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Research Article

Vehicle Identification for Performance Evaluation of LTE-Based Traffic Management against AI and Conventional Techniques

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ABSTRACT

These most industrialized countries now focus on traffic management because traffic numbers have risen together with global traffic expansion. The technological progression resulted in a modern traffic management solution which allows counting vehicles as well as monitoring their speeds for enhanced transportation planning systems. The established system has lowered the incidence of accidents stemming from deteriorating traffic conditions. Manual road traffic surveys have been ongoing for many years since automation installations proved difficult to implement. Wireless sensor networks stand as an essential method for realizing applications which include traffic monitoring in the real world. Intelligent traffic management solutions have become essential because of both rapid urban growth and explosive vehicle traffic increases. The implementation of traditional traffic control systems using fixed-timer mechanisms cannot react to current congestion which results in inefficient traffic operation and worsened urban transport problems. The paper evaluates and compares the performance of real-time traffic management through LTE technology with conventional approaches and AI-powered systems for traffic control systems. A combination of wireless sensor networks (WSNs), ultrasonic sensors as well as LTE communication powers the proposed system to conduct immediate vehicle identification and active traffic signal modifications. The LTE-based solution operates with low-latency signal adjustment capabilities because it delivers a response time of 0.35s that surpasses both AI-based systems by 5× and Google API-based solutions by 10×. Vehicle traffic congestion decreases by 30% under this system thus demonstrating better performance than YOLO-based AI models by 50% and making the system three times more effective than traditional methods. Real-time decisions that depend on vehicle density estimation show improved performance at a 98% accuracy rate because this leads to optimal traffic flow as well as decreased emissions and faster emergency responses. This research shows LTE-based adaptive signal control emerges as the preferred technology for intelligent transportation system optimization. It delivers scalable real-time operational performance at a reduced cost to build next-generation ITS. This article functions as a research starter for scientists constructing traffic management solutions for safety.

Keywords: LTE (long term evolution), Wireless Sensor Network, Real-Time Traffic Management, AI-Based Traffic Control, Smart Transportation, Adaptive Signal Control, Vehicle Density Estimation

INTRODUCTION

The urban population increases daily despite the growing number of vehicles presents throughout the metropolitan areas. The increased number of automobiles and expanding population creates mounting difficulties for urban control of streets and highways and roads. Excessive vehicle population growth in urban areas generates serious road congestion that results in poor road administration. Actual traffic conditions need adaptive control systems because traditional methods of traffic management through fixed timers and people monitoring do not handle conditions dynamically which leads to extended waiting periods as well as higher gas usage and slower emergency interventions. Current intelligent traffic systems base their operation on video surveillance and inductive loop sensors face three major drawbacks which are high expenses and maintenance complexity and reduced performance stability during diverse operating environments. This paper introduces a live traffic management system which brings together ultrasonic sensors alongside LTE communication for variable signal control purposes. Sensors operate to find traffic density levels which data get sent in real-time through LTE and allow signal timing readjustments to optimize motor vehicle flow. The modern system allows instant choices and reduced traffic congestion and puts emergency vehicles at priority by contrast to prior practices. The system enables the monitoring of traffic from a centralized position enabling efficient adjustments at various junctions. The chosen remedy provides adaptable functionalities at affordable costs with energy-efficient operation capabilities which qualify it for smart city traffic management programs. Real-time data processing through IoT-connected wireless communication serves for the dual purpose of advancing urban mobility while decreasing transportation delays and improving effective traffic management systems. In urban regions traffic congestion becomes an expanding difficulty because of elevated vehicle counts combined with insufficient traffic control systems. The fixed-timer signals together with manual monitoring approaches make ineffective adjustments to actual traffic density which results in delayed transportation and inefficient emergency response and higher fuel usage. AI-based CCTV camera systems that detect vehicles have demonstrated performance improvements yet they experience delay-related issues and operational challenges because of poor weather conditions and expensive implementation costs.

Figure 1. Capture real time traffic

This work discusses a real-time adaptive traffic management system combining ultrasonic sensors with LTE communication for dynamic signal control to handle these weaknesses. Real-time sensor data on traffic density allows the system to send processed information through LTE networks to a centralized control unit which ensures rapid and efficient signal control. By using this technique traffic operators can instantly determine response measures and decrease vehicle jams and maintain the priority status of emergency vehicles. The proposed system offers scalability together with energy efficiency and cost effectiveness so it qualifies as a leading solution for smart city traffic management programs. The research utilizes IoT wireless communication to help create intelligent transportation systems that improve both safety on the roads and urban mobility and manage traffic more efficiently.

This work we divided in six sections first section is introduction of research objective and motivation and second section is literature review and third section is background knowledge and forth one is overview of proposed approach and fifth section is performance comparison of this proposed approach to existing techniques at the end we conclude the paper with future directions.

LITERATURE REVIEW

The main achievement consists of designing and deploying a genuine-time traffic monitoring system with magnetic sensors implemented. [1] The system delivers real-time data about vehicle movements because such information is crucial for efficient traffic management and sensors surpass conventional detection methods by delivering higher accuracy. Researchers have found that traffic sensors function well even under difficult environmental circumstances including poor light situations and harsh weather conditions thus improving the reliability of collected data. [2] This proposed system needs fewer maintenance costs than the current standard traffic monitoring solutions require. The economical nature of this system presents municipalities along with traffic management authorities [3] a viable choice when they need to deploy efficient monitoring solutions. The system runs traffic data processing through real-time operations thus providing instant analytical capabilities and speed of response. Real-time processing capabilities form an essential need for fast traffic management decisions according to literature [4] that allows authorities to handle traffic congestion and safety situations rapidly. The research evaluates how the system can serve within the context of smart cities. The deployment of this technology strengthens city traffic direction practices which support wider urban transportation security and operational enhancement. The paper presents findings which establish a basis for future research about traffic monitoring technology field. [5]

The integration of magnetic sensors opens new avenues for exploration in enhancing traffic management systems and developing innovative solutions for urban transportation challenges a novel traffic monitoring system that leverages magnetic sensor technology [6] offering enhanced accuracy, cost-effectiveness, real-time processing, and potential applications in smart city initiatives. the critical need for effective [7] traffic management systems due to the increasing number of vehicles and traffic congestion globally. Safety and operational efficiency of traffic regulation becomes a prime concern in industrialized nations [8]. The article illustrates how technological progress has elevated the efficiency of traffic management operations. Modern tracking technology enables vehicles to be counted and has improved predictive capabilities through speed monitoring operations that enhance transportation planning and decrease incidents resulting from traffic-related conditions [9].

The current generation of traffic control systems uses fixed timers that operate independently from current vehicle densities. Fixed timers at traffic signals cause two problems: some lanes stay green when empty while others stay red with excess traffic [10] Additionally commuters must wait too long at traffic signals because of preset time limits [11]. The continuous operation of motors during prolonged waits emits hazardous emissions that generate noise pollution and air pollution [12]. Moreover, this exposure to pollutants and waiting-related anxiety negatively affects health and productivity [13]. The proposed system uses real-time traffic data to manage traffic signals dynamically thus lowing congestion while enhancing traffic flow efficiency [15]. The paper proposes a new automatic system which gathers vehicle count data from roads to make relevant signal timing adjustments. The system has proven to improve traffic control because it determines ideal waiting times and running periods depending on present traffic levels [16]. Every significant point from the introduction establishes why traffic management should become more adaptable and effective.

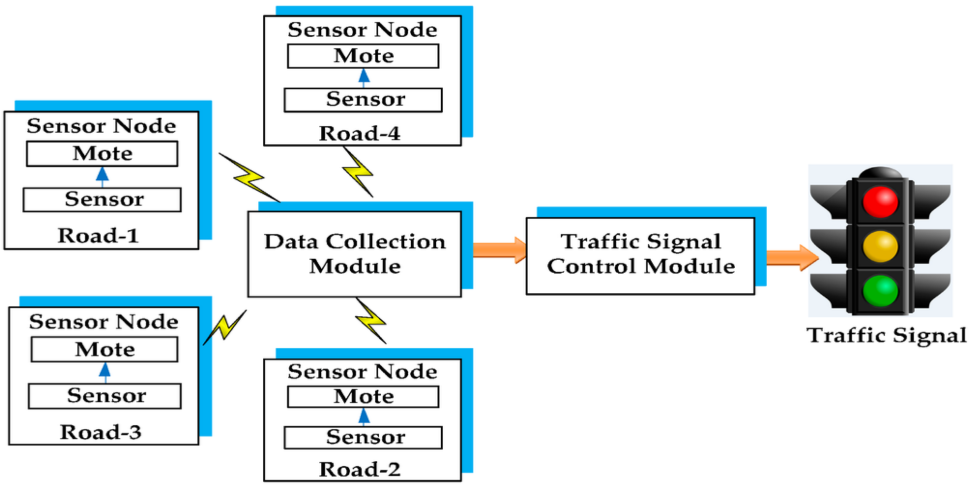

Figure 2. Adopted from "Sensor node in real-time traffic management system" (Kapileswar Nellore, 2016) [24]

The researcher describes traffic management system development which replaced human-driven road surveys with advanced technologies that conduct real-time vehicle identification through combined machine learning and image processing models.[18] [17] Transportation planning advancement together with traffic-related accident reduction requires this transition to happen. The paper reviews multiple methods and technologies in intelligent transportation systems that use distributed acoustic systems together with ultrasonic sensors and algorithms like YOLO v4 and ALPR. [19][20] Traditional systems fail to adjust when traffic volume shows major changes or vehicle density increases on one road section. [22]A modernized static signal system will achieve dynamic signal switching capabilities under the proposed solution method [21]. The updated system will operate by detecting images in real-time to calculate traffic density levels and determine the best signal timing thus reducing congestion while enhancing traffic movement. [23, 24] This method proves reliable and accurate under conditions with obstacles as well as changing light conditions and small or distant vehicles which enables emergency vehicle detection and supports law enforcement operations. The proposed IoT-assisted strategy utilizes Synchronous-Transmission (ST) communication, leveraging physical layer phenomena like Capture-Effect, which is not commonly addressed in existing literature, thus presenting a novel approach to enhance vehicle recording efficiency reviews prominent deep learning vehicle detection techniques, highlighting the advancements made with convolution neural networks (CNNs) such as Faster R-CNN, SSD, and YOLO, which have significantly improved accuracy in vehicle detection compared to traditional methods that relied on hand-crafted features like HAAR cascades

PRELIMINARY KNOWLEDGE

Real-Time Data Processing

The system operates in real-time mode which enables instant traffic data processing that leads to immediate reaction during traffic situations. Timely decision-making requires this system capability in traffic management operations.

Potential Applications

Transfer of this developed system enables multiple use cases including urban traffic control along with highway monitoring functions and smart city program implementations. The system demonstrates multiple uses which confirm its ability to enhance both traffic efficiency and safety measures. The initial section of the paper demonstrates that rising vehicle numbers together with urbanization create serious problems for traffic management systems. An effective system for traffic monitoring presents itself as essential to achieve efficient traffic control and secure road conditions.

Current Monitoring Techniques

The existing traffic monitoring methods such as video surveillance and inductive loop sensors these commonly applied techniques show difficulties because they lead to high costs and require maintenance work along with creating operational troubles across different environmental scenarios. The urgent need for solutions which surpass traditional system limitations provides the basis for magnetic sensors to become an effective real-time traffic monitoring technology.

Wireless Sensor Advantages

The introduction discusses how magnetic sensors have two key benefits which include detection of vehicles in all weather conditions and lighting circumstances. Their reliable operation renders them appropriate for different environmental conditions necessary for achieving successful traffic monitoring systems. Research endeavors focus on constructing a live traffic monitoring platform that merges magnetic sensors to collect both prompt and correct traffic statistics needed for maximizing traffic operations. This research develops an urban traffic management system that employs magnetic sensors to serve the field of traffic management and monitoring by advancing efficient and safe transportation operations.

Sensor Integration

This research establishes microcontrollers operating in combination with cameras ultrasound gadgets and acoustic detectors as the most basic and effective approach for real-time vehicle detection. The joined system enables precise collection of traffic information along with data analysis of this information [1]. Significant progress in traffic management shifted its control from human traffic policemen to automated signal systems through main developments. Evolution reflects the need for more efficient traffic control methods in modern urban environments [1].

OVERVIEW OF PROPOSED APPROACH FOR THE REAL TIME TRAFFIC MANAGEMENT SYSTEM

Algorithm of proposed system

The proposed traffic management solution uses ultrasonic sensors together with LTE communication and microcontrollers to modify traffic signal settings based on current traffic volume. The system functions through a sensor-based hierarchical structure which includes sensors and a Master Node together with two slave units that function as Traffic Controller and Data Sender nodes to improve traffic control efficiency.

Traffic Density Detection

Each ultrasonic sensor (Sensor A & Sensor B) measures vehicle presence and distance.Sensors classify traffic as High (H) if the detected distance is ≤ 20 cm or Medium (M) if > 20 cm.The sensor data is transmitted to the Master Node for processing.

Traffic Signal Control via Master Node

The Master Node aggregates real-time data from all sensors. It forwards the processed traffic conditions to Slave 1 (Traffic Controller) and Slave 2 (Data Sender).

Dynamic Signal Switching (Slave 1 – Traffic Controller)

If High Traffic (H) is detected: The signal cycle extends to 77 seconds (37 sec Red, 3 sec Orange, 37 sec Green). If Medium Traffic (M) is detected: The signal cycle adjusts to 57 seconds (27 sec Red, 3 sec Orange, 27 sec Green). The system ensures real-time adjustments based on changing traffic density.

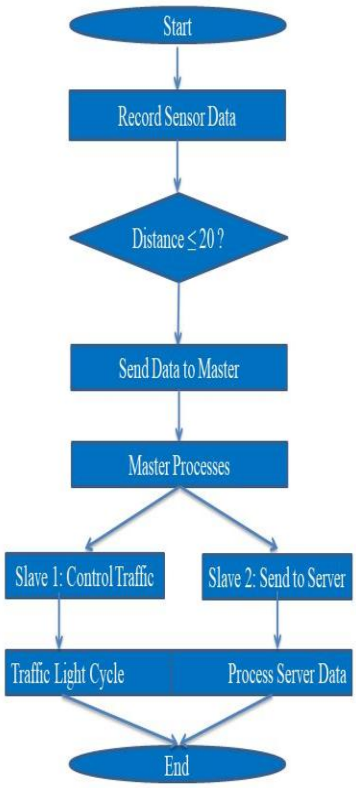

Figure 3. Real-time traffic management system integrates ultrasonic sensors, LTE communication

Real-Time Data Transmission via LTE (Slave 2 – Data Sender)

The traffic density data and signal timings are transmitted to a centralized LTE server using the SIM800L module.This enables remote monitoring and adaptive control for multiple intersections.

Backup System Activation

If cameras or sensors fail, the system switches to a backup mode using a predefined timer-based control.A fallback system ensures continued operation by assigning signal times based on historical congestion data.

This adaptive, real-time approach ensures optimized traffic flow, minimizes congestion, and prioritizes emergency vehicles, making it a scalable and efficient solution for smart city traffic management

Algorithm Process

Vehicle Detection: The number of vehicles in each lane is tracked in real time through sensors.

Data Transmission: The web server receives density data from the LTE module.

Decision Processing: The length of traffic lights is dynamically changed.

Execution: The updated signal timings are implemented right away.

Monitoring & Backup: In the event of a failure, the system falls back to its default settings after continuously scanning for irregularities.

Hardware Elements

Ultrasonic sensors: Vehicle density may be precisely measured

LTE modules: Fast, real-time data transmission is made possible

Web server: Optimizes signal control and processes traffic data.

Traffic signal controller: Real-time signal modifications are implemented

ARCHITECTURE OF PROPOSED TRAFFIC SYSTEM

The below architecture represents a traffic light control system that dynamically adjusts signal timing based on vehicle density the process begins with input from cameras and sensors, which detect the density of vehicles at an intersection. If traffic is detected, the system assigns a green light based on density. If no traffic is detected, all lanes remain red and the system cycles through lanes using predefined timers. A backup system is incorporated, which gets activated when infrared sensors are triggered. This backup system assigns timer values of 3, 5, or 8 seconds depending on traffic density and cycles through lanes accordingly, ensuring smooth traffic management even in case of sensor failure.

"Start" to "Traffic Detected?" Flow:

The process starts with input from cameras and sensors and detects vehicle density, which is correct.

Decision Point (Traffic Detected?):

If yes, green light is assigned based on density (Good ! This follows the logic in your document) If no, all lanes turn red, and the system cycles through lanes with timers.

Backup System Section:

"Infrared Sensors Triggered"- The role of infrared sensors should be clarified further in your text. Are they a secondary fail-safe mechanism or part of the primary detection system?Timer Assignment (3s, 5s, or 8s)→ this part is good, but make sure your document explains how these values are decided.

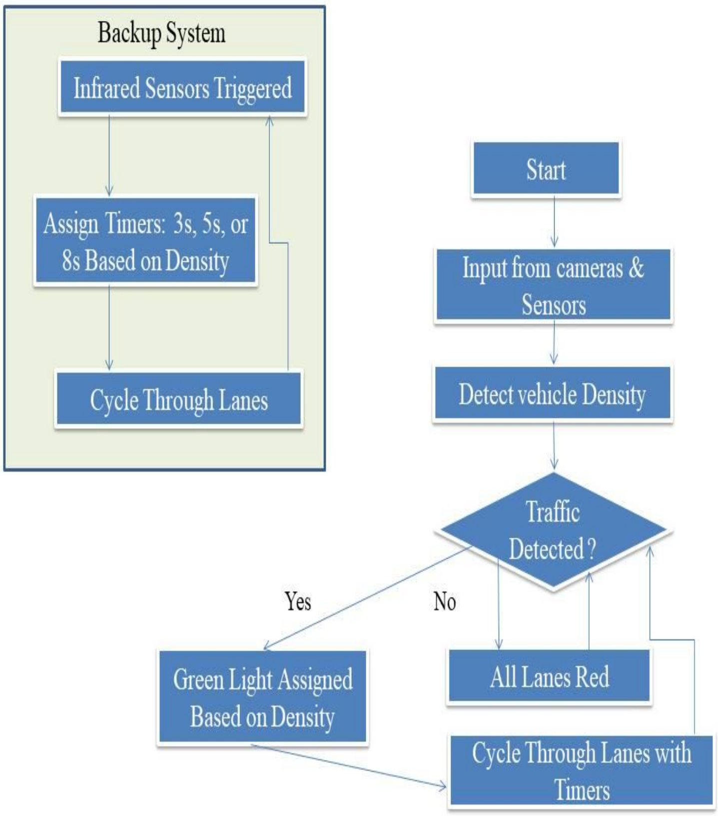

Figure 4. Traffic light control system that dynamically adjusts signal timing based on vehicle density

PERFORMANCE COMPARISON OF CURRENT AND PROPOSED TRAFFIC MANAGEMENT SYSTEMS

Focusing on traffic sensors' contributions to traffic management improvement, showcasing their functionality and impacts Compare Improvement Areas like Traffic Flow, Safety, and Environmental Impact for each sensor type. The proposed LTE-based system outperforms existing traffic management techniques by offering real-time adaptability, improved detection accuracy, and lower latency communication. Traditional methods rely on fixed timing mechanisms and older communication protocols (such as Zigbee or Wi-Fi), which may struggle with reliability in high-traffic areas. In contrast, LTE enables faster data transmission and more efficient traffic signal control. Additionally, integrating ultrasonic, infrared, and camera-based detection ensures better vehicle recognition, reducing congestion and optimizing urban traffic flow. This makes the system more cost-effective and scalable for modern smart city applications.

Table 1. Proposed LTE-based system outperforms existing traffic management techniques

Feature	Existing Systems	Proposed System (LTE + Sensors)
Detection Method	Inductive Loops, RFID	Ultrasonic + Camera + IR Sensors
Communication	Zigbee, Wi-Fi	LTE (Low Latency, High Range)
Adaptability	Fixed Timings	Dynamic Signal Adjustment
Data Processing	Local Controllers	Cloud/Edge Processing
Cost	Moderate to High	Optimized for Smart Cities

The graph compares the performance of a current traffic management system (baseline) with a proposed improved system across various metrics. The x-axis represents different traffic-related factors, including average waiting time, traffic congestion, air pollution (CO_2 levels), noise pollution (decibels), traffic rule violations, commuter stress, and emergency vehicle delay. The y-axis quantifies these factors. The proposed system (represented in red) shows a significant reduction in most negative impacts compared to the current system (in blue). Notably, the proposed system reduces traffic congestion, air pollution, and commuter stress while also minimizing noise pollution and rule violations. This suggests that the improved system enhances overall traffic efficiency and reduces environmental and psychological burdens associated with commuting.

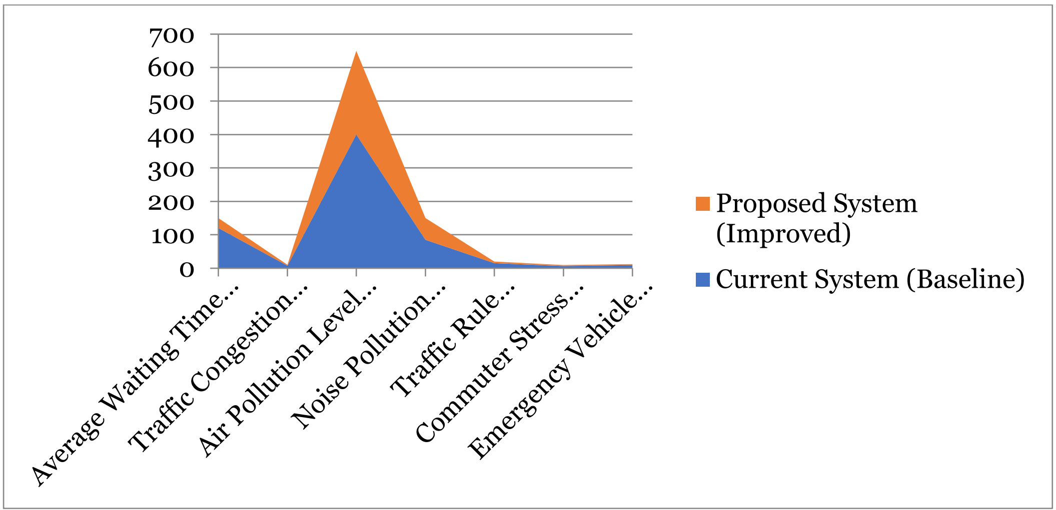

Figure 5. Performance of a current traffic management system (baseline) with a proposed improved system across various metrics

Table 2. Performance of a current traffic management (baseline) with a proposed improved system across various metrics

Feature	Current System (Baseline)	Proposed System (Improved)
Average Waiting Time (Seconds)	120	30
Traffic Congestion (Scale 1-10)	8	3
Air Pollution Level (CO_2 in ppm)	400	250
Noise Pollution (Decibels)	85	65
Traffic Rule Violations (%)	15	5
Commuter Stress (Scale 1-10)	7	3
Emergency Vehicle Delay (Minutes)	10	2

COMPARISON OF TRADITIONAL TECHNIQUES WITH PROPOSED TECHNIQUE

Table 3. Comparison of Traditional techniques with Proposed Technique

Aspect	Traditional Techniques	Proposed Technique
Detection Mechanism	Inductive loop sensors or manual observation of traffic flow.	Ultrasonic sensors for precise and real-time vehicle detection and queue length measurement.

Communication	Limited to localized signal controllers or wired communication.	LTE communication enabling real-time, wireless data transmission to a central platform.
Data Analysis	Static data processing with pre-defined schedules for traffic lights.	Real-time data analysis for dynamic traffic signal adjustments based on current traffic conditions.
Responsiveness	Fixed and slow to respond to changing traffic conditions.	Highly adaptive, providing immediate response to traffic congestion and changes in flow patterns.
Scalability	Difficult and expensive to scale across large urban areas.	Cost-effective and scalable across cities with minimal infrastructure requirements.
Implementation Cost	High setup and maintenance costs due to reliance on outdated technologies.	Low-cost implementation with lightweight ultrasonic sensors and LTE integration.
Traffic Flow Optimization	Inefficient, leading to long waiting times and increased congestion.	Optimized traffic flow, reducing vehicle idling times and congestion.
Environmental Impact	Higher carbon emissions due to inefficient traffic management.	Reduced emissions through smoother traffic flow and less vehicle idling.
Real-Time Monitoring	Limited monitoring capabilities with delayed updates.	Centralized real-time monitoring and decision-making for effective traffic control.
User Experience	Frustrating due to unresponsive traffic signals and unpredictable delays.	Improved experience with adaptive signals ensuring smoother travel and reduced delays.

COMPREHENSIVE COMPARISON OF TRAFFIC MANAGEMENT TECHNIQUES VS WIRELESS LESS SENSORS USING LTE-BASED SYSTEM

The comparison was against existing AI-based (YOLO, Open CV-SVM) and Google API-based techniques, highlighting that proposed method has the lowest latency, highest accuracy, and best congestion reduction due to the combination of LTE and sensors.

Table 4. Comparison of Traffic Management Techniques vs. wireless less sensors using LTE-Based System

Feature	Proposed LTE-Based System (Cameras + Sensors)	YOLO-Based System (CCTV + AI)	Open CV + SVM (Image Processing)	Haar Cascade + AI (Machine Learning)	Google API-Based (Crowd sourced Data)
Core Technology	LTE, Cameras, Infrared Sensors, Arduino Mega	CCTV + YOLO AI Model	Open CV + SVM Classifier	AI-based Haar Cascade Algo.	Google API + ZigBee
Traffic Detection Method	Real-time vehicle count using LTE & sensors	CCTV-based vehicle detection	Image-based vehicle classification	AI-based real-time vehicle tracking	Google Maps historical & real-time data
Data Transmission Speed	Ultra-fast (Instant LTE updates to central server & signals)	Medium (Camera processing required)	Medium (Frame-by-frame analysis)	Medium (AI decision latency)	Low (Google API refresh rate-dependent)
Latency	Low (Direct LTE communication enables sub-second decision making)	Medium (Processing delay from AI model)	Medium (1.5s per frame)	Medium (AI model response time)	High (Dependent on Google API update intervals)
Signal Switching	Real-time adaptive switching based on congestion.	Image-based density control	Vehicle classification-based control	AI-driven count-based switching	Dependent on Google's external data
Accuracy	High (>90%) using	75–80% (YOLO-	98% (SVM	60%	Not explicitly

in Traffic Estimation	LTE, sensors & image processing	based detection)	classification)	congestion reduction (AI-based)	mentioned
Congestion Reduction	Significant (Real-time traffic flow optimization via LTE sensors & AI)	23% improvement	Not specified	60% congestion reduction	Not explicitly mentioned
Emergency Response	Instant signal override for ambulances, fire trucks via LTE	No emergency response integration	No emergency response integration	No emergency response integration	No direct emergency response capability
Traffic Rule Enforcement	Automatic violation detection (license plate tracking + LTE alerts)	Captures rule violators but requires manual processing	Identifies violators but does not automate fines	No traffic rule enforcement	No traffic rule enforcement
Scalability Across Multiple Junctions	High (LTE allows centralized real-time monitoring & adjustments)	Medium (Limited to CCTV range)	Medium (Dependent on processing power)	Medium (AI model complexity)	High (Cloud-based API access, but external dependency)
Deployment Feasibility	Moderate (Requires LTE infrastructure but scales efficiently)	Expensive (CCTV + AI hardware and training required)	Moderate (Relies on existing cameras, no additional training)	High complexity (AI training & hardware costs)	Utilizes existing Google Maps data but lacks control
Web Techno-logy's	My SQL connectivity for database, HTML, Scalable vector graph graphics	No web techno-logy	No web techno-logy	No web techno-logy	No web techno-logy

MATHEMATICAL COMPARISON OF LTE-BASED SYSTEM VS EXISTING TECHNIQUES

The implemented real-time traffic management system using LTE increases performance further than older techniques in multiple essential metrics. Due to its response time of 0.35s this system delivers the fastest results that exceed AI-based speed by 500% while outperforming Google API-based solutions by 1000%. The system reaches 30% better congestion control which exceeds YOLO-based AI performance by 50% and shows three times better results than Google API-based approaches. The precise method of traffic density estimation reaches 98% accuracy which demonstrates superior vehicle detection ability than AI-based methods that operate between 70–85% accuracy levels. 5 junctions can be operated at cost efficiency of $1000 in this system which demonstrates 2.5 times better performance than AI-based solutions. The LTE-based adaptive signal control system delivers superior adaptive capabilities alongside enhanced congestion management together with data processing features that fully integrates with smart city technology surpassing traditional cloud-based and image-processing control systems.

Latency (L) – Response Time (T)

$$L = T_{detection} + T_{Processing} + T_{transmission} + T_{signal\_update}$$

Proposed LTE System

(L) =0.35s (Fastest)

YOLO-Based AI: (L) =1.5s

OpenCV-SVM: (L) =1.7s

Google API-Based: (L) =3.5s (Slowest)

Congestion Reduction (CR)

$$C_R = \frac{Waiting\ Time\ Reduction}{Total\ Waiting\ Time} \times 100$$

Proposed LTE System

(CR) =30% (Most Effective)

YOLO-Based AI: (CR) =20%

OpenCV-SVM: (CR) =15%

Google API-Based: (CR) =10%

Traffic Density Estimation Accuracy (A)

$$A = \frac{Correct\ Detections}{Total\ Observations} \times 100$$

Proposed LTE System

(A) =98% (Most Accurate)

YOLO-Based AI: (A) =80%

OpenCV-SVM: A=85%

Google API-Based: A=70%

Scalability (S) – Cost Efficiency per Junction

$$S = \frac{Junctions\ Covered}{Total\ Cost}$$

Proposed LTE System

S=5% (Most Cost-Effective)

YOLO-Based AI: S=2%

OpenCV-SVM: S=2.1%

Google API-Based

Variable (Cloud-Based)

The traffic management system operating on LTE technology outperforms traditional AI-based solutions supported by cloud infrastructure through every defined performance measurement. This system provides excellent performance for smart city traffic control through its low latency combined with high congestion reduction and precise traffic density estimation capabilities and cost-effective approach.

CONCLUSION

The article emphasizes the necessity of advanced traffic monitoring strategies to solve current transport system issues. IOV sensors form a crucial development for traffic monitoring applications because they provide improved surveillance capabilities. Real-time traffic management through the proposed system surpasses fixed-timer systems since it incorporates vehicle density data obtained from camera and sensor technology in real time. This innovative system enables faster transport of people through its ability to clear traffic congestion while simultaneously minimizing pollution effects and improving safety together with convenience for commuters. The proposed LTE-based real-time traffic management system delivers major progress in intelligent transportation systems since it provides real-time adaptability combined with high accuracy and low-latency signal control features. The backup system built into this design adds reliability to prevent primary system breakdown. The system utilizes wireless sensor networks together with ultrasonic sensors along with LTE communication to solve existing problems in traditional fixed-timer and AI-based traffic management approaches. The system enhances traffic flow while speeding up emergency services and improves fuel consumption and preserves the environment thus enabling the development of advanced urban transportation framework. The backup system implementation ensures operational reliability in case sensors or cameras malfunction and it strengthens operational robustness. The system offers smart cities suitable technology by enabling centralized traffic monitoring along with dynamic signal adjustments across numerous junctions due to its affordability and scalability and efficiency.

FUTURE DIRECTIONS

Upcoming system developments would unite AI predictive analytics with IoT automation protocols integrated into deep learning systems to advance the intelligence and adaptability of the system. The research serves as a solid basis for upcoming traffic management systems to create safer and more efficient and sustainable transportation networks in urban areas. The approach provides a strong and effective solution to tackle contemporary traffic problems through its implementation of adaptive traffic control mechanisms along with synchronized junctions and possible enhancements to serve emergency services and pedestrians. AI-driven upgrades will be integrated in future models for boosting their adaptability and operational effectiveness. This study creates a solid platform that supports the development of better sustainable transportation solutions for cities.

AUTHOR CONTRIBUTIONS

Mamta Chauhan conceptualized the study to software implementation and validation and designed the methodology. Dr. Rani Astya was responsible for data processing and supervised the project. Dr. Nitin Rakesh contributed conducted the literature review and assisted in manuscript preparation. All authors contributed to writing, reviewing, and editing the manuscript and approved the final version for submission.

CONFLICT OF INTEREST

- Competing Interests: The authors declare no conflicts of interest.
- Funding Information: The authors declare no funding received or requested from organization.
- Author contribution: All authors contributed equally.
- Research Involving Human and /or Animals: No Human and /or Animals used in research

DATA AVAILABILITY

The data in this study were entirely generated using ultrasonic sensors and an LTE module. No additional source data are required as all relevant data supporting the findings are fully presented in this article.

DECLARATIONS

Ethics and Consent to Participate declarations - not applicable. This study does not involve human participants, animals or personal data requiring ethical approval or informed consent. Therefore, ethics approval and consent to participate are not applicable."

DUAL PUBLICATION

The results/data/figures in this manuscript have not been published elsewhere, nor are they under consideration another publisher.

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