Smart Traffic Management System based on Traffic Intensity on Busy Road

Rahul Rajput[1], Sourabh Sahu[2], Vedant Panday[3], Yasharth Shrivastava[4], Yashwant Kushwah[5], Dr. Abhishek Sharma[6]
Students, Department of ECE [1,2,3,4,5]
Associate Professor, Department of ECE[6]
Oriental Institute of Science and Technology, Bhopal, India

Abstract: *Traffic congestion is a common problem in regions across India and other countries. Malfunctioning traffic signals, weak law enforcement, and bad traffic management procedures are also contributing reasons. A major difficulty in Indian cities is a lack of ability to extend existing infrastructure, making smart traffic management the only possible option. Congestion harms the economy, the environment, and the overall quality of life. As a result, solving this issue is becoming more critical. Infrared sensors, distributed network, magnetic coil being identified, and surveillance footage are some for the current roadway management techniques. Despite their effectiveness, these methods have long initial stages and quite costly establishment and upkeep costs. Radio Frequency Identification, also called RFID, is an invention that has been recommended to address these issues. Real-time regulation of traffic can be got done more quickly and affordably by integrating RFID with current traffic signaling systems. Compared to conventional systems, this technology allows for faster identification of obstructions to traffic and provides a more affordable price for installation and setup time. Preventive actions can therefore be taken sooner, which will improve traffic flow and save drivers money and time.*

Keywords: RFID, Image Processing, Traffic Congestion, Autonomous Management

I. INTRODUCTION

On road networks, traffic congestion is characterized by higher wait times, slower vehicle speeds, and longer delays. It happens when there are more cars than the road can handle, a condition called *saturation* (Transportation Research Board, 2010) [1]. In India, traffic congestion has grown to be a major problem in urban areas. Congestion is mostly caused when demand for travel exceeds the capacity of the roads (Perallos et al., 2019) [2]. Furthermore, isolated events like collisions or abrupt braking in congested traffic can have a cascading effect, leading to traffic congestion. In some places, congestion is additionally caused by security concerns involving antisocial characters (Uddin, 2009) [4].In India, the economic cost of traffic congestion is staggering, with an annual loss of Rs 60,000 crores, including fuel wastage (FHWA-RD-96-100, 1995) [5]. Congestion has also had a detrimental impact on freight transport, slowing down vehicle speeds and increasing waiting times at checkpoints and toll plazas. For example, the average speed on key highways, such as the Mumbai-Chennai and Delhi-Chennai corridors, is less than 20 km/h, with the Delhi-Mumbai stretch averaging only 21.35 km/h (Chen et al., 2010) [9] According to the Transport Corporation of India and the Indian Institute of Management (IIM), India's freight volume is growing annually by 9.08%, and the number of vehicles by 10.76%, while road infrastructure has only increased by 4.01%. This disparity has led to reduced road space in proportion to the growing number of vehicles (Hannan et al., 2019) [10].As a result of this congestion, fuel efficiency in India is significantly low, with an average mileage of just 3.96 km per liter. The major contributor to this inefficiency is traffic congestion itself (Yoon et al., 2009) [11]. As the second most populous country in Asia, after China, India's population growth is directly correlated with an increase in the number of vehicles on the road. Economic growth has further exacerbated the issue, as rising incomes have led to more people opting for cars instead of two-wheelers (Xie & Zhang, 2016) [12]. Given these challenges, it is clear that traditional methods of traffic management, such as signaling systems, are no longer sufficient to address the growing congestion. There is an urgent need for smarter traffic management solutions to alleviate these issues and improve the flow of traffic (Perallos et al., 2019) [2].

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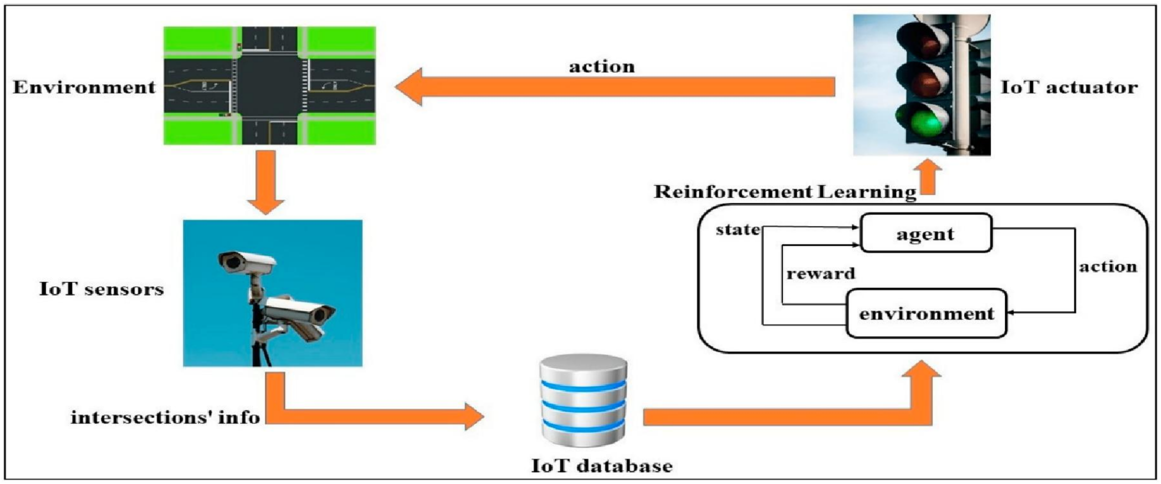

Figure 1: Traffic management System

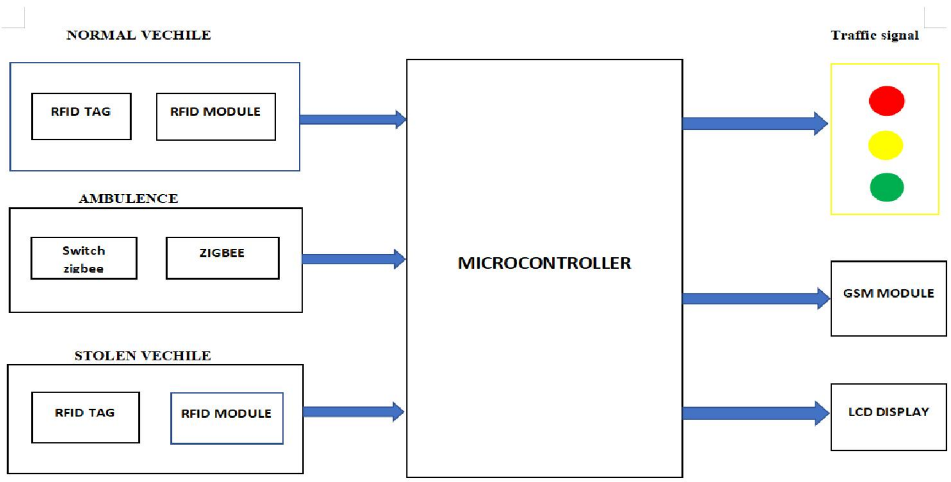

Figure 2: Block diagram of Traffic management

1.1 METHODOLOGY

Inductive Loop Detection

Inductive loop detection operates on the principle of embedding one or more turns of insulated wire in a shallow cutout in the roadway. A lead-in wire connects this loop to a roadside pull box, which is linked to a controller and an electronic unit housed in the controller cabinet. When a vehicle passes over or stops on the loop, the inductance in the wire changes. This change in inductance results in a shift in frequency, which is detected by the electronic unit. In response, the unit sends a signal to the controller, indicating the presence of the vehicle[8].

Inductive loop detection is effective for monitoring vehicle presence, passage, occupancy, and even counting the number of vehicles passing through a specific area. However, there are some limitations with this system. One of the main issues is reliability, which can be compromised due to poor connections in the pull boxes or the application of sealant over the road cutouts. This problem is further exacerbated in areas with poor pavement quality or frequent road excavation, where the system's durability and functionality are often undermined.

Video Analysis:

Video analysis involves the use of a smart camera system, which includes sensors, a processing unit, and a communication unit. The traffic is continuously monitored through this camera, which captures video data. The video is

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then compressed to reduce transmission bandwidth. The captured video is processed to extract relevant scene information, which is subsequently used to generate traffic statistics[11]. These statistics include vehicle count, average vehicle speed, and lane occupancy.

However, there are several challenges associated with video analysis: (a) the overall cost of the system is relatively high, (b) its performance can be significantly impacted in adverse weather conditions, such as heavy fog or rain, and (c) nighttime surveillance requires sufficient street lighting to ensure effective monitoring.

Infrared Sensors:

Infrared sensors are used to detect the energy emitted by vehicles, road surfaces, and other objects. This energy is focused onto an infrared-sensitive material using an optical system, which then converts it into electrical signals. These sensors are typically mounted overhead to monitor traffic flow. Infrared sensors are commonly employed for various purposes, including signal control, pedestrian detection at crosswalks, and the transmission of traffic information.

However, there are some limitations to infrared sensor systems[9]. Their performance can be significantly impacted by fog or other environmental conditions, and the installation and maintenance of the system can be complex and time-consuming.

II. LITERATURE SURVEY

2.1 Background

A Radio Frequency Identification (RFID) system is comprised of two primary elements: the RFID controller and the RFID tag. However, these components function together to facilitate the tracking of objects. The RFID controller processes signals, while the RFID tag transmits data[5]. This interaction is crucial, because it enables real-time identification and inventory management. Although the system is relatively straightforward, its applications span various industries, but the underlying technology remains complex[9].

2.1.1 RFID Controller:

The RFID controller encompasses an RFID interrogator, which facilitates communication with the RFID tag. The interrogator receives signals (or data) from the RFID tag and subsequently transmits this information to the controller. Messaging protocols are employed to relay commands and data between the various components of the controller. Within the RFID controller, there exists a controller core that listens to the interrogators and, depending on the system configuration, is capable of executing read/write operations on the RFID tag[5]. Although the design may vary, the controller core might possess the ability to both listen to data and perform operations on the tag. Moreover, the RFID controller can support serial interfaces, thus allowing external GSM/GPRS devices to connect, transforming the system into a dual-radio device. However, this versatility enhances its functionality significantly[6].

2.1.2 RFID Tag:

RFID tags are wireless devices that utilize radio frequency electromagnetic fields to facilitate data transfer. This data is primarily employed for the identification and tracking of objects. There are two distinct types of RFID tags: Active and Passive. Active RFID tags, however, contain a battery, which enables them to operate independently. Passive RFID tags, on the other hand, depend on an external source (such as the RFID reader)[9] to provide power. The RFID tag stores its data in non-volatile memory and is outfitted with a radio frequency transmitter and receiver[5]. Each tag possesses a unique serial number, which is essential for identification.

2.2 Relevant Algorithm

2.2.1 Input Parameters:

Max_red: The maximum duration the signal can stay red.

Max_green: The maximum duration the signal can stay green.

Min_freq_count: The minimum frequency of vehicles passing per second, stored statically in the controllers.

Act_freq_count: The actual frequency of vehicles passing per second (calculated as the sum of vehicles per second).

Timer: The current timer count.

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III. PROPOSED METHODOLOGY

A smart traffic management system aims to optimize traffic flow, reduce congestion, enhance road safety, and decrease emissions. Here's a proposed methodology to develop such a system:

1. Data Collection

- Sensor Integration: Install IoT sensors, cameras, and GPS devices at key intersections, roads, and vehicles to monitor real-time traffic conditions, vehicle speed, and pedestrian flow.
- Data Sources: Collect data from multiple sources including mobile devices (e.g., GPS and accelerometer data), traffic signal controllers, historical traffic databases, and weather information.
- Data Aggregation: Aggregate data from different sources into a centralized platform for uniform processing.

2. Data Processing and Analytics

- Edge Computing: Process some of the data locally at traffic signal units to reduce latency in decision-making.
- Cloud-Based Analytics: Utilize cloud servers for more complex analyses, such as predictive modeling, using machine learning algorithms on large datasets.
- Traffic Pattern Analysis: Use machine learning to analyze historical data and identify traffic patterns, peak hours, and high-congestion areas.

3. Traffic Flow Prediction

- Predictive Models: Build predictive models using machine learning algorithms (e.g., time-series analysis, deep learning) to forecast traffic conditions in real-time.
- Incident Detection: Develop algorithms to detect accidents, road blockages, or abnormal congestion using real-time sensor data.
- Weather and Event Impact: Factor in weather conditions and special events, which can significantly impact traffic flow.

4. Dynamic Traffic Signal Control

- Adaptive Signal Timing: Implement an adaptive signal control system that adjusts traffic light cycles in real-time based on current traffic conditions and predictions.
- Priority Management: Allow priority access for emergency vehicles and public transportation by dynamically adjusting signals.
- Traffic Signal Coordination: Coordinate signals across intersections to create "green waves" that facilitate smoother flow through multiple intersections.

5. Traffic Information Dissemination

- Real-Time Alerts: Send real-time updates to drivers via mobile apps, variable message signs (VMS), and in-car navigation systems to inform about congestion, accidents, or alternate routes.
- Driver Feedback: Provide information about optimal driving speed to avoid stopping at red lights and to reduce congestion.

6. Intelligent Route Planning and Optimization

- Alternative Routes: Suggest alternative routes to drivers based on real-time congestion data, ensuring better distribution of traffic load across the network.
- Dynamic Pricing: Implement congestion pricing or toll adjustments in certain areas to discourage traffic during peak times or to encourage alternative routes.

7. Safety and Security

- Data Privacy and Cybersecurity: Secure all data transmissions to prevent unauthorized access or tampering with traffic signals and data.

- Emergency Response Coordination: Integrate with emergency services to enable rapid response in case of accidents or road closures.

ALGORITHM:

1. When the signal turns green:
    - While (Timer < Max_green and Timer > 0), do:
        - If (Act_freq_count > Min_freq_count):
            - Keep the signal green.
            - Decrement the timer count by 1.
        - Else if (Act_freq_count <= Min_freq_count):
            - Go to step 2.

2. Switch to red signal:
    - Make the signal red.
    - Turn the adjacent signal green.
    - Go back to step 1.

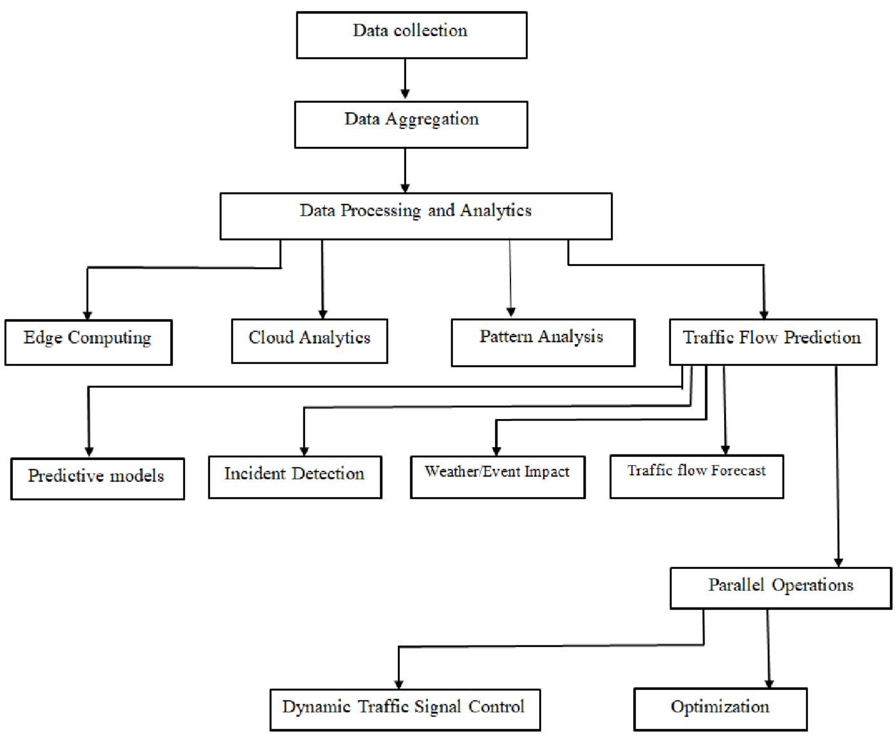

Figure 3: Process of Proposed Traffic management Model

IV. EXPECTED RESULT

The proposed system is expected to achieve significant improvements in traffic flow by reducing congestion and minimizing wait times at intersections. Simulations are anticipated to show a decrease in average travel times, optimized road capacity utilization, and lowered emissions. The system aims to provide a cost-effective and scalable solution adaptable to different city infrastructures. The main advantage is Effective management of traffic congestion.

This version streamlines the explanations and makes the flow of the text clearer, especially in how the RFID system operates and the algorithm functions.

V. CONCLUSION

The proposed project focuses on developing a Smart Traffic Management System using RFID technology to address the limitations of existing systems, such as high implementation costs and dependency on environmental conditions. The proposed system aims to effectively manage traffic congestion while being more cost-efficient compared to current solutions. Additionally, the study highlights the challenges faced by metropolitan areas globally due to traffic congestion and its contributing factors. Traffic congestion has become a significant issue, adversely impacting economies worldwide, particularly in metropolitan regions. It negatively affects a country's financial stability, the environment, and the overall quality of life. The proposed system also offers scope for enhancement by integrating advanced communication networks, potentially surpassing the capabilities of GSM technology.

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