iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 11 **Issue:** XI **Month of publication:** November 2023

DOI: https://doi.org/10.22214/ijraset.2023.57023

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 11 Issue XI Nov 2023- Available at www.ijraset.com

A Comparative Study on IoT Based Traffic Management System

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Abstract: ***The continuous growth of the global population has led to a rapid increase in vehicle production, resulting in an exponential growth of vehicles on the roads. This surge contributes to severe traffic congestion, particularly during peak rush hours in metropolitan cities. Urban planners, city officials, and researchers are increasingly concerned about effective traffic management to ensure safety and economic efficiency. Addressing this issue, Intelligent Transportation Systems (ITS) integrate existing technology with current infrastructure to alleviate congestion. This paper focuses on a comparative study of various traffic control methods, specifically the Traffic Light System (TLS), which includes Radio Frequency Identification (RFID), dynamic and static TLS, and the Internet of Things (IoT).***

I. INTRODUCTION

Traffic congestion poses a significant challenge for urban planners, impacting fuel consumption, air pollution, and overall economic growth. With population growth, congestion is expected to worsen, necessitating a well-organized and adaptable traffic management system. Recent advancements in Radio Frequency Identification (RFID) technology have revolutionized traffic control, offering low-cost and user-friendly solutions. RFID is particularly effective in automatic vehicle identification, reducing the need for expensive infrastructure.

The Traffic Management System (TMS) plays a crucial role in reducing urban traffic congestion. Traditional traffic lights, invented by Lester Farnsworth Wire in 1912, have evolved into dynamic TLS, offering the flexibility to adapt to varying traffic conditions. The integration of advanced technologies, including image processing, wireless communication, data mining, and control systems, has given rise to Intelligent Transportation Systems (ITS). The emergence of the Internet of Things (IoT) further enhances communication capabilities, connecting various platforms for a comprehensive approach to traffic management.

II. RELATED WORKS

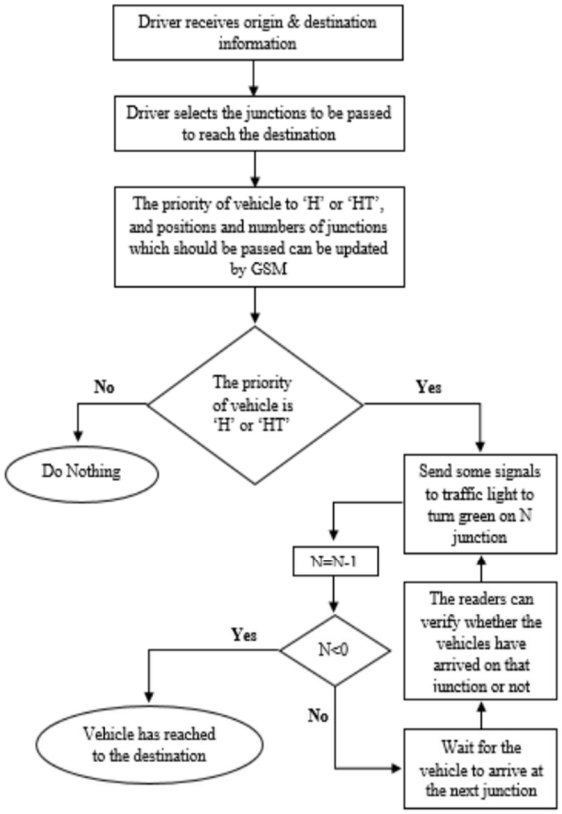
Intelligent Traffic Systems (ITS) leverage IoT applications to enhance traffic control. Studies explore innovative approaches such as the Green Wave System, triggering traffic signal changes based on emergency vehicle movements. However, challenges arise in adverse weather conditions affecting visual processing accuracy. RFID technology, employing tags without batteries, offers an alternative for emergency vehicle identification. Yet, issues persist in determining the necessity of signal changes when emergencies are not imminent.

Wireless Sensor Network (WSN) systems using magnetic sensors aim to improve vehicle detection accuracy. Proper vehicle detection is crucial for effective traffic management, considering lane occupancy, traffic flow, and speed. However, signal-to-noise ratio settings in WSN systems may impact detection reliability. Infrared and magnetic sensors combined enhance vehicle detection in intelligent transportation systems, but challenges persist in industrial zones.

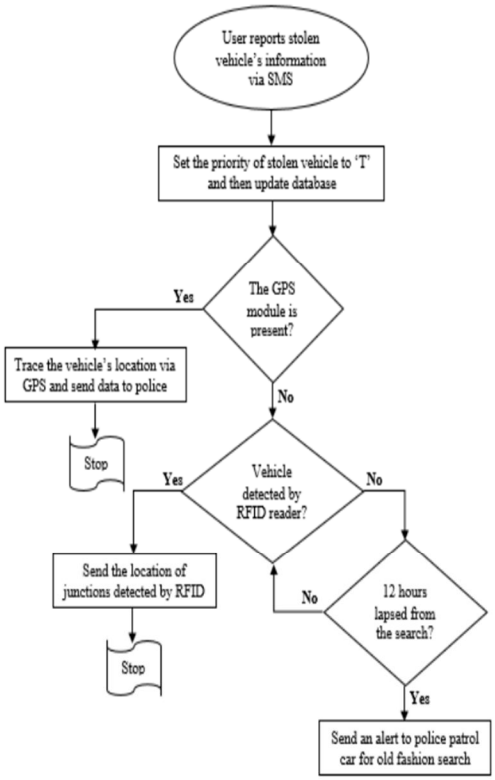
Mobile-based traffic measurement devices present another alternative, monitoring and managing road traffic congestion. Lieskovsky and Badura propose an Intelligent Traffic System architecture with cameras at intersections, delivering real-time data through mobile Ad-hoc networks. Photoelectric sensors offer a method for controlling traffic signals, adjusting based on traffic flow and congestion.

III. METHODOLOGY

The Intelligent Transportation Systems (ITS) discussed in this paper prioritize ordinary, stolen, and emergency vehicles with varying levels of importance. Short Message Services (SMS) dynamically update the database with vehicle priorities and categories. Stolen vehicle tracking involves GPS technology or RFID readers, overcoming challenges of weather conditions affecting reader signals.



Flowchart 1. Green Wave Systems



Flowchart 2. Stolen Vehicle Detection

TABLE 1
OBTAINING RAW DATA METHODS

Method	Description	Rating
Triangulation method	In developed countries as the number of cars increased significantly, some cars contain one or more mobile phones. This phone can transfer the information to mobile phone network. Barring any distortion of data, this method creates a circumstance to measure and analyze network data and produce traffic flow information.	Useful
Vehicle re-identification	In this technique, a set of detectors are required along the road. Here, a unique serial number of device in the vehicle is detected at one location which can be re-identified again down the road. This method is very useful in calculating travel times and speed of vehicle by comparison between real time that the vehicle is detected and time at which a specific vehicle is detected by the set of sensors.	Very useful
GPS based method	These vehicles must be equipped with GPS systems to detect the location and the velocity of the vehicle very accurately and be capable of two-way communications with a traffic data provider.	Useful
Smartphone-based monitoring	Most smart phones also have full GPS features and various sensors for tracking the traffic flow and speed.	Useful

The methodology involves both electrical and software systems, including a cloud server, control system, green light algorithms, and traffic police monitoring apps. Data collection utilizes inductive loop detectors, and a realistic algorithm computes Green Light Phase Time (GLPT). Flowcharts detail the core algorithms for green wave implementation and stolen vehicle identification.

TABLE 2. VARIOUS METHODS FOR TRAFFIC LIGHT CONTROLLER

Method	Description	Pros and cons
Traffic Management System (TMS)	This technique is a top-down management perspective that integrates with technology in order to improve the traffic flow and safety. In this situation the task is divided into smaller systems put in various place. Real time traffic data is gathered from cameras and speed detectors are transmitted into Transportation Management Center (TMC) for improving traffic flow.	**Pros: 1.** Increased road user satisfaction for saving precious time of commuters. **2.** Reduce possibilities of traffic jams. **Cons: 1.** Excessive delay may be caused due to TMS malfunction and downtime. **2.** Unnecessary delays result in significant fuel waste and higher motorist time.
Green wave system	In this technique whenever the vehicle is crossing the intersections, an incoming emergency vehicle enables the traffic light to change to green. Image processing can be used for detecting the location of emergency vehicles more accurately. As a result, an emergency vehicle will receive all green signals along its route and will not be affected by any stops while on its way to its target destination	**Pros: 1.** Can allow emergency vehicle to pass through intersections safely and rapidly. **2.** Useful for detecting the stolen vehicles that pass through intersections. **Cons: 1.** Weak performance in severe weather conditions. **2.** If it does not work correctly, it can cause a heavy traffic jam
RFID tags	This technique overcomes the severe weather problem in Green Wave System as Radio Frequency is not affected by the weather. RFID uses tags assembled in the dashboard of the ambulance and RFID readers are installed at the 200 meters from junctions. The RFID reader will read all the data from tags in order to detect the ambulance as it approaches traffic light systems.	**Pros: 1.** The RFID tags can store a lot of information, and follow instructions **2.** It is not affected by severe weather conditions. **3.** These RFID tags are usually smaller than thumb tack and they can be embedded into dashboards. **Cons: 1.** Active RFID can be expensive because of power sources such as battery. **2.** RFID may be easily intercepted, even if it is Encrypted.
Wireless Sensor Network (WSN)	This technique utilizes a set of magnetic sensors to improve the accuracy of vehicle detection. As a vehicle approaches a magnetic detector, there is a partial distortion of the local magnetic field that is generated by the detector. Whenever the vehicle is in the middle and the last portion of the magnetic field generated by the detector, the total local magnetic field is distorted. After that these data can be transmitted to a controller.	**Pros: 1.** WSN can be applied in large scale and in various fields as it avoids wiring. **2.** It performs well at high speed and is flexible to go through a centralized monitor. **Cons: 1.** If Signal-to-Noise Ratio (S/N) is too low, it can potentially cause adverse effects in sending false alarm. **2.** Easy for hackers to hack the system because the propagation of waves cannot be controlled.
Global System for Mobile Communication (GSM)	In this technique, embedded controller is used to produce data pattern as an input for microcontroller. The C program language, then is converted in HEX code and transfer into receiver of microcontroller. Then transmitter of microcontroller will send these data to GSM. The GSM can active messaging service with the 3G connection of SIM alert a specialist with message.	**Pros: 1.** Very useful in saving time because it can send a message to medical doctors about patient's situation before arrival of the ambulance. **2.** It can show video display by using 3G connection in ambulance. As a result, the doctor can analyze the condition of patient and recommend some first aid steps. **Cons:** Concerns about losing control of their network and the data. Also, losing battery of mobile can disconnect the connection.
Infrared Sensor (IR)	Most of the traffic light systems have IR sensors which consists of IR transmitter and receiver. Whenever the vehicle passes between sensors, the IR sensors can be activated. The collected information can be analyzed to change the traffic light to green.	**Pros:** Reportedly stolen vehicles or vehicles of criminal suspects can be tracked, and the time and direction of travel can be traced. **Cons: 1.** Initial setup cost is high **2.** An emergency cannot be automated and normally requires human intervention.

TABLE 3. COMPARISON OF THE PERFORMANCE OF TRAFFIC LIGHT CONTROLLER
Low = L, Medium = M, High = H

	Safety	Trustability	Efficiency	Overall Rating
Fixed Cycle TLS	**M** Sometimes in rush hours the police should control the traffic congestion	**H** This is the most basic TLS with the least chance of failure.	**L** It leads to increased traffic density at peak hours, or unnecessary delay behind red light when there is no traffic at all.	**Widely used.** Its use is diminishing in smart cities.
Dynamic Cycle TLS	**H** A reasonably safe and a proven technology.	**H** A reasonably safe and a proven technology.	**H** The vehicle's driver can pass the road when there is no traffic density.	**Very useful** It can adapt traffic pattern based on the number of vehicles on the road at any given time.
Green Wave System	**M** Sensors are continuously and in real-time are tested for added safety and reliability.	**M** If the sensors cannot work very accurately, it will cause traffic density	**L** In severe weather conditions, it cannot detect the emergency vehicle accurately	**Not very useful** It can be useful in areas where winter and sever weather condition is not an issue.
RFID tags and readers	**M** Store lots of info and instruction for sending to server	**L** It cannot be affected by weather conditions	**M** Not cost efficient because of power source requirement.	**Useful** Can keep track of stolen & emergency vehicle.
Wireless Sensor Network (WSN)	**L** Easy to hack the system because still there is little security in WIFI systems.	**M** By the help of magnetic sensors, emergency vehicle are detected more reliably.	**M** If Signal-to-Noise Ratio (S/N) is too low, it can potentially cause adverse effects in sending false alarm	**Useful** WIFI and AI are promising technologies for real-time detections now and with increasing reliability.
Global System for Mobile Communication (GSM)	**H** The EMS assistants can send their assessment of the patient to the medical team before arriving to hospital	**M** Dead battery or loss of mobile network is of prime concern.	**H** Communication about the condition of the patient can be enhanced via video call	**Very useful** Saving time because it can send a message to specialist doctor about patient's situation before arrival of ambulance
Infrared sensors (IR)	**M** It can send high resolution images to traffic light control center to decide safely for duration of green light.	**L** It's a little difficult for large areas and more complex to gather all traffic data from IR sensors.	**L** The initial setup is too much expensive and sometimes emergency cannot be automated.	**Useful** It can detect stolen vehicles while they are passing between IR sensors.

IV. CONCLUSION

The paper explores various intelligent traffic management technologies, including smart phones, Green Wave Systems, RFID, and wireless connectivity with Big Data centers. Tables summarize applications, benefits, and drawbacks of each method. IoT technology enhances data collection precision, with mobile applications serving as a user interface for identifying and addressing traffic congestions. Intelligent Traffic Systems offer priority to emergency vehicles.

Overall, the study presents a comprehensive overview of intelligent traffic management approaches, addressing challenges and proposing solutions for efficient and adaptive traffic control.

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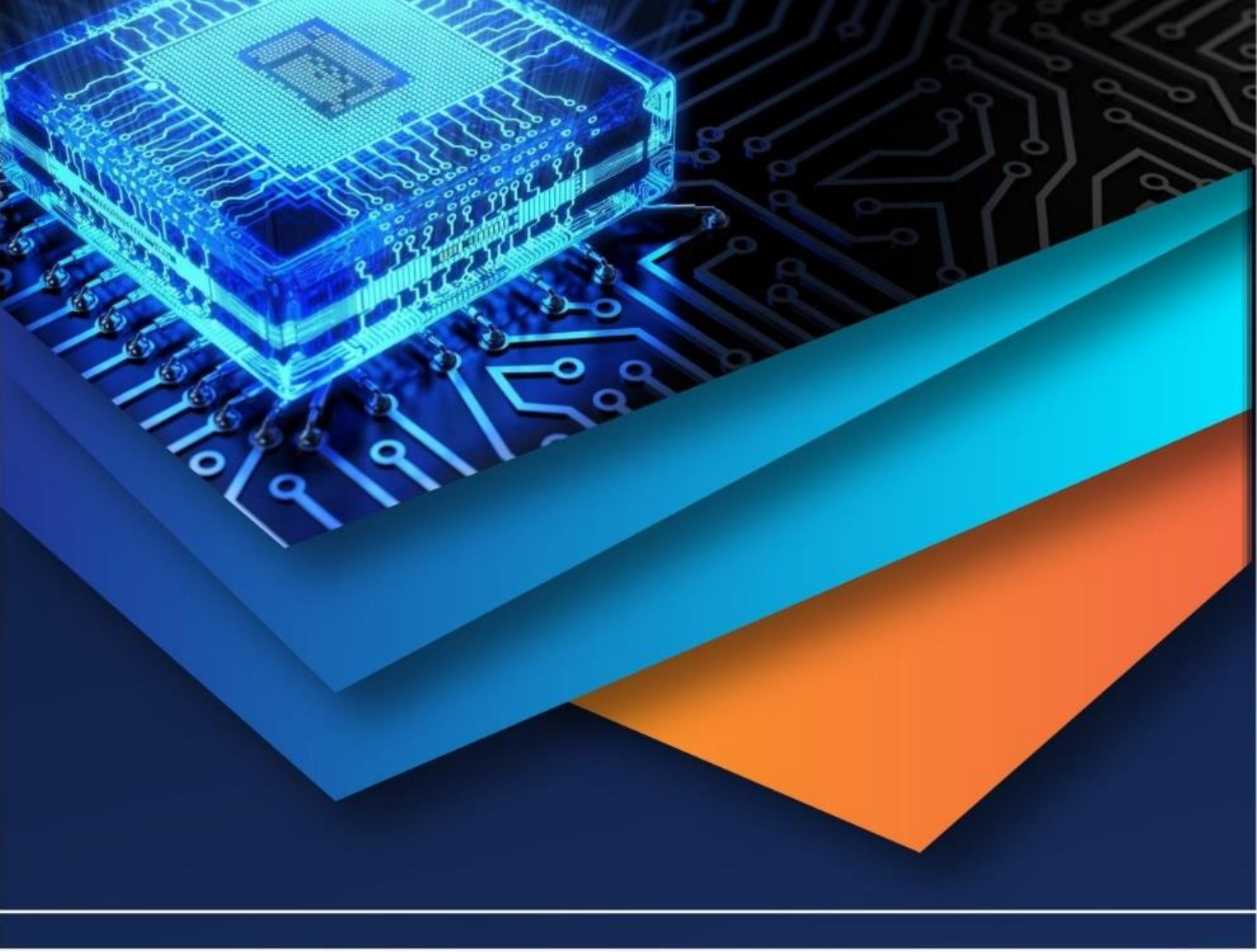

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