

Smart traffic management with emergency vehicle exit using Arduino Mega and Esp8266

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Abstract—The Traffic congestion and inefficient signal control are among the most critical challenges faced by modern cities, often resulting in long wait times, fuel wastage, environmental pollution, and delayed emergency responses. Traditional traffic light systems operate on fixed time intervals and lack adaptability to real-time traffic conditions, making them inadequate for dynamic urban environments.

This project presents a Smart Traffic Management System with Emergency Vehicle Exit, developed using Arduino Mega 2560, IR sensors, 433 MHz RF modules, 74HC595 shift registers, and ESP8266 Wi-Fi module. The system controls a four-lane junction, where each lane is equipped with traffic signals, IR-based vehicle detection, and a countdown timer displayed on a 7-segment display.

The system dynamically adjusts the green signal duration for each lane based on real-time traffic density. If vehicles are detected, the lane receives a standard green time (e.g., 9 seconds); otherwise, the time is reduced (e.g., to 5 seconds), improving overall traffic flow. For emergency vehicle handling,

I. INTRODUCTION

The increasing global demand for clean and sustainable energy has accelerated the adoption of solar photovoltaic (PV) systems as a key renewable energy solution. Grid-connected PV systems are particularly advantageous due to their ability to supply power directly to the electrical grid while minimizing reliance on fossil fuels. However, the efficiency of PV systems is highly dependent on environmental factors such as solar irradiance, temperature, and shading, which cause fluctuations in power output. To maximize energy extraction from PV arrays under varying conditions, Maximum Power Point Tracking (MPPT) techniques are employed. Among various MPPT methods, the Incremental Conductance (INC) algorithm stands out due to its fast tracking speed, reduced

oscillations, and high accuracy compared to traditional methods like Perturb & Observe (P&O).

II. OBJECTIVE

The key objectives include:

1. 4-Lane Traffic Control:

Use Arduino Mega 2560 to manage traffic lights and displays at a four-way intersection.

2. Traffic Density Detection:

Employ IR sensors to detect vehicle presence and adjust green light durations in real-time.

3. Countdown Display:

Use 7-segment displays with 74HC595 shift registers to show remaining signal time for each lane.

4. Emergency Vehicle Priority:

Integrate a 433 MHz RF system with HT12E/HT12D ICs to manually prioritize a lane for emergency vehicles after the current cycle ends.

III. METHODOLOGY

The entire system is built around the Arduino Mega 2560, which serves as the main controller. The Mega was selected due to its higher number of digital I/O pins, sufficient to handle the multiple sensors, LEDs, and display modules required for a four-lane traffic signal system. Each lane includes:

- Three LEDs (Red, Yellow, Green) to simulate traffic lights.
- Two IR sensors (entry and exit) to detect the presence and count of vehicles.
- One 7-segment display to show the countdown timer, controlled via a 74HC595 shift register.

IV. SIGNIFICANCE

Improves Traffic Flow – Adjusts signals based on real-time traffic.

Supports Emergency Vehicles – Gives priority to emergency lanes.

Fully Automated – Reduces human error with smart control.

IoT Ready – Supports remote monitoring and future expansion.

V. WORKING

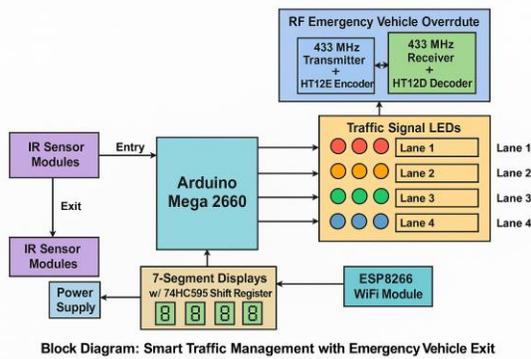


Fig.01 Block Diagram of smart traffic management

The proposed Smart Traffic Management System with Emergency Vehicle Exit aims to improve traffic flow and enable emergency vehicle prioritization through an intelligent, automated setup. The system architecture incorporates multiple hardware and software elements, including an Arduino Mega 2560 microcontroller, infrared (IR) sensors for vehicle detection, a 433 MHz RF module for emergency signal transmission, 7-segment displays driven by 74HC595 shift registers for timer display, and an ESP8266 module for IoT-based communication and monitoring.

A. Traffic Density-Based Signal Control

The core working principle of the system revolves around real-time traffic density detection. Each lane at the intersection is equipped with a pair of IR sensors positioned at entry and exit points. The entry sensor detects incoming vehicles, while the exit sensor confirms vehicle departure. Based on this data, the system dynamically categorizes each lane as either active (high traffic) or inactive (low or no

traffic). Active lanes are assigned a longer green signal duration, typically 9 seconds, whereas inactive lanes receive a reduced duration, such as 5 seconds. This adaptive timing ensures efficient lane management and minimizes waiting time, especially during non-peak hours.

The signal flow operates in a cyclic manner across all four lanes. The Arduino Mega governs the state of the traffic lights for each lane using digital output pins. Red, yellow, and green LEDs indicate the signal status per lane. During the green signal phase, a countdown timer is displayed via a 7-segment display, updated in real time using shift registers. Once the countdown ends, the system transitions to the next lane and repeats the process.

B. Emergency Vehicle Prioritization

A key innovation of the system is its ability to prioritize emergency vehicles, such as ambulances or fire engines. This is achieved using a 433 MHz RF transmitter and receiver pair along with HT12E (encoder) and HT12D (decoder) ICs. Emergency vehicles are equipped with transmitters configured to specific lane codes. Upon activation, the RF signal is received by the receiver at the junction, decoded by HT12D, and read by the Arduino Mega.

When a valid emergency signal is received, the system flags the corresponding lane as a “priority lane.” However, the current green cycle is allowed to complete to maintain order and avoid sudden disruptions. Once the ongoing cycle ends, the system immediately switches to the priority lane and grants it full green signal duration. After serving the emergency lane, the flag is cleared, and the regular traffic cycle resumes. This mechanism ensures minimal delay for emergency vehicles while preserving intersection safety.

C. Display and User Feedback

For user feedback and system monitoring, each lane is equipped with a 7-segment display to indicate the remaining green time. These displays are driven using 74HC595 shift registers, which reduce the number of required I/O pins and simplify circuit complexity. The countdown is synchronized with the signal light state, providing clear visual feedback for drivers and pedestrians.

Additionally, the system can send traffic data and emergency alerts to a cloud platform using the

ESP8266 Wi-Fi module connected via Serial1 on the Arduino Mega. This IoT capability enables real-time monitoring and remote diagnostics. The system can also receive commands or configuration changes from a central server if required, enabling integration with larger smart city infrastructure.

D. System Loop and Automation

The entire process operates within a continuous loop executed by the Arduino. At each iteration, the system:

1. Reads sensor inputs for all lanes.
2. Updates traffic signal states and timer displays.
3. Checks for emergency RF signals.
4. Updates priority status and determines the next active lane.
5. Communicates data to the cloud (optional).

This automation allows the system to function independently without human intervention, reducing operational costs and enhancing response time. The modular nature of the design also allows it to be scaled for larger intersections or additional features such as pedestrian crossing signals and weather-based adjustment.

RESULTS & ANALYSIS

The Smart Traffic Management System was successfully implemented and tested at a prototype level using four lanes with simulated traffic conditions. The system was able to dynamically adjust green light durations based on real-time traffic density detected by IR sensors. Active lanes consistently received a longer green signal (9 seconds), while inactive lanes were assigned a shorter duration (5 seconds), resulting in improved flow and reduced idle time.

Upon triggering the emergency signal from the RF transmitter, the system prioritized the corresponding lane after the current green cycle ended. This ensured that emergency vehicles could pass with minimal delay while maintaining safety and order at the junction.

Analysis of the test runs showed that the system effectively reduced congestion in high-traffic lanes and improved response times for emergency scenarios. The 7-segment displays and traffic LEDs functioned accurately, and communication with the ESP8266 module allowed for successful data logging

and monitoring. Overall, the system demonstrated reliability, scalability, and practical benefits for urban traffic management.

VI. CONCLUSION

1. The system efficiently manages traffic flow by dynamically adjusting signal timings based on real-time vehicle density.
2. Emergency vehicles receive timely priority access without disrupting overall traffic order.
3. The design is scalable, cost-effective, and suitable for integration into smart city infrastructure with IoT support.

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