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Green Lights Ahead: An IoT Solution for Prioritizing Emergency Vehicles

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Abstract

An improvised solution for the impact of IoT-enabled real-time traffic management on emergency vehicle response times has been presented in this research. The study was conducted using real-time traffic data and IoT sensors to monitor the flow of traffic and the movement of emergency vehicles. The results show that the integration of IoT technology improve emergency response times by enabling more efficient navigation of traffic. The benefits of IoT-enabled traffic management for emergency services include reduced response times, improved safety, and a more efficient use of resources. The results of this study have implications for the wider adoption of IoT-enabled traffic management in cities and other areas and suggest the need for further research in this area to explore the potential benefits and limitations of this technology.

Keywords: Real-time traffic data, response time optimization, traffic flow improvement, Internet of Things (IoT).

1. Introduction

In emergency situations, the timely arrival of emergency vehicles is crucial for saving lives. However, navigating through congested roads and intersections poses significant challenges, often leading to delayed response times, increased risks, and operational inefficiencies. To address these issues, researchers and technology developers are actively exploring innovative solutions that integrate Internet of Things (IoT) technology into traffic

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management systems. The IoT paradigm involves the utilization of sensors and real-time data to effectively manage and optimize traffic flow.

This study aims to investigate the impact of IoT-enabled traffic management on various aspects of emergency vehicle operations, including response times, safety, and resource utilization. By leveraging IoT capabilities, this study seeks to address the following research questions: How does the integration of IoT technology into traffic management systems affect the response times of emergency vehicles? What is the impact on overall safety levels and resource utilization in emergency situations? By thoroughly exploring these questions, this research endeavors to provide a comprehensive understanding of the potential of IoT technology in enhancing emergency services.

By analyzing and evaluating the effects of IoT-enabled traffic management on emergency vehicle operations, this study contributes to the advancement of knowledge in this field. The findings obtained sheds light on the practical implications and benefits of incorporating IoT technology into traffic management strategies, paving the way for improved emergency response systems and more efficient utilization of resources. Ultimately, the research aims to enhance the effectiveness and efficiency of emergency services, leading to enhanced public safety and well-being.

2. Literature Survey

A system comprising three components: an Automatic Signal Control system, a stolen vehicle detection system, and the clearance of emergency vehicles, was presented. The system utilized RFID Transmitter and Receiver technology. An RFID transmitter was installed in emergency vehicles, while the receiver located on traffic light poles receives the data and automatically adjusts the signal to green for 10 seconds, allowing safe passage for emergency vehicles [1] [11].

A density-based dynamic traffic signal system that adjusts signal timing based on the traffic density at a junction was developed. IR sensors are employed to measure vehicle density, and the system operates by delaying the traffic signal change. In the presence of an emergency vehicle equipped with a unique RF transmitter, the transmitted signal is detected by an RF receiver connected to the server or controller, resulting in the opening of signals and creating a zero-traffic scenario. This information is then relayed to the subsequent station [2] [19].

A traffic management system that integrates IoT and Artificial Intelligence techniques to control traffic on local and centralized servers was proposed. Artificial intelligence algorithms aid in predicting future traffic congestion and optimizing signal management. For emergency vehicles, the system utilized RFID Transmitter and Receiver technology [3] [10]. The model focused on creating Green Corridors for emergency vehicles using IoT technology [4] [16]. The system employed RFID Transmitter and Receiver components, where an RFID scanner updates the signal to green and notifies all vehicles to create a green corridor.

ETL (Emergency Traffic Light) Control System, a reprogrammable solution that utilizes Radiofrequency (RF) Communication was introduced. The receiver device consists of an Arduino Mega Platform with 5 switches and is integrated with a Radio Frequency Transceiver of the same type as the sender's RF transceiver. When an emergency vehicle, such as an ambulance, reaches a closed traffic light, the driver activates the appropriate switch to select the desired traffic light phase to turn green, thereby avoiding conflicts [5] [15].

A model incorporating Infrared Sensors to measure traffic intensity and a microcontroller to process the data and make decisions regarding signal timing was proposed. The system also includes a wireless module for detecting emergency vehicles. When an emergency vehicle, such as an ambulance or fire engine, approaches a traffic signal, a transceiver placed at the intersection receives the signal and relays it to the microcontroller. The microcontroller then activates the green light in the corresponding lane [6] [12].

Research involves regulating traffic by determining density on each side of the road and activating signals accordingly when an emergency vehicle, identified through its siren signal, is detected. The system employs a camera to capture real-time images of the traffic intersection, while a microcontroller generates the difference frame by comparing the current image with a reference image. Digital Image Processing algorithms are utilized to calculate traffic density, and the data is transmitted to the server for managing traffic lights. When an emergency vehicle is recognized, the traffic light sequences are automatically adjusted to provide a green signal in the detected direction, reverting to normal operation once the vehicle has passed through the signal [7] [18] [20].

The use of RFID technology for traffic management was proposed. Emergency vehicles are detected using RFIDs with varying ranges. When an emergency vehicle is detected, the corresponding lane is cleared to facilitate smooth passage. The signals collected are then processed by an Arduino controller, which makes the necessary decisions for efficient traffic control [8] [13] [17]. A smart adaptive traffic monitoring and control system designed to detect vehicles and pedestrians and prioritize emergency vehicles was presented. A new Convolutional Neural Network was trained using the YOLOV3 architecture, achieving a detection precision of 91.3% [9] [14].

3. Methodology

The generalized block diagram of the entire system is shown in Figure 1.

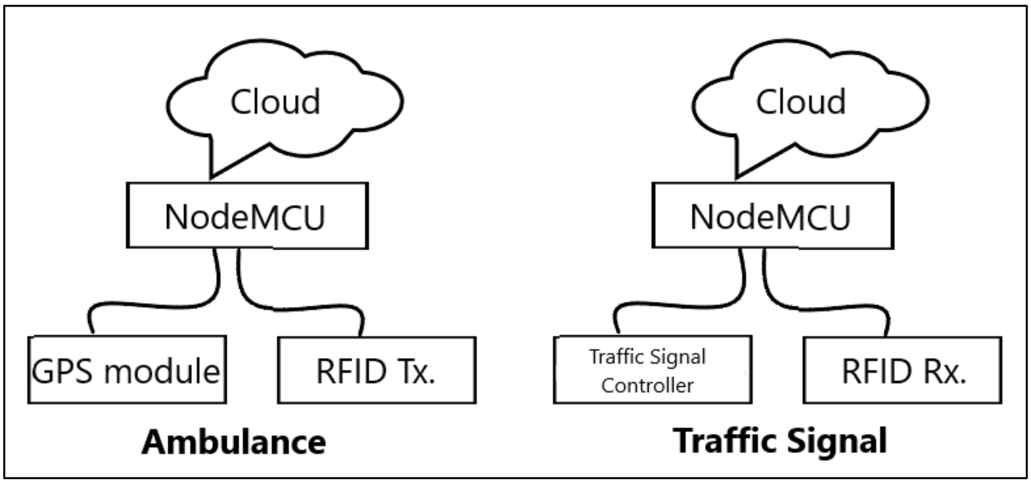

Figure 1. Block Diagram

The left half of the block diagram shows the system to be implemented with the ambulance, whereas the right half of the block diagram shows the system to be implemented with the traffic signal. The system of an ambulance consists of an RFID transmitter, a GPS module, and a microcontroller (e.g., a NodeMCU). The system of traffic signals consists of an RFID reader, a GPS module, and a microcontroller (e.g., NodeMCU).

The RFID reader at the traffic signal detects the radio frequency signals transmitted by the RFID transmitter of the ambulance traveling towards the traffic signal. According to the distance of the ambulance, i.e., the strength of the radio frequency signal received, the microcontroller at the traffic signal switches the mode of the traffic signal from Normal to Emergency, making a green corridor for the ambulance to traverse to the hospital. A green corridor indicates that the lane from which the ambulance is traveling is made free by turning the traffic signals to green and blocking all other lanes by turning the traffic signals to red. The GPS modules installed at the ambulance help the hospital track the ambulance in real time. This makes it possible for the ambulance in an emergency to travel to the hospital in less time, saving the patient's life.

The flowchart of the proposed system is shown in Figure 2.

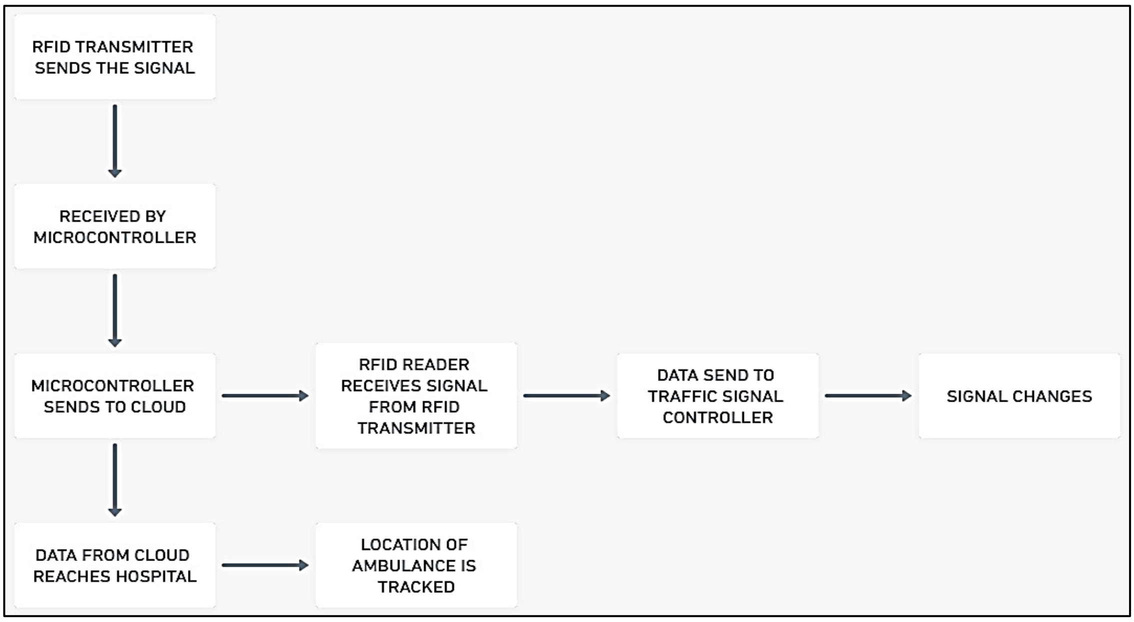

Figure 2. Flowchart of the Proposed Model

4. Implementation

The simulation of the entire system is carried out using Supervisory Control and Data Acquisition (SCADA) with Wonderware Intouch software. The simulated model is illustrated further below.

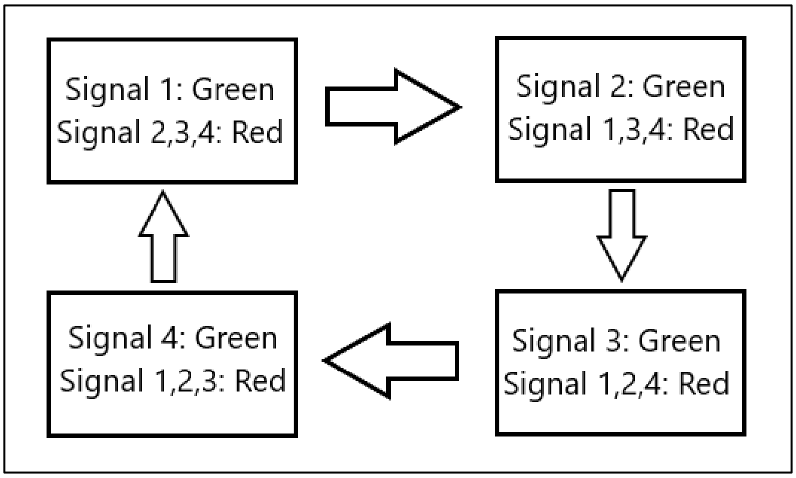

Figure 3. Signaling System in Normal Mode

Figure 3 depicts the signaling system in normal mode. Each consecutive signal turns green after its previous signal turns red and continues to be in the same loop.

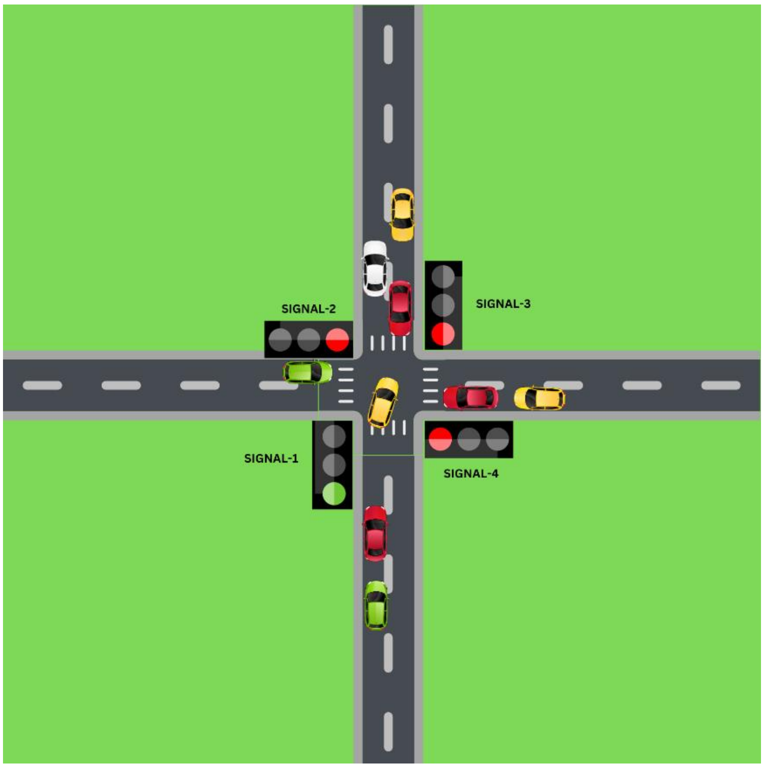

Figure 4. Normal Mode 1

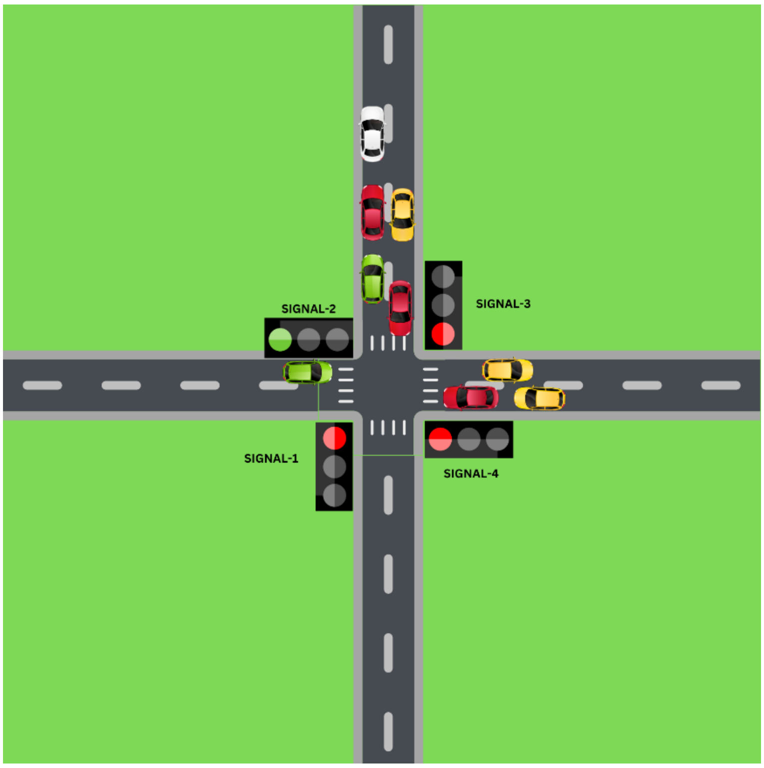

Figure 5. Normal Mode 2

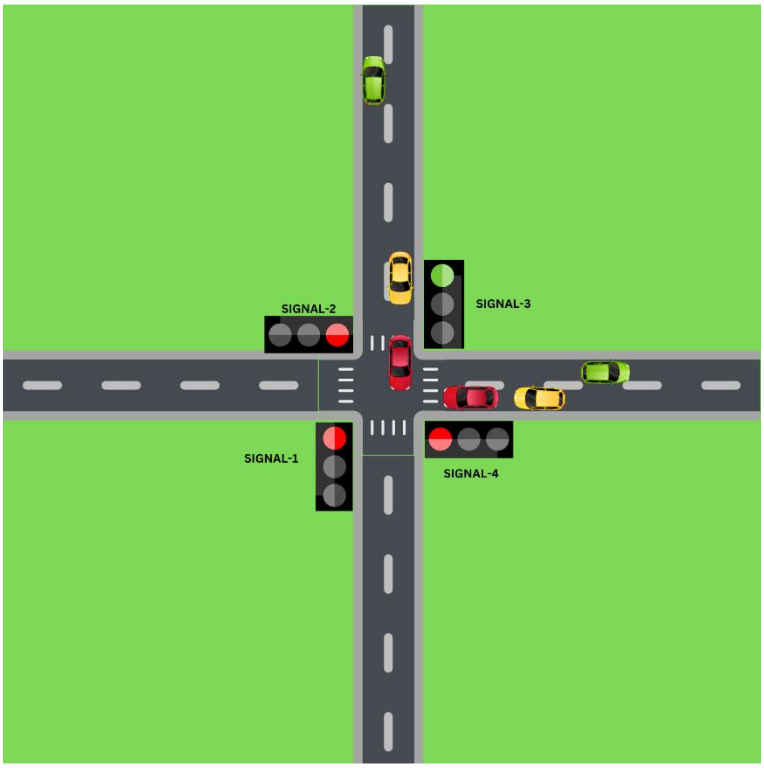

Figure 6. Normal Mode 3

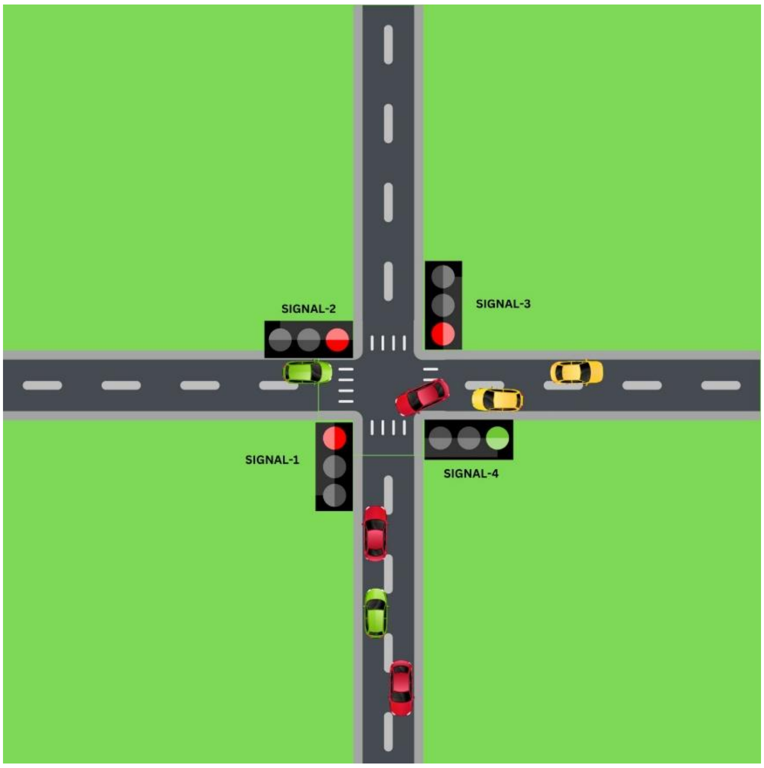

Figure 7 Normal Mode 4

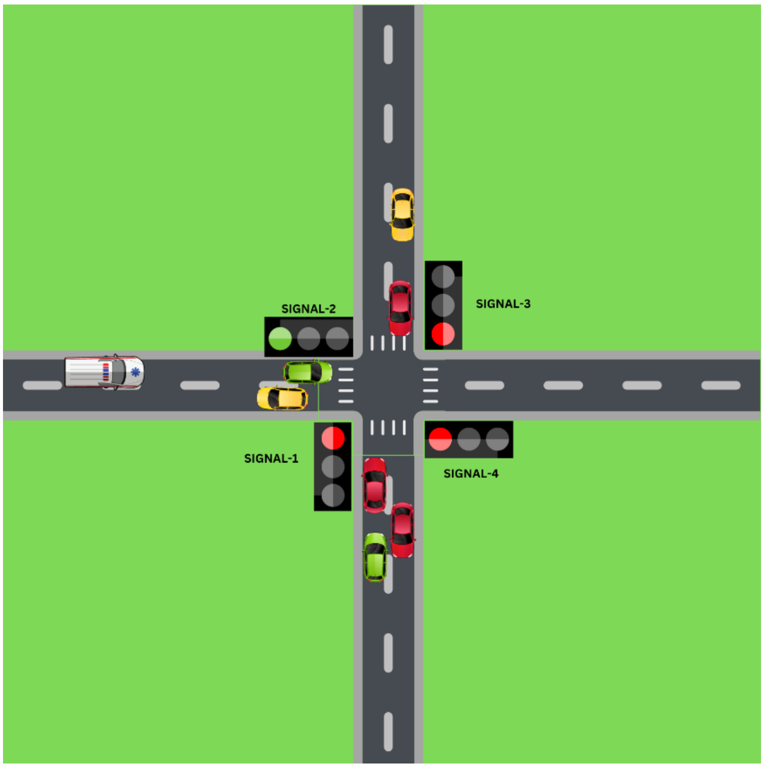

Figure 8 Emergency Mode

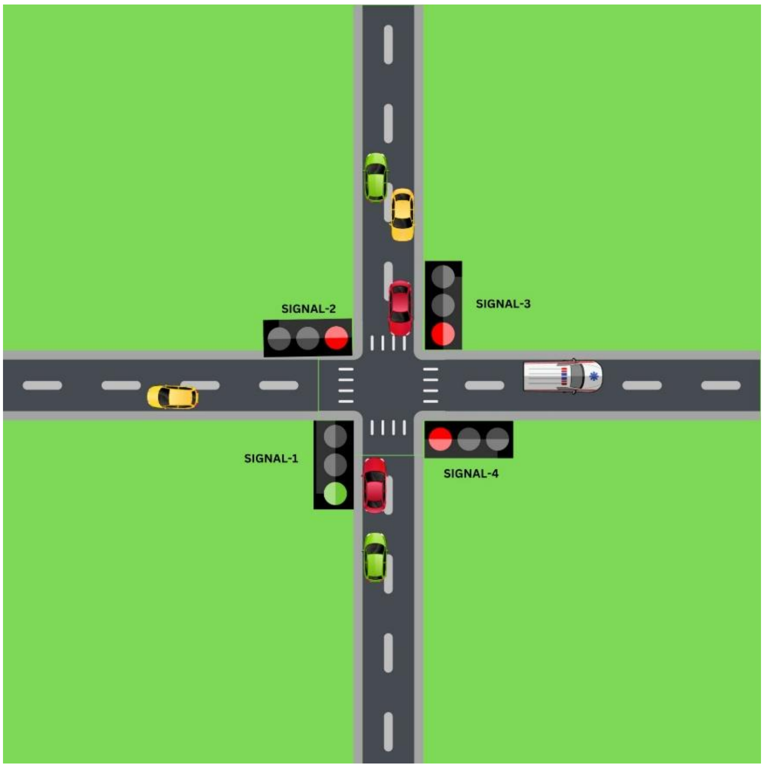

Figure 9 Normal Mode after Emergency Mode

Figures 4, 5, 6, and 7 depict the normal working of the signaling system as shown in figure 3. As soon as an ambulance is detected by the RFID receiver in its vicinity, the respective signaling system enters emergency mode and turns the lane's signal to green until the ambulance passes by, as shown in figure 8. Once the ambulance passes far away from the signal, the signaling system returns to normal mode, as shown in figure 9. This ensures that the proposed systems prove to be highly accurate and beneficial for emergency lifesaving situations. This not only reduces the traversal time of the ambulance but also enhances traffic management, saving the lives of those threatened. The hardware and software components utilized in the given solution are listed in Table 1.

Table 1. Hardware and Software Components

Hardware Components	Software Components
NodeMCU microcontroller	Cloud Platform
RFID Transmitter (Tx.)	GPS Navigator
RFID Receiver (Rx.)	-
GPS Module	-

5. Advantages and Usefulness of the Proposed System

The proposed design, which integrates IoT-enabled traffic management into emergency services, offers several advantages and is highly useful compared to the existing systems. In terms of response times, the improvements achieved by the proposed design can be highlighted by comparing those to the existing systems.

Enhanced Traffic Management: The integration of IoT technology allows for real-time monitoring and optimization of traffic flow. This leads to more efficient management of intersections, reduced congestion, and improved overall traffic conditions. By leveraging IoT-enabled traffic management, the proposed design can better handle emergency vehicle movement through congested areas.

Improved Emergency Response: The proposed design aims to optimize emergency vehicle response times. By utilizing IoT technology and the integration of RFID transmitters and receivers, the system can prioritize emergency vehicles at traffic signals. This ensures smoother and faster passage for emergency vehicles, leading to reduced response times and potentially saving more lives.

Resource Utilization: Using IoT-enabled traffic management, the proposed design optimizes the utilization of resources such as emergency vehicles, personnel, and infrastructure. By minimizing delays caused by traffic congestion, emergency services can operate more efficiently, resulting in better resource allocation and improved overall effectiveness.

Safety Enhancement: By reducing response times and improving traffic management, the proposed design enhances safety for both emergency vehicles and other road users. Quicker response times mean emergency vehicles can reach their destinations faster, potentially minimizing risks or further harm. Additionally, optimized traffic flow helps mitigate the chances of accidents caused by congested roads.

Comparing Improvements in Response Times

In comparison to the existing systems, the proposed design offers significant improvements in response times for emergency vehicles. The integration of IoT technology and the use of RFID transmitters and receivers enable the system to automatically detect and prioritize emergency vehicles at traffic signals. This feature allows for the swift adjustment of traffic signals, providing green corridors and reducing waiting times for emergency vehicles [21].

By facilitating faster passage through congested areas, the proposed design effectively minimizes delays and improves overall response times. This contrasts with the existing systems that may rely on manual interventions or lack the advanced technology and real-time data integration provided by the proposed design [22].

The improvements achieved in response times with the proposed design have the potential to make a substantial impact on emergency services. The reduction in response times can lead to enhanced patient outcomes, improved emergency care, and ultimately save more lives.

It's important to note that the specific improvements and advantages of the proposed design over existing systems may vary depending on the context, available infrastructure, and implementation details. The proposed design, leveraging IoT-enabled traffic management, demonstrates great potential in addressing the challenges associated with emergency vehicle response times and making significant advancements in the field of emergency services.

6. Discussion

In this research work, "Green Lights Ahead," an improvised solution that harnesses the power of Internet of Things technology to prioritize emergency vehicles and optimize response times, has been proposed. By leveraging real-time traffic management and the dynamic adjustment of traffic lights, the Green Lights Ahead system aims to provide emergency vehicles with a clear path through traffic, reducing delays and improving overall traffic management in urban areas.

Through the implementation and evaluation of the Green Lights Ahead system, significant contributions are made to the field of IoT-enabled traffic management and emergency vehicle prioritization. The findings demonstrate the potential of this solution to have a substantial impact on improving emergency response times and enhancing the efficiency of emergency services.

The results of the simulations and analysis indicate that the Green Lights Ahead system effectively reduces response times for emergency vehicles compared to scenarios without the system in place. By dynamically adjusting traffic lights to prioritize emergency vehicles based on real-time traffic conditions, a reduction in average vehicle delay, alleviation of congestion, and improvements in overall traffic flow are observed. These outcomes highlight the practical implications and benefits of implementing the Green Lights Ahead system in urban areas.

However, it is important to acknowledge the limitations of this research. The simulations and evaluations were conducted under specific scenarios and assumptions, which may not capture the full complexity and variability of real-world conditions. Further research and testing should be conducted to validate and refine the findings of this study in diverse geographical locations and traffic contexts.

The Green Lights Ahead system holds promise for emergency service providers, city planners, and policymakers who seek innovative solutions to improve emergency response capabilities and traffic management. By leveraging IoT technology, this solution provides a cost-effective and scalable approach to prioritizing emergency vehicles without the need for extensive infrastructure modifications.

7. Conclusion

In conclusion, this research underscores the potential of the Green Lights Ahead system to revolutionize emergency vehicle prioritization and enhance traffic management. By reducing response times for emergency vehicles, this IoT-enabled solution has the capacity to save lives, minimize property damage, and improve the overall efficiency of emergency services. As technology continues to advance, further exploration and implementation of IoT-based systems like Green Lights Ahead can pave the way for smarter and more effective urban transportation systems in the future.

Further research and collaboration in this field is encouraged to explore additional enhancements, overcome challenges, and fully realize the potential of IoT-enabled solutions for emergency vehicle prioritization and traffic management. By prioritizing the development and implementation of such innovative approaches, striving towards safer, more resilient, and sustainable cities can be accomplished, where emergency vehicles can navigate efficiently and effectively to save lives and protect communities.

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Author's biography

Soham Methul, a driven and accomplished individual, is currently in his fourth year of undergraduate studies at the College of Engineering Pune, specializing in the Electronics and Telecommunication Department. His educational journey began with a diploma in Electronics and Telecommunication Engineering from the esteemed Cusrow Wadia Institute of Technology, where he passed as the college topper with an impressive score of 99.35%.

Soham's passion for technology extends to the field of the Internet of Things (IoT), where he has developed a keen interest. He recognizes the transformative potential of the IoT in connecting and enhancing various aspects of our daily lives. Eager to expand his knowledge and skills in this domain, Soham has actively engaged in coursework, projects, and research related to the IoT. Throughout his academic journey, Soham has demonstrated exceptional dedication and a thirst for knowledge. His commitment to excellence has earned him accolades and recognition from both faculty and peers. With his strong academic foundation and passion for IoT, Soham envisions a future where he can contribute to the development of innovative and sustainable solutions that leverage the power of connected devices. Soham's determination, academic achievements, and keen interest in IoT make him a promising young professional poised to make a significant impact in the field of Electronics and telecommunications.

Saket Kaswa is a dynamic and ambitious individual currently pursuing his undergraduate degree at the College of Engineering, Pune. While specializing in Manufacturing Science and Engineering, Saket's curiosity and passion for technology extend beyond his chosen field. Despite not studying in the branches of Computer science or engineering and technology, he has developed a keen interest in the technologies taught in these disciplines. Saket's determination and drive have led him to explore various programming languages and delve into the world of computer science in his spare time. He consistently seeks opportunities to enhance his skills and broaden his knowledge in the realm of technology. With a thirst for knowledge and a natural inclination towards problem-solving, Saket strives to make a meaningful impact at the intersection of manufacturing and emerging technologies. In addition to his academic pursuits, Saket is an active participant in college events, where he displays strong leadership qualities and excellent teamwork. His commitment to personal and professional growth has earned him recognition from both peers and faculty. With a bright and promising future ahead, Saket continues to push boundaries and embrace new challenges, aiming to bridge the gap between his chosen field and the world of computer science and electronics.