AMRITA SCHOOL OF ARTIFICIAL INTELLIGENCE, BENGALURU

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END-TERM PROJECT REPORT

on

TRAFFIC SIGNAL OPTIMIZATION AND EMERGENCY VEHICLE PRIORITY SYSTEM

Submitted by Group No. 05

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TRAFFIC SIGNAL OPTIMIZATION AND EMERGENCY VEHICLE PRIORITY SYSTEM

The ongoing city expansion causes traffic congestion to become an ongoing problem which increases journey times and results in the consumption of more fuel along with environmental degradation. Standard traffic light systems count on fixed duration timers which fail to detect current changes in traffic patterns and control priorities for emergency vehicles. The time-based lighting systems from the past do not detect changing traffic movements so they create traffic congestion issues at busy intersections.

A Fully Autonomous Smart Traffic Management System functions to address such existing challenges. The system functions without requiring artificial intelligence systems or high-resolution camera surveillance networks. The system implements affordable IR sensors for detecting traffic movements and sound sensors for recognizing emergency alarm signals. The system consists of four linked 4-way traffic signal junctions which function through ESP32 microcontrollers for their management. The nodes connected through Wi-Fi share information about traffic density during their network communications. The system gathers data from all nodes to permit each separate node to automatically control signal times which enhances traffic flow while ensuring immediate emergency vehicle passage.

In other words, the aim of this project is the design of a system which coordinates the traffic signals across two nodes, in such a way, that when one node turns green, the other next has to wait for certain amount of time to turn green so that vehicles can effectively pass through the intersections.

FUNCTIONALITIES

The system operates autonomously for traffic management through real-time data communication in conjunction with sensing equipment. Every intersection maintains constant vehicle density observation through sensors placed at a faraway point from the lane. The system collects traffic data which enables it to distribute green light signals according to present road congestion levels.

Sound detection devices at the intersection activate when the emergency vehicles approach. After detection the system responds by activating the green signal in the promising lane immediately to provide safe and quick travel for emergency vehicles.

The Wi-Fi inter-node network allows nodes to share traffic data and vehicle travel times information with adjacent junctions. Exchange of information possible between nodes which allows the next junction to modify its signal cycle before incoming traffic arrives which produces a more organized flow throughout the network system.

In other words, node A sends signal to node B upon turning green and the node B waits for the calculated delay before turning green.

CIRCUIT DIAGRAM

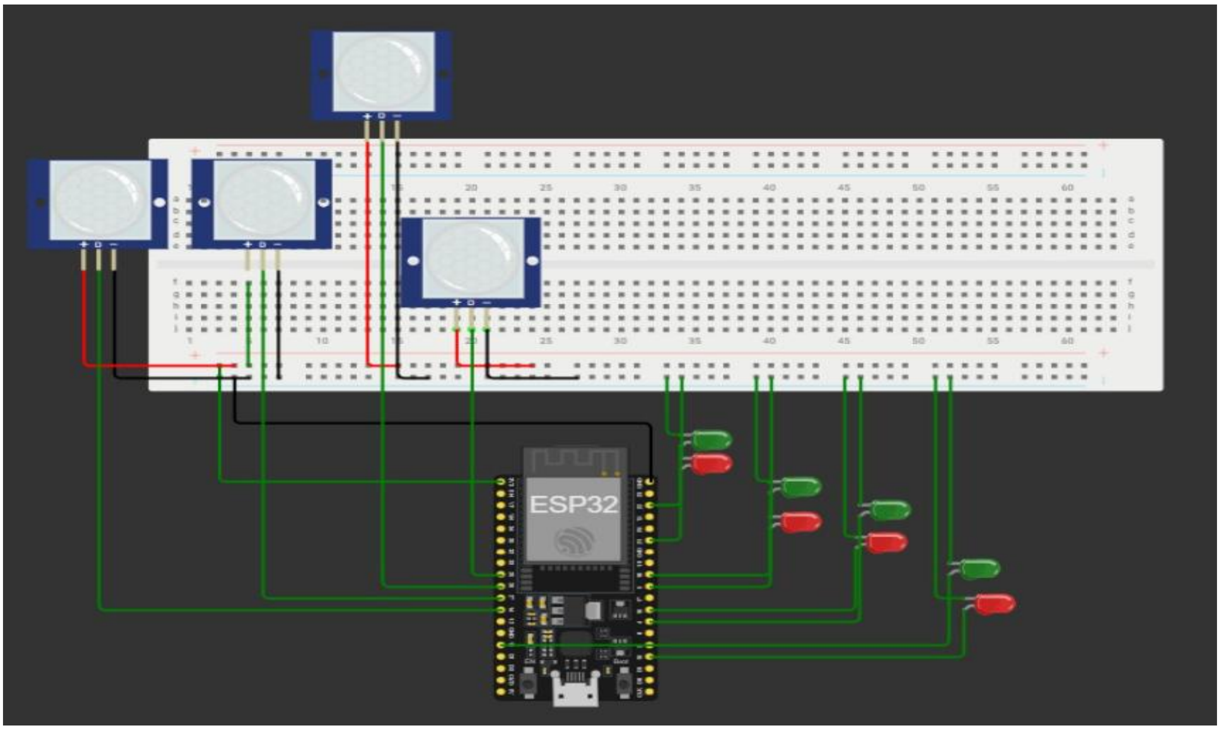

Figure 1. Circuit Diagram

The connections have been specified in detail below:
3.3 V and ground pins of ESP32 are connected to VCC (+) on sound sensors and G (-) on sound sensors, shared ground rail on breadboard respectively. The D0 pins of sound sensors are connected to GPIO 32 and 33 respectively. The pins of the four IR sensors have been connected to GPIO 14,27,26,25 respectively. In road 1, red LED pin is connected to GPIO 15 and green LED pin is connected to GPIO 4. In road 2, red LED pin is connected to GPIO 16 and green LED pin is connected to GPIO 5. In road 3, red LED pin is connected to GPIO 18 and green LED pin is connected to GPIO 21. And in road 4, red LED pin is connected to GPIO 22 and green LED pin is connected to GPIO 13.

COMPONENTS USED

Hardware Components Used

Component	Purpose
ESP32	Central microcontroller for each intersection
IR Sensors	To detect the intensity of the traffic
KY-038 {Sound Sensors)	Emergency vehicle siren detection
Red and Green LEDs	Traffic light indicators
Breadboards	Mounting and wiring ESP32 and components

Software Components Used

Component	Purpose
Arduino IDE	Writing and uploading firmware to ESP32

METHODOLOGY – HARDWARE

A sensor layout has been built as first step in hardware methodology for accurate traffic density detection. The ESP32 receives digital signals from the IR sensors that lead to congestion assessment data processing.

Every intersection has an emergency vehicle detection function provided by a sound sensor out operating for two roads alongside the existing IR sensors for four roads. The ESP32 produces an emergency response algorithm after receiving an interrupt due to the defined threshold crossing sound intensity.

The breadboard holds each ESP32 with all GPIO ports assigned carefully to steer clear from boot-reserved pins. Individual intersections power from USB cables or portable batteries in order to perform simulations of real-world traffic management needs. The four traffic intersections establish a wireless cooperative network through their interconnected configuration.

METHODOLOGY – SOFTWARE

The software with ESP32 support has been written with Arduino IDE. Node A controls its own signals and sends HTTP GET request to the IP address of node B as it turns green. The node B hosts a web server and would listen for the requests which are incoming. Therefore, the software monitoring system continuously checks inputs from every IR sensor as its initial step. Each road obtains its density score through ESP32 calculations from collected signals that represent the detected vehicles' occurrences and frequency. A signal control algorithm uses the gathered data to identify the mostly crowded road alongside determining how long the green light should remain activated.

A siren detection by the sound sensor causes the system to stop following normal traffic rules and activate the emergency lane access. In cases where three roads have no vehicles passing through them and one road has many vehicles, that road will be prioritized and the green light will be triggered even in the next iteration for that road. The system transfers into normal operating mode following emergencies by maintaining smooth traffic flow without creating any interruptions.

Each node keeps track of travel duration between intersections for improving overall performance. The recorded timestamps serve as the basis for determining typical traveling durations. A JSON object combines the collected data with current density data and active emergency flag status to transfer it to adjacent ESP32 nodes through the Wi-Fi connection. The data transmission between interconnected nodes supports upcoming signals to receive early warnings which they can utilize when adjusting their signal periods.

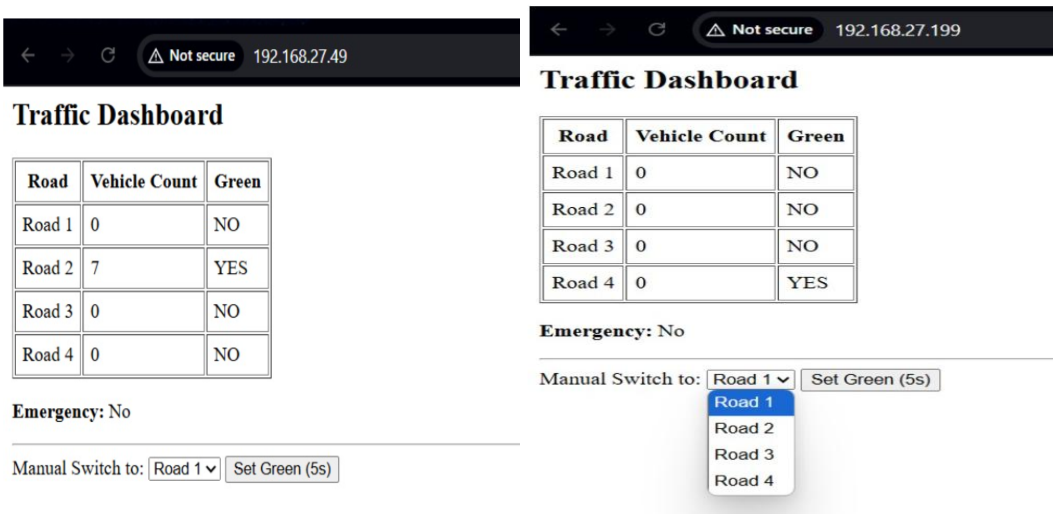

Figure 2. Traffic Dashboards for the two nodes

CONCLUSION

The proposed autonomous Smart Traffic Management System demonstrates an innovative approach to solving the expanding citywide traffic jam issue. Human intervention is also possible if there is a need for any traffic protocol to be followed seamlessly. The system combines straightforward IR and sound sensors with real-time vehicle detection functionality which does not require expensive AI processing and image software features. The system allows traffic junctions to work independently through ESP32 controllers while functioning in a coordinated network by exchanging data through Wi-Fi.

Through effective inter-node communication the system becomes more efficient at managing congestion ahead of time. Through the dynamic update of webpage based on the vehicles in the lane, the successful demonstration of our work is highlighted. Furthermore, this project illustrates how affordable Internet of Things components combined with smart integration and connectivity systems enable scalable solutions that define next-generation smart cities.