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Research Article

Intelligent Traffic Signal Management using Global Positioning System and Distribution based optimization in Edge-Cloud Ecosystem

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Abstract:

Increasing population and Industrialization are the major problems of today's modern world. Due to this, there's an increased traffic demand. And this, besides positive profits, also has its negative impacts like pollution and accidents. To divert the congestion of vehicles, a traffic signal has been designed, typically operating on a predefined timer. The traditional system fails to respond to live traffic conditions. However, this approach is not an entirely effective solution for managing traffic. The scope of the proposed system is to dynamically change the time between each green signal by monitoring the traffic in a specific direction. This solves the problem of longer unnecessary waiting time of passengers through an automated system which works using Google cloud and IoT Edge device. The primary objective of the system lies in efficient opening of traffic signals by continuously watching the traffic density in a road of single direction using Google Maps, analyzing traffic strength with color detection, and sending/receiving these data through cloud. The system can be easily integrated in real time on existing traffic signals, with minimal setup costs. The result indicates a minimal waiting time due to dynamic traffic density and self adaptive nature. In the best-case scenario, each lane takes 20 seconds, making the system more efficient than conventional traffic systems by reducing the cycle time by 27.76 seconds per signal loop.

1. Introduction

On the roads, it is essential that the traffic flows freely and safely. Traffic control signals are therefore crucial for coordinating the movement of vehicles on motorways. Additionally, there is a need for traffic management signals that aid in assembling the traffic information needed to any situation to help manage the traffic in an organized and effective manner. The main duty of these centers is to continuously, 365 days a year, process, gather, and communicate the vital information on a particular traffic status [1]. In order to prevent accidents and get people where one needs to go, it also assists in directing and controlling traffic on various roadways. Maintenance is a major crucial part in effective traffic control. As already mentioned, a correctly maintained traffic control system is crucial for both security of pedestrians crossing the road and drivers' safety [2].

The traffic signals or traffic management signals are most helpful in ordering the vehicles' flow. These gadgets give roadways the most control possible, especially at various traffic crossings. These devices convey information to the driver, such as when to stop or go, road closures, or changes in speed. Additionally, traffic signals have the power to designate a different path for traffic that is moving the other way in a road or at a road intersection [3].

There's a growing demand for new vehicles all around the world and that's the major reason for increased traffic. Vehicle production data up to 2023 is depicted in Figure 1. Except for the 2019-2020 period where the global lockdown happened, it has been a steady growth and nevertheless to say it's growing again in 2023 [4]. Due to this increased vehicle occupancy in every city, traffic jams are more common nowadays.

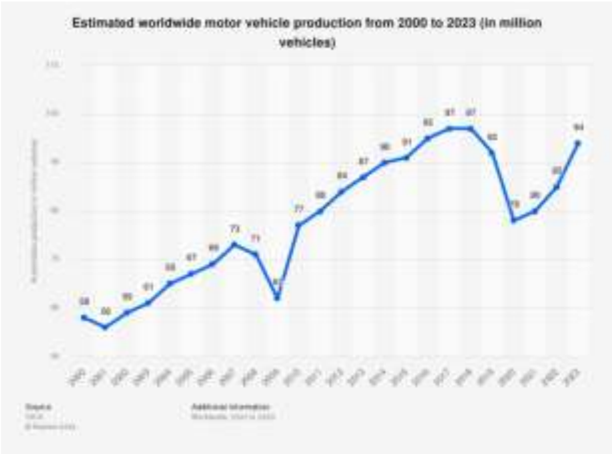

Figure 1. *Estimated worldwide motor vehicle production (2000- 2023)*

Because of the increased vehicle movement, there's an increasing need to efficiently control traffic at crossroads where traffic signals are already installed. And the ultimate aim should be minimizing waiting time for the public at crossroads [5]. The city traffic changes during the day. Morning and evening traffic in most cities increases. On weekends, the majority of vehicles leave the city.

Conventional traffic lights work based on a timer or pre-defined logic. At times, police officers manually regulate the traffic lights. This approach is unsustainable as urban traffic increases daily. So instead of a predefined timer, the proposed system focuses on dTraffic signal timing optimization based on real-time traffic flow at that instant of time and works accordingly. This will lead to an efficient way of managing traffic even incase of non uniform traffic distribution throughout the city and throughout the day [6].

The proposed system will act as a point of entry and a source of technical support for the advancement of the Internet of Vehicles, autonomous driving industries and V2X systems. As a result, the accomplishments of the self adaptive traffic system have exceptionally wide application potential [7]. In today's cities, road traffic is a major issue. An increase in vehicle density and inefficient traffic management are the primary causes. This system aims to optimize traffic control by integrating Google Maps and IoT to assess congestion.

With the growing popularity of personal vehicles, the volume of traffic on the roads continues to increase. When roads are not controlled or regulated, traffic congestion and accidents may result. Traffic lights, or traffic signals, are essential tools for controlling vehicle movement on roads. Traffic at intersections, pedestrian crossings, and other key points is controlled by alternating waiting and proceeding vehicles.Traffic signals will display traditional color-coded lights to assist drivers and pedestrians with directions. Red, yellow, and green are the three colors commonly used in traffic signals. [8].

To promote road safety and efficiency, traffic signals need to be controlled through advanced technology. Traffic control systems are integrating electromechanical controllers with clockwise motion or modern solid-state computerized systems designed for simple installation and maintenance. With increased use, networks of autonomous vehicle lanes would emerge, allowing for higher per-lane capacity than is possible with close-headway operations, when vehicles are closely spaced. This form of evolution, however, may take some time [9].

There are a few existing control techniques in maintaining urban traffic. The sequence of traffic lights at intersections is managed by electronic devices known as traffic signal controllers. The controllers are clustered together and deployed in many traffic signals or junctions or ramps forwarding to highways to manage traffic with the help of sensors, detectors, communication equipment, and of course computers. The system's vital functionalities remain the same even though the brand or the type of equipment changes.The four fundamental components of a computerized traffic control system comprises computer, device for communication, related hardware, and detectors or sensors for sensing cars [10].

The detectors detect the traffic status and send that data via communication equipment to the computer for further processing. Typically, the sensors are either fixed in or held hung above the road. The data like the count of vehicles passing by and their respective speeds are measured. The type of vehicle (such as an auto or truck) may also be determined. To establish the appropriate sequence for the lights at intersections or ramps, the computer analyzes data on traffic movement. The signals get the sequencing data from the computer via communication equipment. Information is also sent from the traffic signals to the road side unit, confirming appropriate functioning, in order to ensure safe and proper operation. By gaining access to the computer resource in some way, people can interact with the system [11].

Even though these are the guiding principles, significant deviations are still possible. The traffic signal at the intersection or ramp that needs to be managed frequently includes roadside units. Processing traffic flow data locally decreases the dependency on communication networks and lowers expenses. An alternative approach is allowing specific automobiles to send traffic information directly to the computer system [12].

The paper is structured as follows: Section two presents related works, reviewing existing traffic management approaches. Section three details the proposed methodology, outlining the framework and key techniques. Section four discusses the system implementation, describing the development process and components. Section five covers the experimental setup and results, analyzing system performance and effectiveness. Finally, Section six summarizes the paper and highlights potential future enhancements for further improvements in traffic management.

2. Related Work

The evolving intricacy of traffic networks enables the development of adaptive traffic signal management to reduce congestion and enhance traffic efficiency. With advancements in computing technologies, researchers have explored various traffic signal management methods. This section presents existing studies on traffic signal management. Additionally, it identifies key research gaps and potential future directions to advance the effectiveness of signal management in urban transport networks.

Almukhalfi et al. [13], explored the impact of deep and machine learning-based solutions in traffic signal systems. The study introduces generic architecture for traffic management based on assessment. The factors such as transport optimization, emergency responses, congestion density were considered in the methodology. The system indicates there is a need for hybrid architecture that balances edge level processing with cloud enabled data analytics. Dallas Leitner et al. [14], focused on signal retiming to mitigate congestion in the traffic pattern. Data driven decision making was considered as an approach. The methodology uses probe vehicles for data collection and sensors for collecting speed and accuracy. The key parameters such as vehicle count, cycle length, red light violation, idle time were considered in the evaluation. The performance evaluation methods ensure the efficiency of the traffic signal. The integration of probe vehicle and sensor complicates the traffic analysis process. The dynamic fleet adoption rate affects the accuracy. The evaluation methods lack implementation in the complex networks.

Peixiang sun et al. [15], examined the traffic pattern in underground loops in central business districts. The congestion patterns were simulated with various traffic scenarios. Ramp and plot-based control techniques are proposed to regulate traffic flow and distribution. The results evaluate the strategies with respect to improving capacity and safety. The study does not focus on real-time systems validation and complex traffic networks. The interaction between private, public and non-motorized traffic are not addressed. Sarrab et al. [16], integrated Internet of Things and Artificial Intelligence in smart traffic systems. The system focuses on live traffic updates on highways and urban traffic networks. The data were collected using roadside message units. The decision making is enhanced by broadcasting traffic updates. The results show low real-time error and better accuracy in vehicle identification. The research gives limited focus to collector roads and closed campuses.

Mahima et al. [17], proposed a Google Maps-based system for dynamic traffic signal optimization. Traffic lights are adjusted dynamically according to real-time traffic flow. The congestion and waiting time were considered in the system prototype. The fuzzy controller receives the traffic information on a periodic time interval. Factors such as traffic signal distance, crossing duration, and vehicle count impact the controller's efficiency. Wang et al. [18], focused on heterogeneous traffic flow and adaptive control methods. Multi-agent based reinforcement learning was adapted for self learning capabilities.The adaptive control method gives better results in terms of accuracy and real-time adaption.

Hazarika et al. [19], implemented a traffic light control system that adjusts based on live road conditions. The vision uses the YOLO model for object detection. The system tracks and enumerates vehicles passing through the traffic signal. The methodology enables the communication between adjacent junctions to prioritize the high traffic areas. The approximate computing was used to minimize the computation and communication overhead. The green corridor mechanism was used to handle emergency vehicles. The system lacks provision for pedestrian crossing and cyclists. The use of efficient wireless data transfer introduces security vulnerabilities in the traffic light signaling system.

Adaptive traffic signal control systems utilize real-time data monitoring, AI-driven decision-making, and smart communication technologies to enhance urban traffic efficiency. Pre-programmed traffic lights lack flexibility, causing traffic buildup, prolonged delays, and ecological concerns. To overcome these issues, researchers have explored vision-based systems, IoT-enabled models, and AI-driven adaptive traffic control mechanisms. Traffic prediction and optimization have been addressed using approaches like reinforcement learning, deep learning, machine learning, and multiple agents based systems, while object detection algorithms like YOLO facilitate real-time vehicle counting and dynamic signal adjustments. Additionally, V2X communication and IoV (Internet of Vehicles) technologies improve traffic coordination between intersections and enable priority-based signal adjustments for emergency vehicles. However, key research gaps remain, including limited real-world deployment, scalability challenges, integration issues with existing systems, computational constraints, and security concerns in IoT-based networks. Moreover, factors such as non-motorized traffic, pedestrian crossings, and adverse weather conditions require further exploration. This review highlights the need for robust, scalable, and secure self-adaptive traffic control systems that effectively integrate AI, IoT, and V2X technologies while ensuring practical feasibility and sustainability in urban transportation networks.

3. Proposed Methodology

The intelligent traffic signal management system operates based on the study suggesting that traffic lights can adapt to changing conditions. Using the Internet of Things component, the system dynamically changes the signal according to traffic density and Google Maps API examines road traffic conditions.

Figure 2. *Intelligent Traffic Signal Management Methodology*

The traffic light adjustments are made dynamically based on traffic conditions, meaning the signals will change in response to the situation by assessing traffic density and direction. Figure 2 shows the methodology for the intelligent traffic signal management. Firstly, the script file runs which calls the program to fetch the screenshots of the signals. After a screenshot is taken, the color at the given coordinates is detected using the Color detection module which gives the result in RGB format. The RGB values are converted to HSV values using pre-defined logic. Weights are assigned based on the intensity of the identified colors. From the Google database, the data entered at all dependent signals are read. Then the sorting of lanes happens on multiple criteria namely, weightsum, current weights and laneorder. If on certain criteria, both the values to be compared are matched then the sorting happens on next criteria so that the sorting returns an unique order.

Algorithm 1: Intelligent traffic signal management system

// Input : Image of signal with the traffic layers, Coordinates, weights of dependent lanes from other signals taken from cloud (Image, Coordinates[][], Weights[][], Open[])
// Output : Enable or Disable the traffic signal by GPIO ports (HIGH or LOW)
Begin
Initialize Image, Coordinates[][], Weights and Open[] and Read the signal image using OpenCV
for i ← 1 to N_lane do
Lane_i = Find the weight of each lane using RGB and HSV values
Signals weights are sorted according to weight sum and current weight and lane order
for i ← 1 to N_signal do
Identify the decision to open the signal using Signal_Decision(Algorithm 2)
End

The lanes are opened according to the sorted order and the dependent signals for the opened lane are also checked and notified. All the dependent lanes work based on the condition of those lanes at that instant and respective actions take place. Also the current open lane's status is updated in the database which is a cloud platform offered by Google.

Algorithm 2: Signal_Decision

// Input: lane_no (current lane number), curr_open (the lane currently open)
// Output: Light up the signals for the relevant lanes based on the traffic conditions.
Begin
Define the dependencies of each lane
Lane X is affected by Lane X+1 and X-1, with circular connections between 1 and 4
prev_lane = lane_no - 1 and next_lane = lane_no + 1
if prev_lane == 0:
prev_lane = 4 // Circular connection for lane 1
if next_lane == 5:
next_lane = 1 // Circular connection for lane 4
lane_current = get_lane_status(lane_no)
lane_prev = get_lane_status(prev_lane)
lane_next = get_lane_status(next_lane)
lane_main_signal = get_lane_status(lane_no + lane_no * 10) // Represents dependent signal
if lane_main_signal < 3: // Case when current lane's traffic is low
if lane_current < 3 and lane_next >= 3:
    signal_on(lane_no, next_lane)
else if lane_current >= 3 and lane_next >= 3:

```
        signal_on(lane_no, next_lane),
        signal_on(lane_no), prev_lane)
else if lane_main_signal >= 3:
 // Case when current lane's traffic is high
if lane_current < 3 and lane_next >= 3:
        signal_on(lane_no, next_lane)
else if lane_current >= 3 and lane_next >= 3:
        signal_on(lane_no, next_lane),
        signal_on(lane_no), prev_lane)
else
        signal_on (lane_no), prev_lane)
End
```

A smart traffic signal management system provides a practical approach to mitigating congestion in urban areas. The system optimizes urban traffic flow by continuously adjusting signal timings in response to seasonal trends and temporary traffic shifts. There are many different ways to collect traffic data as a result of the development of computing technologies, self-driven driving, V2X communication, and mobile Internet. TThe expansion of holographic data includes improvements in its volume, classification, and collection accuracy..

4. System Implementation

The system is designed to analyze traffic patterns using the Google Maps API and regulate traffic signal timing accordingly. In the preliminary stage, the traffic light system is set up at a four-way junction.

Table 1. *Google Maps Color Code*

Color Code	Description
Green	Free-flow traffic
Orange	Light traffic
Red	Moderate traffic
Dark Red	Heavy traffic

As commonly known, Google Maps is widely used to find routes and identify those with the least traffic. Traffic conditions for both directions on each road are shown on Google Maps. Figure 3 indicates the Traffic density at Signal 1 (11.0129° N, 76.9861° E). The coordinates refer to live traffic data from the Lakshmi Mills traffic signal in Coimbatore, Tamil Nadu, India. As presented in Table 1, Google Maps employs four color codes to depict traffic conditions on the road. Figure 4 presents the road's traffic conditions in both directions at Nava India traffic junction in Coimbatore, Tamil Nadu, India. The IoT-based system relies on these traffic data within the prototype application. This will ensure the integration of real-time situations into the traffic light management systems.

Figure 3. *Traffic density at Signal 1 11.0129° N, 76.9861° E (Lakshmi Mills, Coimbatore, Tamil Nadu, India)*

Figure 4. *Traffic density at Signal 2 11.0201° N, 76.9921° E (Nava India, Coimbatore, Tamil Nadu, India)*

The implementation process is divided into four main components: a Google Maps-based traffic monitoring system, a traffic-based travel time calculation module, read/write operations with a cloud database, and an IoT-enabled traffic light control system.

Figure 5. *Traffic density spots at any Signal*

4.1 Google Maps based Traffic Monitoring

The proposed system utilizes the Google Maps API, integrated with Python, to monitor traffic conditions. The system retrieves traffic data from the road near a traffic light, specifically 100 meters away, as represented by the blue ring in Figure 5.

The color is determined and the output is in RGB value for the specific spots using the OpenCV module. At any given location, the traffic density is

determined by the intensity of the color detected at the corresponding coordinates of the signal in Google Maps. The Hue of HSV Model is used to differentiate warm colors from cold colors. Warm colors necessarily mean that the traffic is high at a given signal and prompts the signal to open. Google Map module can be used to find the RGB values at a given coordinate using pre-defined logic. Differentiation of colors does not follow a pattern in the RGB model. So, the RGB values are converted to corresponding HSV values. Based on the Hue and Value, a pattern can be recognized between warm and cool colors.
With this distinction between the colors based on the warmness or coldness, the colors can be separated and helpful in accordance with weights can be assigned. The RGB is converted to HSV for further classification based on Hue angle using the equations given below.

$$\delta = Cmax - Cmin \quad (1)$$
$$Cmin = \min(R/255, G/255, B/255) \quad (2)$$
$$Cmax = \max(R/255, G/255, B/255) \quad (3)$$
$$H = \{60o * (B-R)/255*\delta)+2 \text{ , } Cmax = G/255 \quad (4)$$
$$60o * ((R-B)/255*\delta) \% 6 \text{ , } Cmax = R/255 \quad (5)$$
$$60o * (R-G)/255*\delta) +4 \text{ , } Cmax = B/255\} \quad (6)$$
$$S = \{ \delta / Cmax \text{ , } Cmax \mathrel{!=} 0 \text{ ; } 0, Cmax = 0; \} \quad (7)$$
$$V = Cmax \quad (8)$$

4.2 Traffic-based ordering component

At any given junction, the lanes meeting are numbered starting from 1 in West direction and increasing in counter clockwise direction equaling the number of lanes meeting at that junction, which is depicted in Figure 6.
The primary sequencing of signals is determined by the proposed algorithmic approach calculates the traffic distribution in each direction.

The criteria in which the signals are sorted are as follows:

- Weightsum (Current Weight of signal plus Weight read from previous signal)
- Current Weight of the lane in the signal (Determined using GMaps)
- Main lane factor (1 in case of Main lane or 0 if not)
- Lane Order (Starting from 1 in West direction and 2, 3, … in counter clockwise direction)
- These conditions ensure a unique sorting process, guaranteeing that only one signal is activated at a time, preventing any conflicts between signals.

The current weight of lanes is calculated by fixed values for each traffic condition.

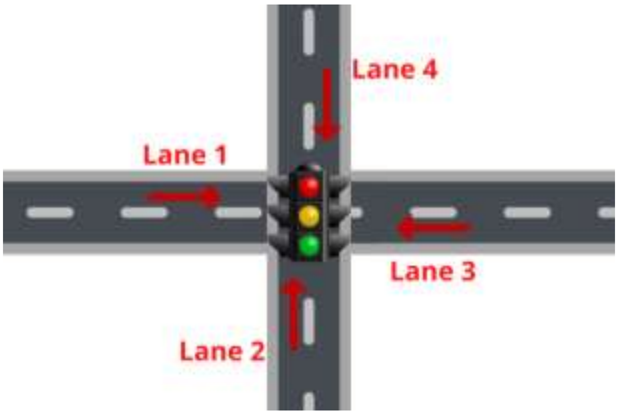

Figure 6. *Lane order at any signal*

Dark Red represents level four, Red corresponds to level three, Orange indicates level two, Yellow signifies level one, and Green denotes level zero.

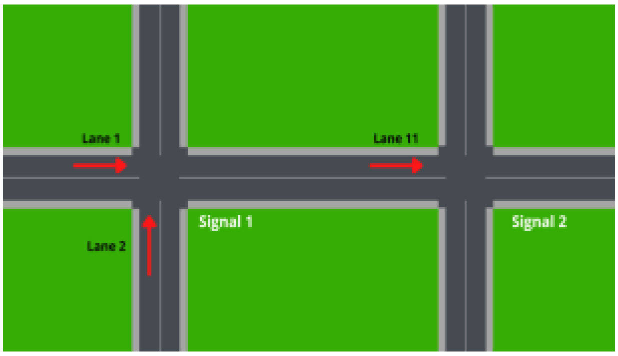

Figure 7*. Dependency between Lane 1 and 2 of Signal 1 and Lane 1_1 of Signal 2*

Figure 7 illustrates the dependency between Lane 1 and 2 of Signal 1 and Lane 1 of Signal 2. Considering Signal 2's open, if Lane 1_1 is chosen as first in the sorted order of directions to be operated, previous signal's Lane 1 and Lane 2 are to be considered since all these lanes are interdependent. Free left is considered negligible in the project and Lane 4 of Signal 1 does not affect because Lane 4 and Lane 1_1 are in opposite directions to each other. For Lane 1, these conditions are checked and the corresponding result is chosen. Similarly for each lane, these conditions are repeated in all the neighboring signals as shown in Figure 8 in the respective dependent directions. Signal 2's Lane 1 is dependent on Signal 1's Lane 1 and Lane 2. Signal 2's Lane 2 is dependent on Signal 3's Lane 2 and Lane 3. Signal 2's Lane 3 is dependent on Signal 4's Lane 3 and Lane 4. Signal 2's Lane 4 is dependent on Signal 5's Lane 4 and Lane 1. The ultimate goal of the proposed system is to inform other dependent signals based on the decision taken at the current signal. The previous knowledge of any signal is so useful for the effective functioning of the next signal. Alerts from previous signals can ensure high priority for those lanes and so the predicted traffic jam can be reduced in this manner.

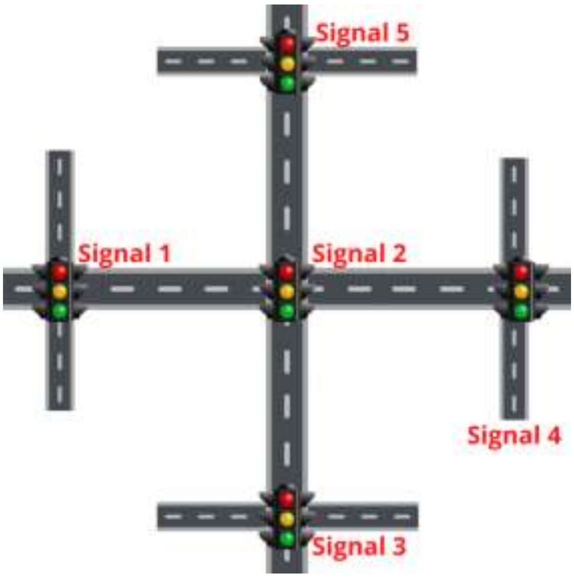

Figure 8. *Dependency among neighboring signals*

Figure 9. *Working of traffic lights at Signal 2 (Lakshmi Mills, Coimbatore, Tamil Nadu, India)*

4.3 Read / Write operations in cloud database

Traffic status of each signal is written into a cloud database and is read by the next traffic signal in that direction.The objective of the system is to collect the traffic status of each signal, analyze and store it in cloud for next signal to make prior use of the pre existing data of previous signal. The flow of the system is based on traffic density in the previous signal, which would be found using a color detection module and GMaps; it would then update the status of the signal at cloud. The next signal which reads the status of the previous signal iteratively reads it. If there were low traffic density at any signal, then no action to be taken. Other than the traffic density data, there's also another data named 'Open' which is stored which implies which lane of the signal is opened at that instant and will change dynamically.

4.4 IoT component connected Traffic Light Management

The main objective of the prototype is to apply the developed algorithm for managing traffic lights. Raspberry Pi is used to regulate the traffic light system through the combined efforts of the hardware and developed software components. The Python-based algorithm is deployed on the Raspberry Pi module using PuTTY and the VNC Viewer interface. Based on the output, each GPIO port is connected to each light of every lane of Signal 2. Eight ports are being used for setting up the lights and eight grounds respectively for each light.

4.5 Experimental setup

The system implemented using Raspberry Pi 3 B+ Kit enhances connectivity with dual-band Wi-Fi, Bluetooth 4.2/BLE, and upgraded Ethernet, powered by a 1.4GHz 64-bit quad-core processor and PoE support through a separate HAT. The algorithm developed using Python 3.12. The system uses libraries such as OpenCV, RPi.GPIO, Time, Gspread, Oauth2.

5. Result Analysis and Discussion

The prototype model of the proposed system is shown in Figure 9 displaying the traffic status of Signal 2 at that instant of time. Lane 4 is opened with green light turned on and the other lanes are closed restricting the movement of vehicles in those lanes. Iterative operation of script file takes live data two signals namely Signal 1 and Signal 2. The deployed system reads the data entered in the cloud and performing necessary calculations results in a sorted order of signals. Finally the signals' lanes are opened using the proposed algorithm.

The process takes place in a loop dynamically updating the changes occurring currently at the signal.Taking a sample case where Lane 4 has to be opened at the considered point of time, the other lanes are to be closed to prevent the traffic flow from those lanes. The lane which is opened, will be opened until the traffic density considered is reduced form one level to another or at a maximum of 20 seconds for each lane. In Figure 10, Lane 2 is opened allowing vehicles to move through the junction with other lanes being closed. Comparison between the conventional system's timing and the self adaptive system's timing is compared in the best, average and worst cases. Figure 11 depicts the duration for which each lane will be opened in seconds.

Figure 10. *Opening of Lane 4 at Signal 2 (Lakshmi Mills, Coimbatore, Tamil Nadu, India)*

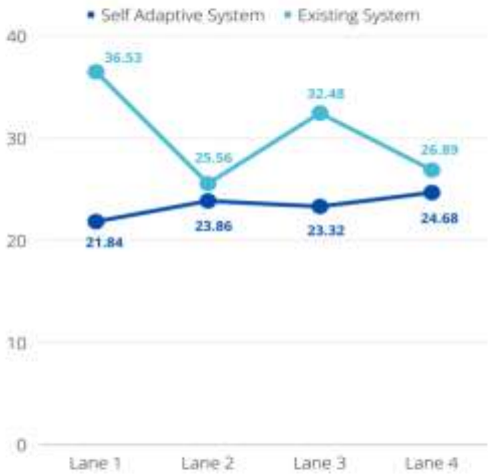

Figure 11. *Best case of proposed system at Signal 2 (Lakshmi Mills, Coimbatore, Tamil Nadu, India)*

In the best case of the proposed system, it is observed that every lane will take approximately 20 seconds which indicates the intelligent system is more efficient than the conventional traffic system, reducing time of 27.76 seconds in a single loop of operation at a signal. The average case duration where each lane will be opened in 29 seconds. The result shown in figure 12 indicates that every lane will take approximately 29 seconds except some lanes taking almost double of expected time. This occurs due to passing of information to dependent signals from selected lane(s) and their operation. In this scenario, the system proves to be more efficient than traditional traffic systems, reducing time of 6.93 seconds in a single loop of operation at a signal. In the worst case scenario where each lane will be opened in seconds as shown in Figure 13, it can be noticed that every lane will take almost double of expected time. This occurs due to passing of information to dependent signals from all the lanes associated and their operation as well.

Figure 12. *Average case of proposed system at Signal 2 (Lakshmi Mills, Coimbatore, Tamil Nadu, India)*

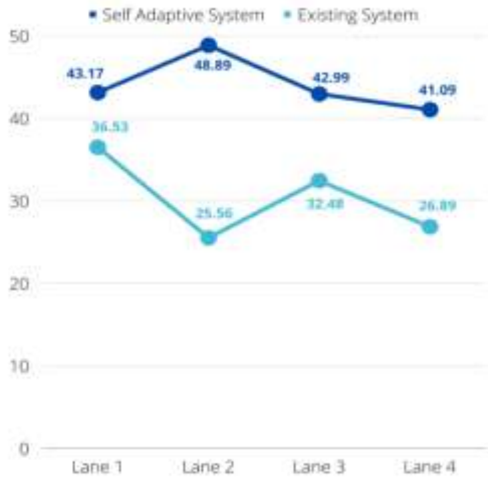

Figure 13. *Worst case working of proposed system at Signal 2 (Lakshmi Mills, Coimbatore, Tamil Nadu, India)*

In this case, the traditional system is more efficient than the proposed traffic system with a time difference of 54.68 seconds in a single loop of operation at a signal. There's a chance of deadlock that can take place in any signal because of the dependencies involved between the signals. The dependency of a signal will affect the actual working of the dependent signal. So the waiting time will be infinite, where each signal depends on and waits for the other to open for this signal to open. Internet of Things is studied and reported in the literature [20-31].

6. Conclusion

The proposed system achieves its primary goal by regulating urban traffic through a dynamically adaptive traffic light system using Google Maps and

IoT technology. The results obtained from the system, which is waiting times for each signal, were observed and compared. This system is to be integrated with real time traffic signals for effective working. In the best case of the proposed system, it is observed that every lane will take approximately 20 seconds. The average case duration where each lane will be opened in 29 seconds. Special cases such as Ambulance arrival at any signal can be included with the help of sensors and provide appropriate logic for opening of signals. The system is to be developed to manage the deadlock situation which can occur at the worst-case scenario where the waiting time is high. To prevent the deadlock situation, the future system can have a timer or a breakpoint so as to function properly so that the waiting time is less.

Author Statements:

- **Ethical approval:** The conducted research is not related to either human or animal use.
- **Conflict of interest:** The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper
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