework using evolutionary algorithms (EA) to regulate vehicular flow, significantly improving transport system efficiency [13]. However, its deployment was occasionally constrained by computational limitations. The study additionally presented an eco-friendly, flow- approximation solution to set signal durations for each straight route based on vehicle density [14] incorporating machine learning and AI techniques to estimate timing intervals over brief periods.

In Dearborn Heights, more than 98 percent of respondents reported seeing ambulances on public roads, yet 82.9 percent had experienced at least one instance of not responding properly when emergency vehicles (EVs) were approaching. From 2004 to 2008 in the United States, there were 3,708 recorded accidents involving EVs [15]. In-vehicle information systems—such as onboard units, smartphones, and radios—can further distract drivers, leading to slower responses to approaching EVs [11]. Rapid response from EVs is essential to preserve lives and property; in emergencies, every second matters [16]. Delays of just one minute in providing first aid can reduce a patient's survival rate by 7–10 percent. In fire emergencies, a 30-second delay can double the fire's spread. In traffic incidents, one-third of vehicle-related fatalities could be prevented with faster EV rescue times, underscoring the critical importance of swift EV access and response. Table 1 comparison study of RFID-based traffic management systems.

2.2. Research Gap

1. Despite the advancements in this project, there exists a gap in seamlessly integrating these agents into real time and user-friendly interactions.
2. Need for seamless integration into a unified, scalable traffic management system.
3. Systems must better handle unexpected incidents like accidents and emergency responses.
4. Need for more reliable, faster systems using real-time data and predictive analytics to enhance response times and reduce accidents.
5. More research needed on eco-friendly solutions that balance traffic flow with environmental sustainability.
6. Need for more research on public response, especially regarding emergency vehicle prioritization and traffic compliance.
7. Focus on real-world testing and developing standards for traffic management technologies.

Table 1. Comparison Study of RFID-Based Traffic Management Systems

Paper title	Advantages	Disadvantages	Tools used	References
RFID-based traffic violation system	• Efficient traffic monitoring • Automated case filing • Real-time data collection	• High initial implementation costs • Privacy concerns for vehicle owners	• RFID technology • Node MCU • Web server	Al-Abassi, et al. [3]
Smart traffic system using RFID and Node MCU	• Reduces manual monitoring efforts • Sends instant notifications • Accessible via mobile application	• Limited to vehicles with RFID tags • Requires stable internet connection for real-time data transmission	• Node MCU • Web server • RFID	Neelakandan, et al. [5]
Automated violation detection with RFID	• Real-time updates on violations • Encourages compliance through accountability	• Dependence on cellular networks • Potential RFID signal interference	• RFID readers • SMS gateway • Mobile app	Masek, et al. [17]
RFID-based traffic light management system	• Enhanced traffic management • Reduces traffic congestion in key areas	• Possible inaccuracies with RFID reading • Additional costs for RFID tag issuance	• Node MCU • RFID tag and reader • APIs	Oliveira, et al. [18]
AI-Driven traffic violation system with RFID	• Enhanced violation classification accuracy, • Adaptive AI learning for better rule compliance	• High computational needs, • Complex data management, • Potential biases in AI models	• RFID readers, • AI algorithms, • Cloud processing server	Saini and Sharma [10]

3. METHODOLOGY

In my project i have developed to the objective of the project is to identify those who do not follow traffic rules and bring those vehicle users under the rule of law. Private cars are one of the reasons for increasing the number of traffic jams in our country. Moreover, one of the reasons is the disobedience of traffic rules by motorists in our country. Due to which many disorders are created on the roads in our country, from which a lot of traffic jams are created. In our country there is no strict law for traffic police crisis and violation of traffic rules. Because of which we cannot bring them under the rule of law in most cases. Due to which traffic congestion is increasing day by day. Through this project of mine, life is traffic control and I will include in the law all those vehicle drivers who violate traffic rules. Violation of traffic rules 10 through RFID, cases will be automatically filed against those vehicles and a message to file a case for violation of traffic rules will be sent directly to the users of those vehicles through a mail or SMS. Then server to data connect with Mobile app. Mobile app show the data condition and making the decision for against data user.

Below is the Block diagram for making Automatic Traffic control system Assemble the Block as shown in the Figure 1:

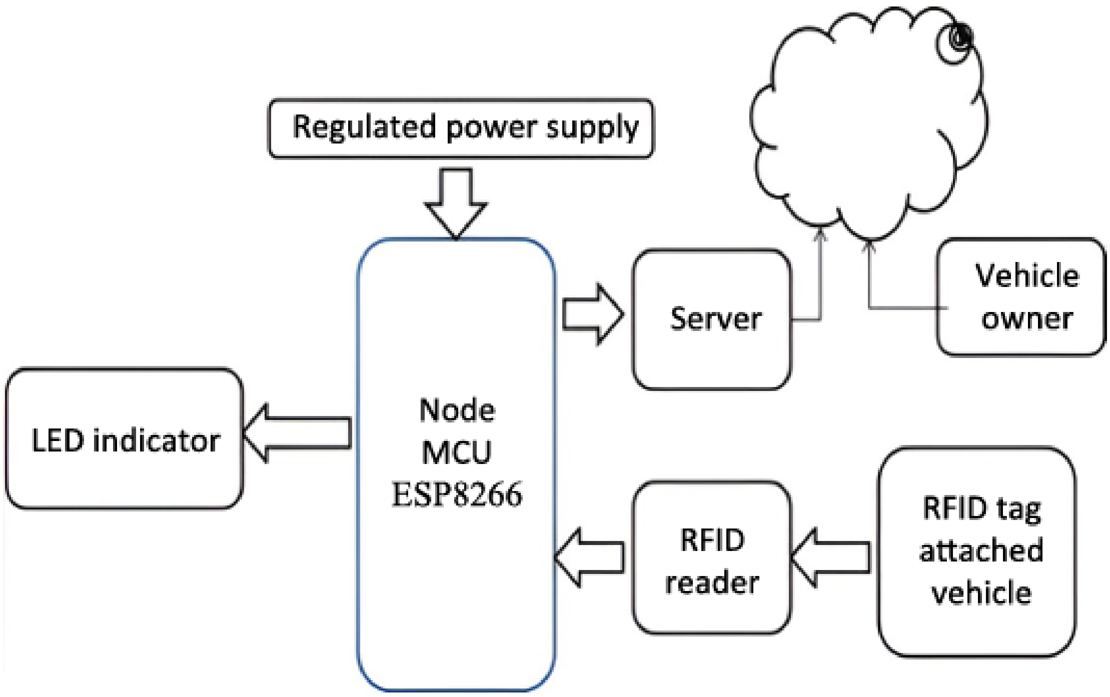

Figure 1. Block Diagram of the system.

Figure 1 the regulated power supply ensures all components, especially the Node MCU ESP8266, receive consistent power. The RFID reader scans the RFID tags attached to vehicles as they pass by. The scanned information is sent to the Node MCU ESP8266. The Node MCU ESP8266 processes the RFID data. It communicates the relevant data to the server for further processing and storage. The server processes the received data and may perform actions such as updating records, sending notifications, or triggering alerts. It also communicates with vehicle owners as needed, providing updates or receiving inputs. It also manages the LED indicator to show the system's status.

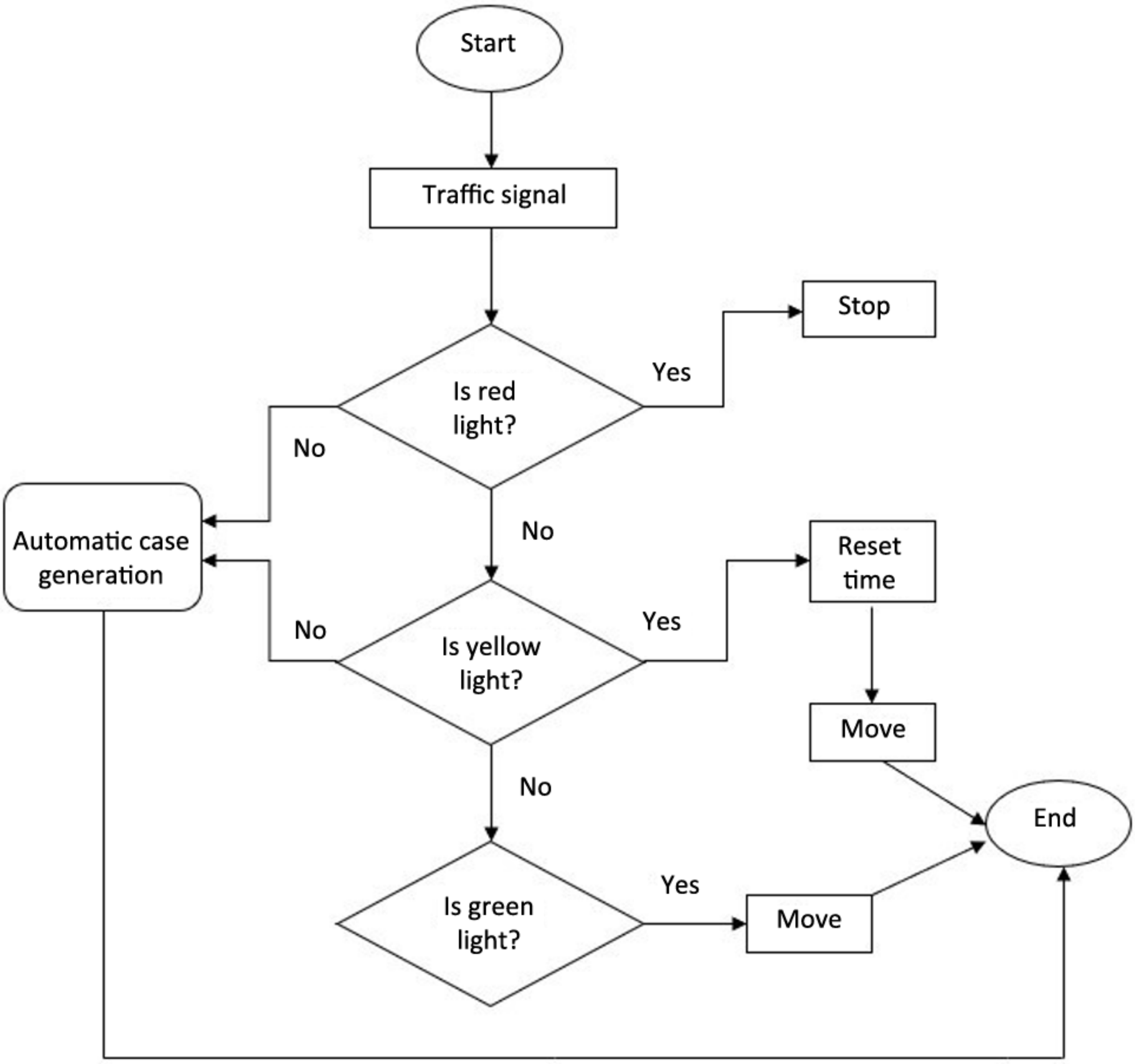

Figure 2. Flowchart of the system.

The flowchart Figure 2 of the system is given below:

• The process starts at the "Start" point.

• The system checks the state of the traffic signal.

• If the light is red, the system instructs to "STOP".

• If the light is not red, the system checks if the light is yellow.

•If the light is yellow, the system performs the "RESET TIME" action, then allows movement ("Move"), and ends the process ("END").

• If the light is not yellow, the system checks if the light is green.

• If the light is green, the system allows movement ("Move") and ends the process ("END").

• If none of these conditions are met, the system initiates the "Automatic Case Generation" process, which implies generating a case based on the traffic situation, and then rechecks the state of the traffic signal.

This flowchart efficiently outlines the automated decision-making process based on traffic light states and integrates an automatic case generation mechanism to handle any irregularities.

3.1. Proposed Classification Model

The diagram illustrates the organizational structure of a Traffic Control System, dividing it into several key components and their sub-functions. Here's a detailed breakdown:

The Traffic Control System is organized into three main sections:

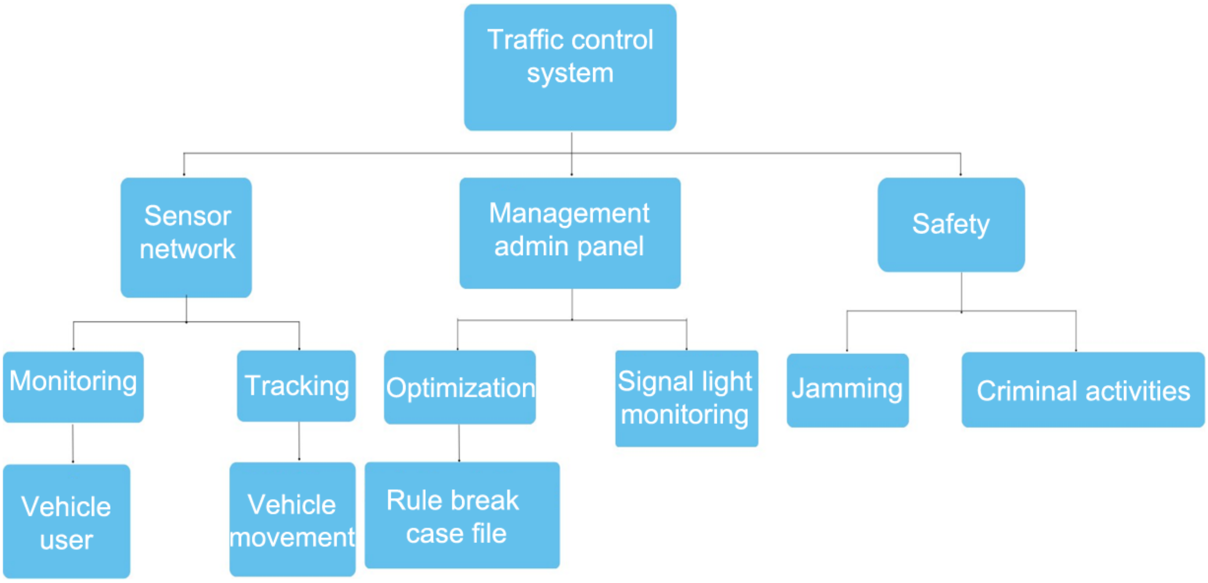

Figure 3. Framework of a traffic control system.

Figure 3 framework of a traffic control system.

3.2. Purpose of the Framework

The primary objective of this system is to:

- Strengthen traffic monitoring and control mechanisms.
- Promote safety and minimize the risk of accidents.
- Streamline traffic flow by mitigating congestion and enforcing rule compliance.
- Utilize real-time data to support effective decision-making.

This framework highlights how modern technological advancements can be seamlessly incorporated into urban traffic management systems to create a smarter, more efficient, and safer transportation network.

Sensor Network: Focuses on monitoring and tracking vehicle activities. Management Admin Panel: Responsible for optimizing traffic flow, monitoring traffic signals, and handling rule break cases. Safety: Addresses traffic jamming issues and monitors criminal activities to ensure overall traffic safety.

The intersection is managed with traffic signals to ensure smooth and safe vehicle movement. Each lane has corresponding traffic signals at the start or end to manage the flow of vehicles in different directions. Vehicles must adhere to the signals for proper traffic management and safety. If someone violates the traffic rules, they will be penalized according to the law and will be required to pay a fine. This setup is typical in urban traffic management systems to regulate the flow of vehicles and minimize the chances of accidents.

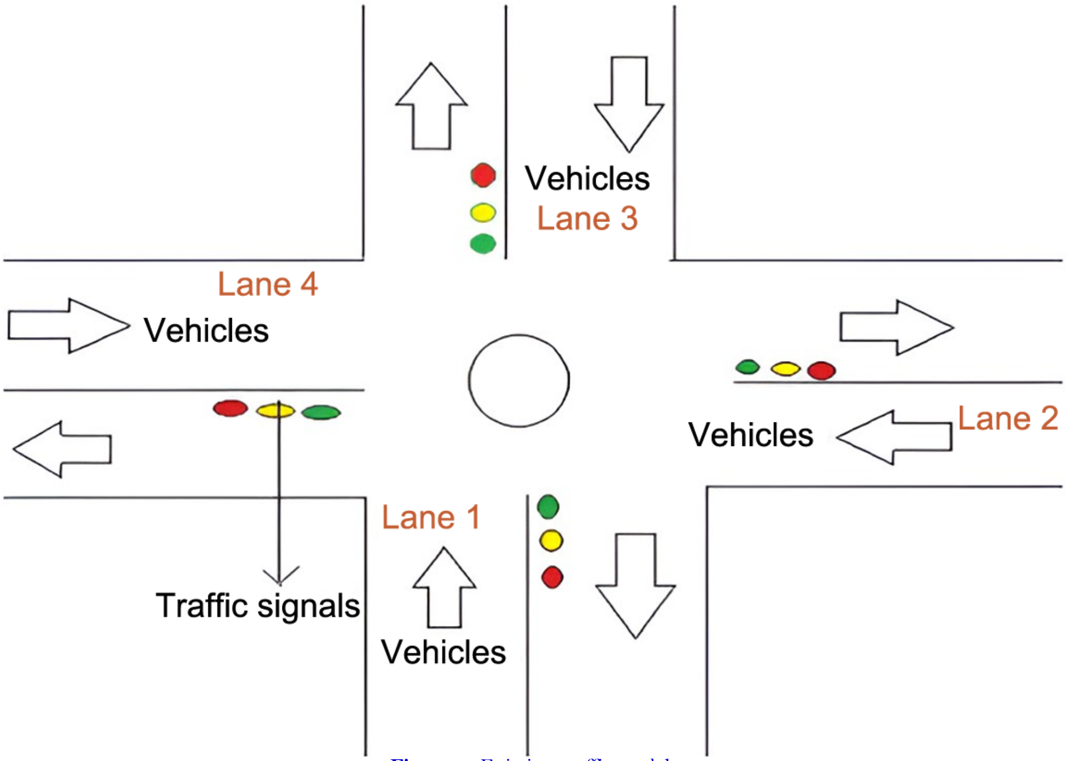

Figure 4. Existing traffic model.

The intersection Figure 4 is managed with traffic signals to ensure smooth and safe vehicle movement. Each lane has corresponding traffic signals at the start or end to manage the flow of vehicles in different directions. Vehicles must adhere to the signals for proper traffic management and safety. If someone violates the traffic rules, they will be penalized according to the law and will be required to pay a fine. This setup is typical in urban traffic management systems to regulate the flow of vehicles and minimize the chances of accidents.

3.2. Data Processing Methodology

The proposed TMS system helps choose those routes that provide higher precision. The model is validated for its performance with the benchmark's lower bound precision value. Still, suppose the proposed model generates the desired precision for the lower bound. There's a detailed description of the components and flow:

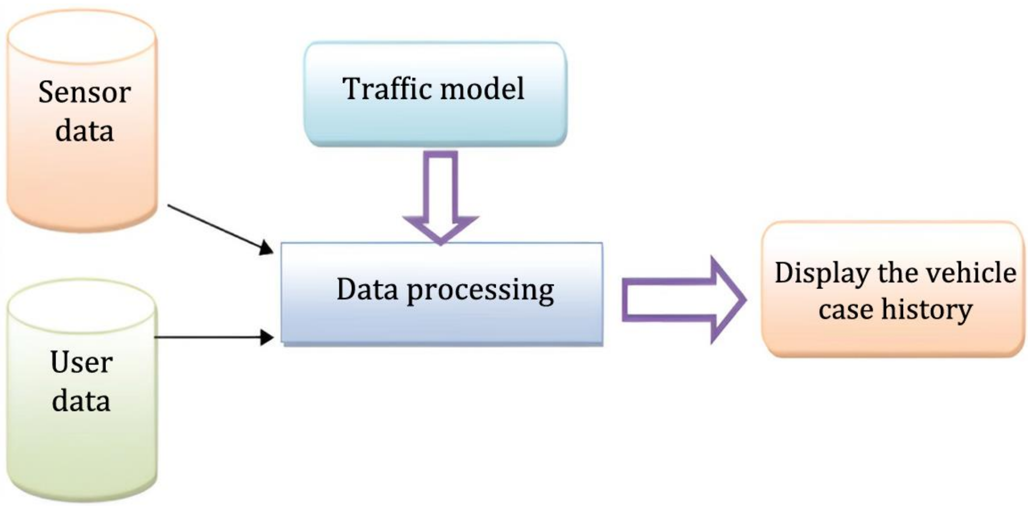

Figure 5. Vehicle data tracking in traffic management system

The proposed Figure 5 TMS system helps choose those routes that provide higher precision. The model is validated for its performance with the benchmark's lower bound precision value. Still, suppose the proposed model generates the desired precision for the lower bound. There's a detailed description of the components and flow

Sensor Data: This is a data source, depicted as an orange database cylinder, that supplies data gathered from sensors. User Data: This is another data source, depicted as a green database cylinder, that supplies data related to users. Data Processing: This is a processing unit, depicted as a blue rectangular box, where data from both the sensor and user data sources are processed. Sensor Data and User Data both feed into this unit. Traffic Model: This component appears to enhance data processing and is depicted as a light blue rectangular box, feeding into the Data Processing unit with a downward arrow. Display the Vehicle Case History: This is the final output, depicted as a beige rounded rectangular box, which shows the processed information as the vehicle case history.

4. IMPLEMANTATION

The diagram illustrates a system designed for real-time traffic signal monitoring and the automated generation of traffic violation cases. This system employs RFID technology along with a NodeMCU (or a comparable microcontroller). Below is a detailed breakdown of the components and their interactions:

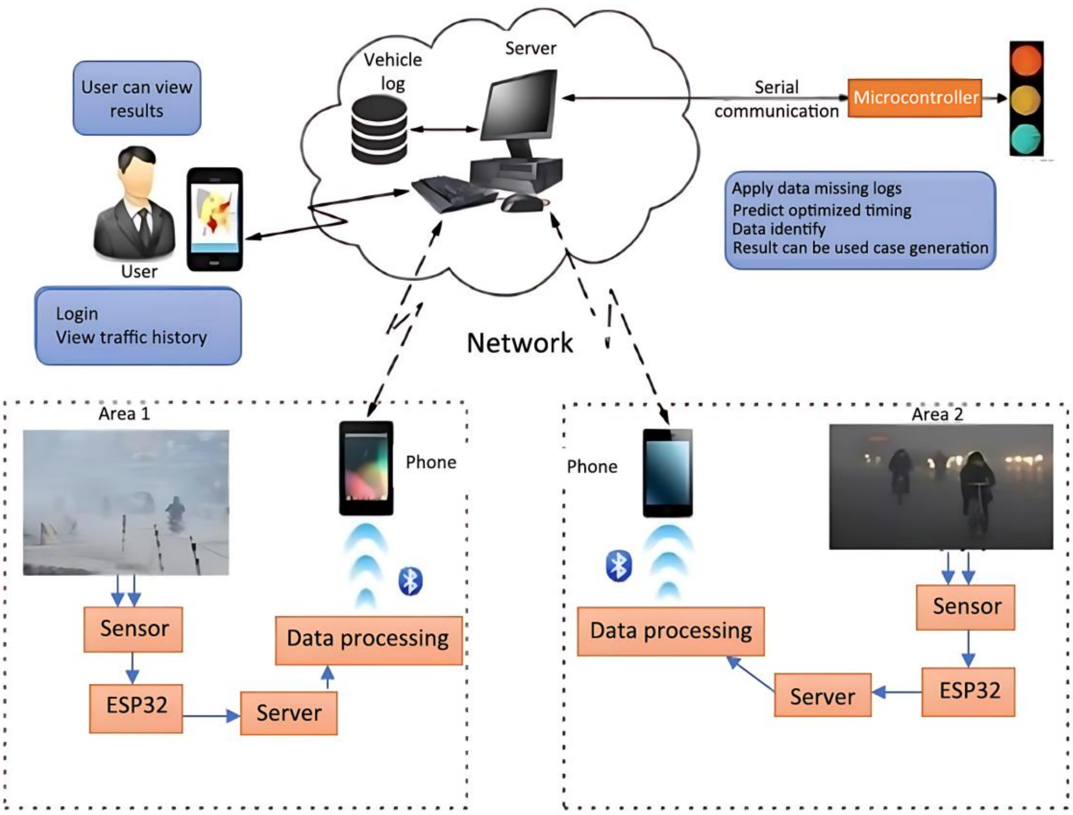

Figure 6. Traffic management system architecture diagram.

Figure 6 network architecture for traffic monitoring and data processing.

Users can log in and view traffic history and results on their devices. A central server communicates with various components via a network. The server maintains a vehicle log and processes data to apply missing logs, predict optimized timing, identify data, and generate case files.

Sensors: Detect vehicle activity. NodeMCU ESP32: Collects data from sensors and sends it to the local server. Local Server: Processes data before forwarding it to the central server. Data Processing Units: Likely smartphones or other devices processing and displaying data from the sensors. Data from these areas is sent via Bluetooth to nearby phones for local processing and is also forwarded to the central network for broader analysis and case generation.

A microcontroller, likely connected to traffic lights, ensures proper traffic signal management and can communicate with the central server via serial communication. Data Processing and Case Generation:

The central server applies various algorithms to predict optimized timing for traffic signals, fill in missing data logs, and generate case files for vehicles that run red lights. These case files are then automatically emailed to vehicle owners.

The system integrates real-time data collection, processing, and automated legal action generation, providing both local and centralized traffic management and monitoring.

4.1. System Design

To design and construct a NodeMCU-based live Traffic Signal Monitoring System using RFID, the system will automatically generate a case file for vehicles that run a red light. RFID tags will be used to track these vehicles, with the RFID reader capturing the information and sending it to a web server. The NodeMCU will interface with this web server, which will process the data and create a case file for the offending vehicle. This file will be automatically emailed to the vehicle owner.

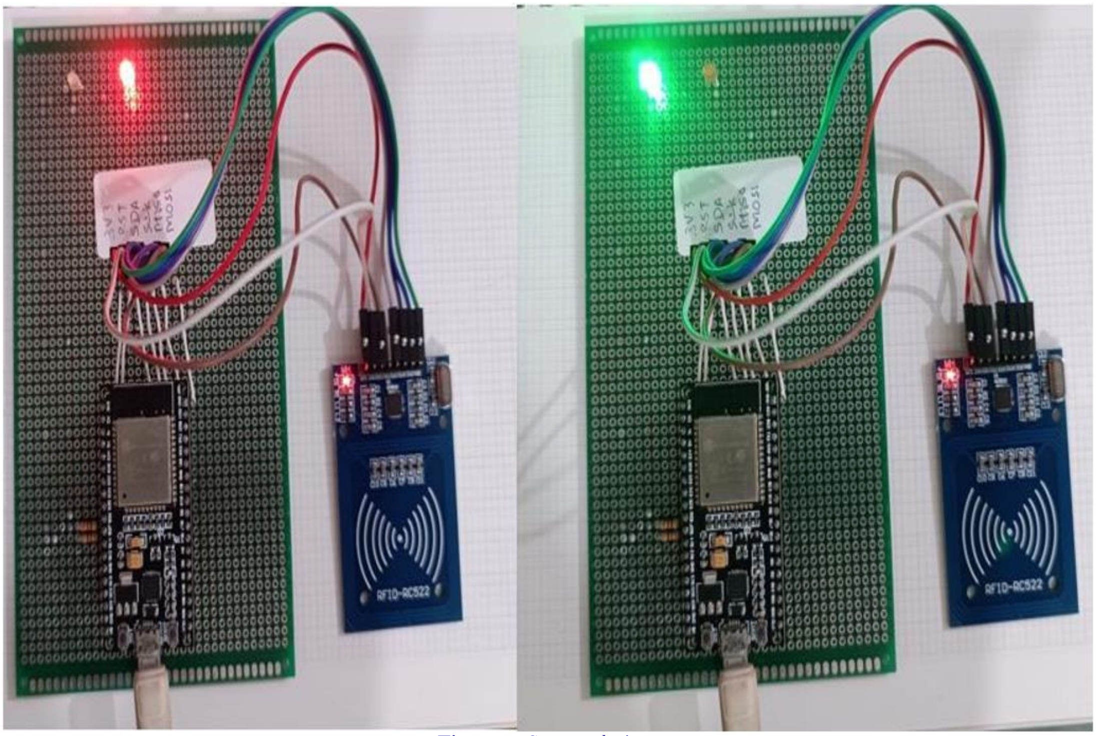

Figure 7. System design.

Figure 7 Hardware design.

5. RESULTS

To start, assemble the circuit as depicted in the provided diagram, and then proceed to upload the main ino file to the NodeMCU32 board. Upon successful code upload, obtain the

IP address of the ESP32 from the serial monitor. Afterward, paste the IP address or domain server into a web browser like Google Chrome. Press enter, and you'll be presented with an appealing widget that displays the Traffic Monitoring System.

Figure 8 RFID Admin Dashboard Interface.

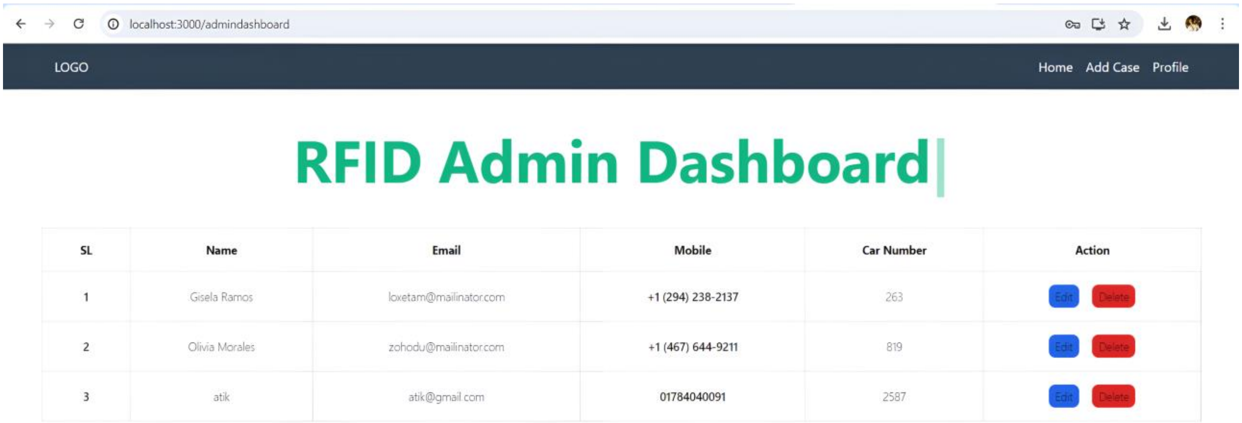

Figure 8. Admin dashboard.

This admin dashboard acts as a monitoring system to track vehicle movements. Whenever a vehicle violates traffic rules, its data is displayed here, facilitating the identification of the responsible party. Subsequently, necessary legal measures, like imposing fines, can be implemented against the violator.

Figure 9 RFID Admin Portal - Case Submission Success Screen.

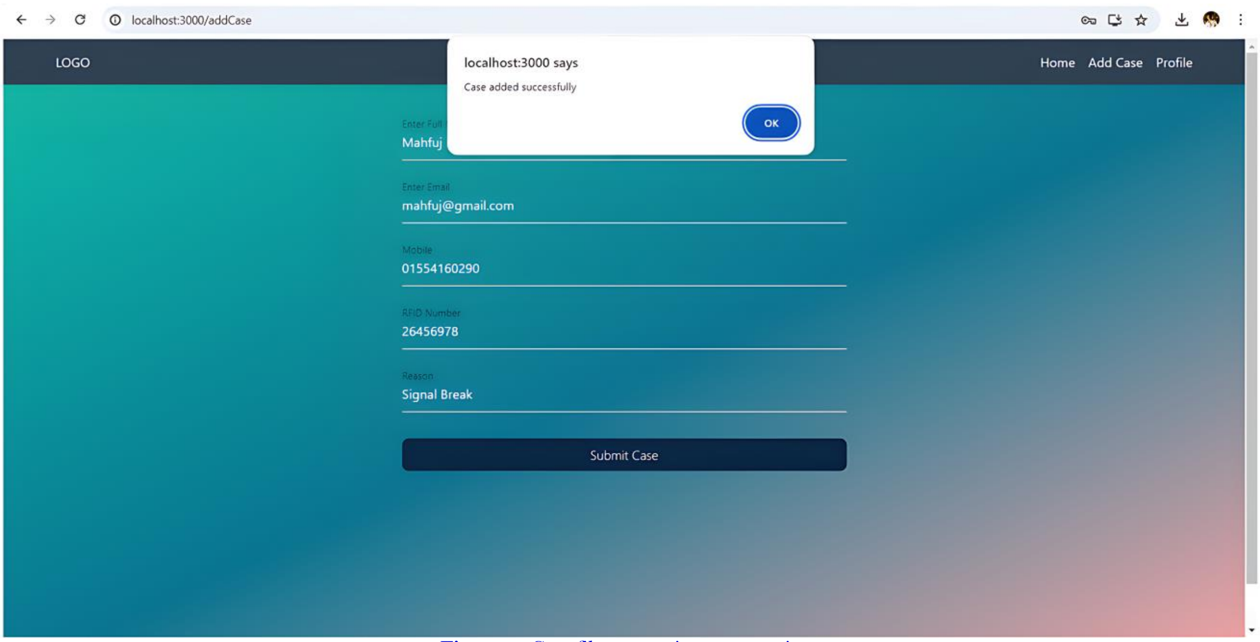

Figure 9. Case file generating system view.

This interface presents a case filing system primarily de- signed for automated operations. Nonetheless, it includes the option for manual case filing for future use. Additionally, it provides the capability to specify the crime committed by the vehicle if required.

6. DISCUSSION

This IoT-based Traffic Control System provides a scalable solution for managing traffic and tracking violations. Through automation and real-time monitoring, it ensures driver account- ability and gives law enforcement the tools required to enforce traffic laws more effectively. The inclusion of a web server and mobile app improves accessibility and flexibility, allowing both administrators and vehicle owners to access and engage with traffic data at any time.

This project not only solves the challenges associated with traffic enforcement but also lays the groundwork for future advancements, such as integrating digital penalty systems or utilizing data analytics for predictive insights. The IoT-based Traf- fic Control System showcases the potential of IoT to revolutionize traffic management, making roads safer and more efficient for everyone.

7. CONCLUSIONS

This project represents the culmination of the knowledge ac- quired throughout the degree program, with the goal of enhancing comprehension across various domains to develop a final project that integrates three essential electronic components: hardware design, software programming, and device communication. This project is very useful for the mega cities. As the deceleration of the government to make our country as " Digital Bangladesh" this project is helpful for make our country as a digital country. Here the manual traffic system is update as the automation. So all the traffic signal system can be automatically handled. So it is very helpful to make the country digital and for the make full fill of the government announcement.

This project is also making our city as a smart city. Governments also work for making our city as a smart city. This project is a very low-cost project so it can be easily implemented as much we need. If we implement this in everywhere in our city then it should be get a better result for each. And it also helps us for to turn over the mega city as a smart city. This project also helps for cometh back discipline on the roads. In the recent few years in our country there was a big amount of accident occurred for the indiscipline on the roads. We also saw some movement for the road safety. This project is helps us to get the road safety.

To summarize, we have delved into key components of our degree curriculum, utilizing existing knowledge and further developing it, thereby ensuring we possess the necessary expertise to enter the professional market with confidence.

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Competing Interests: The authors declare that they have no competing interests.
Authors' Contributions: Both authors contributed equally to the conception and design of the study. Both authors have read and agreed to the published version of the manuscript.

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