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IoT-Enabled Smart Traffic Management and Alert System with Green Corridor for Emergency Vehicles

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Abstract: This paper presents a Smart Traffic Management Alert System (STMAS) designed to improve emergency medical response time in urban environments by leveraging Internet of Things (IOT) technology. The system addresses the critical delays ambulances face due to conventional, fixed-time traffic signal patterns that fail to adapt to real-time emergency needs. Our approach integrates GPS- enabled ambulance tracking, microcontroller-based traffic signal control, cloud-based data processing, and digital display boards to ensure prioritized passage for emergency vehicles. When an ambulance is detected within a predefined radius of an intersection, the system first activates LED display boards with warning messages to alert nearby drivers and pedestrians. Once the path is cleared, the corresponding traffic signal is switched to green in the ambulance's direction. Tests and simulations show that the system can greatly reduce the time ambulances spend in traffic and improve coordination between emergency services and traffic control. This determining the patient's chances of survival. Unfortunately, traditional traffic control systems, which are based on fixed-time signal patterns, lack the flexibility to adapt to real-time traffic conditions or prioritize specific vehicles. As a result, ambulances often face unnecessary delays while navigating through crowded intersections, even when their journey is time-critical. These delays can be the difference between life and death, highlighting the urgent need for an intelligent, responsive traffic management system.

The advancement of the Internet of Things (IoT), cloud computing, and real-time data analytics has opened up new opportunities to address these challenges. IoT makes it possible for devices and systems to share data instantly, allowing traffic lights, sensors, and emergency vehicles to communicate project adds to the field of intelligent transportation systems (ITS) by offering an automated, scalable, and dependable solution for giving priority to emergency vehicles, which can help save more lives in critical situations.

Keywords: Smart Traffic Management, IoT, Ambulance Prioritization, GPS Tracking, Cloud Computing, Intelligent Transportation System (ITS), Emergency Response, Digital Display Boards.

I. INTRODUCTION

Traffic congestion has become a growing challenge in most urban areas due to the continuous rise in population, vehicle ownership, and limited road infrastructure. This problem not only affects daily commuters but also has a serious impact on emergency services. In cases such as heart attacks, severe accidents, strokes, or other medical emergencies, every second plays a crucial role in determining the patient's chances of survival. Unfortunately, traditional traffic control systems, which are based on fixed-time signal patterns, lack the flexibility to adapt to real-time traffic conditions or prioritize specific vehicles. As a result, ambulances often face unnecessary delays while navigating through crowded intersections, even when their journey is time-critical. These delays can be the difference between life and death, highlighting the urgent need for an intelligent, responsive traffic management system. The advancement of the Internet of Things (IoT), cloud computing, and real-time data analytics has opened up new opportunities to address these challenges. IoT makes it possible for devices and systems to share data instantly, allowing traffic lights, sensors, and emergency vehicles to communicate effectively. With the integration of GPS tracking, location updates from ambulances can be monitored in real time, and traffic signals can be adjusted automatically to clear their path. This is a significant shift from conventional systems, where manual traffic police intervention or pre-set patterns are the only options. Combining IoT with automated control units, cloud-based decision-making, and live traffic monitoring can lead to a smarter, more responsive system that ensures emergency vehicles move with minimal hindrance.

The proposed Smart Traffic Management Alert System (STMAS) aims to create such a solution by using a combination of GPS-enabled ambulance tracking, microcontroller-based traffic signal control, cloud data processing, and digital display boards for public awareness. When an ambulance enters a predefined detection zone near an intersection, its location data is sent to a cloud server, which processes the information and triggers a sequence of actions. First, LED display boards at the upcoming intersection are activated with warning messages such as "Ambulance Approaching – Give Way," alerting nearby drivers and pedestrians. This ensures that road users have time to clear the path. Only after the alerts are displayed does the system change the relevant traffic signal to green, providing the ambulance with an uninterrupted route through the intersection. This step-by-step process enhances both safety and efficiency, ensuring smoother passage without causing confusion to other drivers. The proposed solution represents a major step toward intelligent transportation systems (ITS) that are designed not just for efficiency, but for saving lives.

II. RELATED WORK

The field of intelligent traffic management for emergency vehicles has been explored through various methodologies that integrate Internet of Things (IoT), cloud computing, and real-time communication technologies.

Ahamad et al. [1] proposed an IoT-enabled ambulance prioritization system using GPS modules to track ambulance positions and control traffic lights dynamically, demonstrating a 40% reduction in average delay time.

Masanta et al. [2] developed an edge-assisted traffic management system that uses cameras and machine learning to detect congestion and emergency vehicles, reducing response latency through on-site computation.

Su et al. [3] introduced a Vehicle-to-Infrastructure (V2I) communication framework employing deep reinforcement learning to implement dynamic queue-jump lanes for ambulances, effectively reducing travel times during emergencies.

Humagain and Sinha [4] applied real-time systems theory to route autonomous emergency vehicles, ensuring predictable and consistent arrival times.

Khan and Pathan [5] designed an IoT-based autonomous emergency vehicle traffic management system incorporating GSM modules for backup communication, highlighting the importance of redundancy in real-world deployments.

Panwar et al. [6] explored the integration of Vehicular Ad Hoc Networks (VANETs) with IoT features to improve traffic management in smart cities, enabling broader system scalability. These studies collectively demonstrate the effectiveness of GPS tracking, IoT integration, and communication technologies in enhancing emergency response times. However, many existing approaches focus solely on traffic signal control without incorporating public-awareness mechanisms, such as roadside digital displays, which can further improve safety and compliance. In addition, while redundancy is addressed in some designs, comprehensive multi-channel alert systems remain less explored. The proposed Smart Traffic Management System for Medical Emergencies builds on these works by combining GPS-based ambulance detection, automated traffic light prioritization, real-time public alerts via digital boards, and SMS-based backup notifications for traffic personnel. This hybrid approach addresses gaps in public awareness, communication reliability, and adaptability, ensuring a more robust and scalable solution for urban emergency traffic management.

III. PROPOSED METHODOLOGY

This part of the paper delves into an explanation of the methodology covering aspects such as GPS data collection, location logging, communication, storage and data processing, decision-making, and output/feedback.

A. GPS Data Collection

The live data feed to track the ambulance is the most important part of this project. To collect data, we designed an IIoT device that collects the live location and transmits it to the server. This device includes an ESP32, which acts as a microcontroller to collect data from the GPS module (NEO-7M) and transmit it to the server. To connect to the server, the ESP32 uses its built-in Wi-Fi module and a hotspot provided in the ambulance for internet access. After collecting the data and verifying its validity, the ESP32 calls an API on the server to send the data, which is then stored in the database.

B. Location Logging

This is done by connecting the database to the server and executing an SQL query to store the data in a predefined table. This enables tracking of the ambulance's recent locations in order to find the nearest device as well as determine the direction of motion. It also allows tracking of the ambulance's run-time.

C. Communication

In order to communicate between the IIoT device and the server, we use Wi-Fi to connect to the internet so that HTTP protocols and methods such as POST and GET can be used. The APIs are made public to be called by the ESP32 in order to POST (send) GPS data to the server. We also use the GET method so that the static device can request the status message to make changes to the traffic lights accordingly.

D. Decision-Making

This includes the logic used to calculate the distance between two distinct GPS coordinates. To calculate this, we use the predefined Python library *geopy* and its geodesic formula.

A geodesic is the curve of shortest distance between two points on a curved surface or in spacetime. Geodesics are the shortest paths, similar to straight lines on a plane or great circles on a sphere. As the Earth is curved, this method provides a more accurate distance between two GPS coordinates than methods such as the Euclidean formula, which does not consider surface curvature.

For two points on a sphere given by latitude and longitude:

Point1:(lat_1, lon_1)

Point2:(lat_2, lon_2)

Radius of Earth (R): ~6,371 km

$a = \sin^2(dlat/2)+\cos(lat1)*\cos(lat2)*\sin^2(dlon/2)$

$c = 2*\text{atan2}(\sqrt{a}, \sqrt{(1 - a)})$

$d = R*c$(where R is the radius of the Earth, mean radius = 6371 km)

where,

dlon = lon2 - lon1

dlat = lat2 - lat1

Formula: Haversine Formula

In order to calculate, the distance between an active ambulance and a static device, each static device calls an API with the GET method to obtain a status response and determine what actions to perform after activation. The device passes its device_id, latitude, longitude, and altitude as parameters. This function then calls another function that uses the Haversine formula to calculate the distance between each recent ambulance location entry to find the nearest active ambulance.

The next function calculates the bearing (direction) of the moving ambulance by retrieving the second-last coordinates of the nearest ambulance. For this, we use the Initial Bearing (Forward Azimuth) formula, which is the horizontal angle measured clockwise from a reference direction (usually North or South) to a specific line or object. It indicates the direction of a line and is expressed in degrees, ranging from 0 to 360. We set North as the reference direction so that it gives the direction of motion relative to North.

After calculating the distance for all recent ambulance GPS coordinates, we find the nearest ambulance and compare the result with a pre-set parametric distance (e.g., 25 meters). If the calculated distance is less than or equal to the pre-set distance, we send the status message to the static device that made the request, in JSON format, over the internet. After receiving the JSON data, the ESP32 reads it.

E. Database and Storage

In this paper, the data about static devices are stored in MySQL database, hosted on XAMPP server which is locally hosted. This would later be shifted on any cloud server. Structure of database contain only two tables first- gps_data which is used to store the GPS information of each active ambulance and second-Static device used to store information about the latitude and longitude of device installed at the intersection.

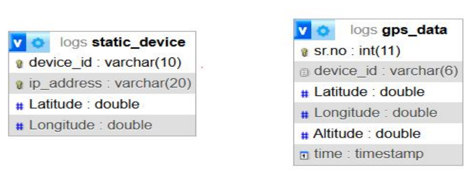

Fig. 1 Database Structure

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F. Output/Feedback

After reading the data received from the server, the static device changes the state of the traffic signals. First, it sets every signal to red for the next five seconds, then changes to green in the direction the ambulance is moving. This helps the traffic in front of the ambulance move forward and provide a safe passage or clear route for it. We also intend to display a message on the screen (if present) to inform people about the situation and reduce confusion. All of this is controlled by a single ESP32, making the system simple and easily replaceable in case of failure.

IV. HARDWARE IMPLEMENTATION

A. Overview

The hardware design for the Smart Traffic Management System for Medical Emergencies consists of two primary modules: the Ambulance Unit and the Traffic Signal Unit. These two modules communicate in real-time through a central server over a Wi-Fi network, enabling dynamic traffic control for emergency vehicle prioritization. The system is powered by rechargeable lithium-polymer (Li-Po) batteries and is built around the ESP32 microcontroller, chosen for its processing capability, integrated Wi-Fi, and flexibility in handling multiple input/output interfaces.

B. ESP32 Microcontroller

The ESP32 is the central control unit of the system, responsible for data acquisition, communication, and actuator control.

In the Ambulance Unit, it collects positional data from the NEO-7M GPS module through UART serial communication. The data is processed and transmitted to the server using HTTP POST requests at predefined intervals (e.g., every 5–10 seconds).

In the Traffic Signal Unit, it sends HTTP GET requests to the server to check for ambulance proximity. Based on the server's response, it updates the traffic light sequence in real time.

C. GPS Module (NEO-7M)

The NEO-7M GPS module provides high-accuracy geolocation data with fast satellite acquisition times.

1) Outputs: Latitude, longitude, altitude, and speed in NMEA sentence format.
2) Communication: Interfaces with the ESP32 via UART at 9600 baud.
3) Noise Reduction: A 1.00 µF capacitor across the power lines stabilizes voltage and reduces signal noise, ensuring consistent GPS performance even in urban environments with high RF interference.

D. Traffic Signal LED Module

The Traffic Signal LED module is a compact three-LED arrangement (red, yellow, green) used for intersection control.

In prototype testing, the LEDs are driven directly by the ESP32 through current-limiting resistors.

In real-world deployments, the ESP32 controls industrial traffic light systems via relay modules for higher voltage operation.

E. Relay Modules

Relay modules interface the low-voltage ESP32 control signals with high-voltage traffic light circuits.

1) Electrical Isolation: Uses optocouplers to prevent voltage spikes from damaging the ESP32.
2) Load Handling: Rated to switch currents suitable for industrial traffic signal operation.

F. Power Supply

Each unit is powered by a 3.7 V Li-Po battery.

A DC–DC boost converter steps up the voltage to 5 V for the ESP32 and GPS module.

The converter ensures stable voltage even when battery charge fluctuates.

This configuration allows uninterrupted operation in locations without direct grid access.

G. Working of the Traffic Signal Unit

The Traffic Signal Unit starts by powering the ESP32 through the boost converter. Once connected to Wi-Fi, it periodically queries the server for ambulance location data. If the ambulance is detected within a pre-defined range, the system changes all signals to red for a short clearance period and then activates the green signal in the ambulance's direction.

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Prototype Mode: Operates using low-voltage LED modules.
Deployment Mode: Uses relay modules to control high-voltage traffic signals.

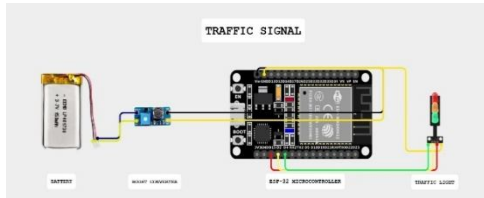

Fig. 2 Traffic-Signal device circuit

The circuit shows the connection of the Li-Po battery to the boost converter, ESP32 microcontroller, and three-LED traffic light module, with optional relays for high-voltage control.

H. Working of the Ambulance Unit

The Ambulance Unit continuously tracks the vehicle's position using the GPS module. The ESP32 processes this data and sends it to the central server using HTTP POST requests. The GPS module's capacitor ensures stable power, preventing positional drift due to voltage fluctuations.
Transmission Interval: Optimized to balance real-time responsiveness and battery efficiency.
Server Role: Calculates distance between the ambulance and each intersection and sends clearance commands to the nearest Traffic Signal Unit.

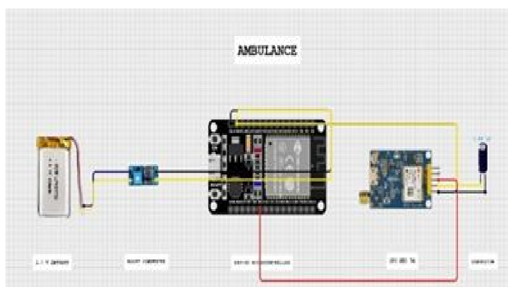

Fig. 3 Ambulance device circuit

The circuit illustrates the Li-Po battery, boost converter, ESP32 microcontroller, GPS NEO-7M module, and the noise-filtering capacitor for stable GPS operation.

I. Integrated System Workflow

The Ambulance Unit sends GPS data to the server in real time. The server computes the ambulance's distance from each intersection using geodesic formulas. The nearest intersection's Traffic Signal Unit receives a clearance command. The Traffic Signal Unit updates its lights to prioritize ambulance movement. After the ambulance passes, normal signal operation resumes. This synchronized operation reduces emergency response times, improves road safety, and minimizes manual traffic control requirements.

V. FUTURE WORK

Future improvement directions for this system include:

1) Expanded Coverage: Deployment of additional IoT-enabled traffic lights across both urban centers and rural highways to maximize system reach and effectiveness.
2) Advanced Communication Infrastructure: Adoption of robust communication channels such as 4G/5G networks or satellite connectivity to ensure real-time data transfer even in regions with unreliable Wi-Fi access.
3) Hospital System Integration: Direct integration with hospital emergency systems so that medical staff are fully prepared prior to patient arrival, further streamlining emergency response processes.

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VI. LIMITATIONS AND CHALLENGES

The development and deployment of the proposed system encountered several key challenges:

1) GPS Signal Reliability: In dense urban environments, tunnels, or under bridges, GPS signals can be inaccurate or unstable, affecting the precision of ambulance tracking.
2) High Initial Implementation Cost: Significant investment is required for installing GPS modules, IoT devices, and upgrading existing traffic light infrastructure.
3) Hardware Integration Complexity: Achieving seamless connectivity among the GPS module, ESP32 microcontroller, and server APIs demanded multiple iterative testing cycles.
4) Network Connectivity: Consistent, high-speed internet access is critical for real-time system operation; any network disruption can reduce system reliability and response effectiveness.
5) Data Management and Security: The system must process large amounts of sensitive location data securely and reliably, presenting technical and cybersecurity challenges.

VII. CONCLUSION

The proposed Traffic Management System for ambulances aims to reduce delays during emergencies by dynamically managing traffic signals using the real-time location and movement data of ambulances. The system integrates GPS tracking, IoT devices (such as the ESP32 microcontroller), and real-time server communication to identify the ambulance nearest to a given traffic signal. By calculating distance and direction using formulas such as Haversine distance and bearing calculation, the system sends advance control signals to change upcoming traffic lights, enabling ambulances to pass without unnecessary stops and thus improving response times. This approach minimizes human intervention, facilitating large-scale implementation in busy urban areas. Through the use of microcontrollers and internet-based APIs, quick and reliable data transfer is achieved between moving ambulances and fixed traffic devices. Integrating this solution into city traffic networks enhances the ability of emergency services to respond promptly, potentially saving lives and decreasing accident risks related to delayed medical attention. This project demonstrates how IoT and location-based technologies can transform traditional traffic systems into intelligent, responsive networks suitable for future smart city paradigms.

VIII. ACKNOWLEDGMENT

The authors acknowledge the technical hurdles and financial investments involved in the project. The need for repeated testing during hardware integration, the cost of upgrading existing infrastructure, and challenges related to GPS signal reliability—particularly in metropolitan areas—were significant constraints during development.

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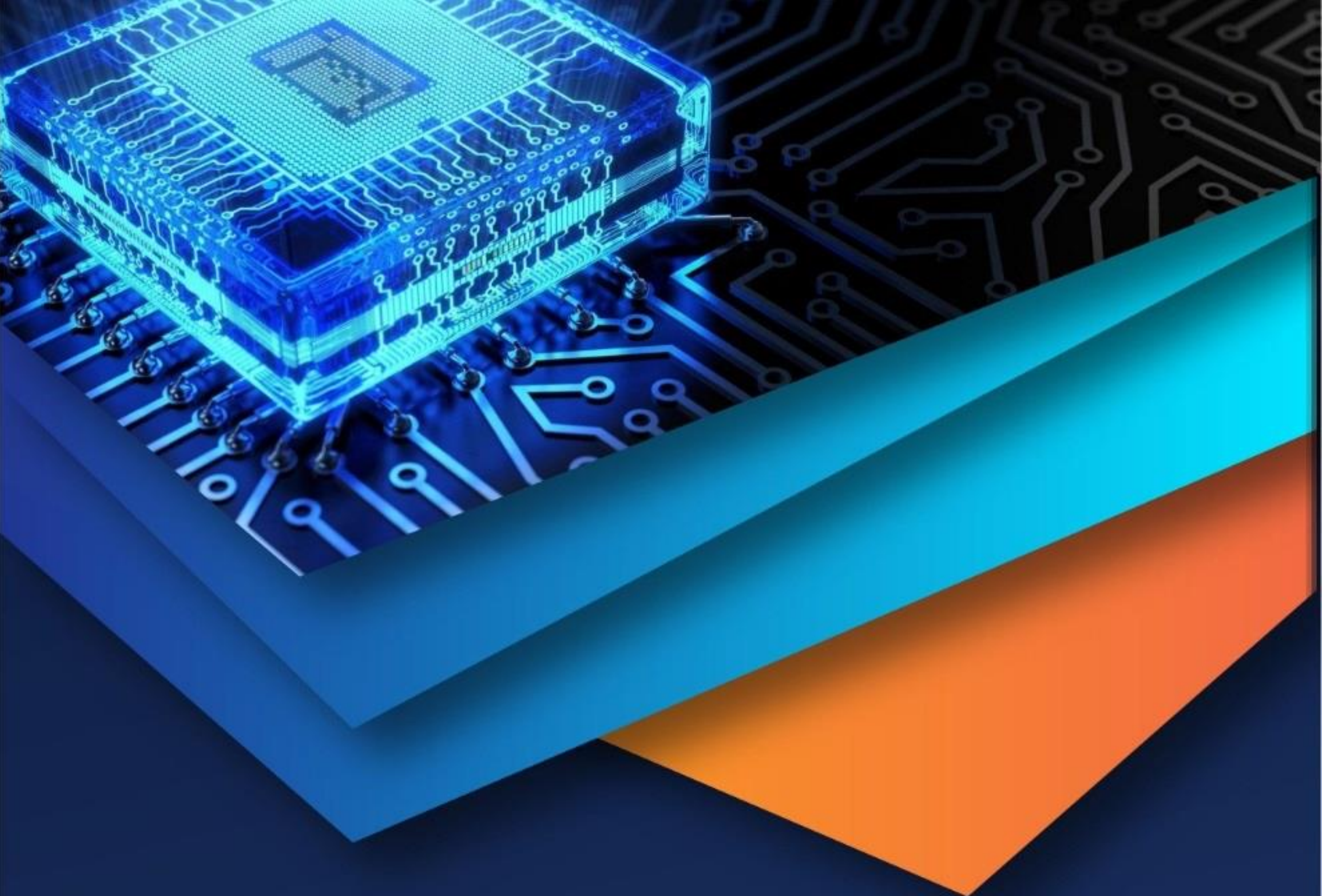
REFERENCES

[1] Agarwal, S. Bose, "Challenges and Solutions of IoT-Enabled Traffic Surveillance Systems," J. Traffic Manag. Res., vol. 2, no. 1, pp. 802f0c52b9, 2025.
[2] S. M. Dutta, "The challenges of IoT-based applications in high-risk environments," Sci. Direct, 2023.
[3] P. Joshi, M. Kaur, "An Exploring IoT Solution for Enhanced Smart Traffic Management," Int. J. Appl. Adv. Multidiscipline. Res., vol. 1, no. 2, pp. 193-206, Jun. 2023.
[4] R. Kumar, N. Sharma, "Real-time traffic monitoring system using IoT-aided robotics," Sci. Direct, 2023.
[5] J. Kumar, "IoT-Enabled Traffic Signal Systems for Urban Mobility Optimization," Sup. Chain Oper. Deci's. Mak., vol. 2, no. 1, pp. 31-38, 2025.
[6] C. Zhang, L. Liu, "Intelligent Traffic Signal Control for Emergency Vehicles," Int. J. Creative Research Thoughts, vol. 13, no. 1, pp. 951, Jan. 2025.
[7] Scriber, "IEEE Reference Page | Example & Format," Scribbr.com. (accessed Aug. 12, 2025).



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