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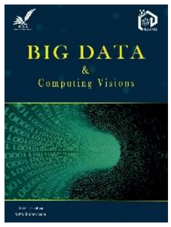

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ITS-Based Wireless Traffic Monitoring Solution

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Abstract

In recent times, we have witnessed an extraordinary surge in technological advancements. The rise in transportation, driven by various factors such as schools, offices, factories, and more, has become increasingly apparent. The extensive use of personal vehicles contributes significantly to the escalation of transportation demands, resulting in pollution and a rapid surge in traffic congestion, especially in urban areas. To curb this issue, it is imperative to implement effective techniques. This paper explores the contemporary approach to traffic monitoring systems and highlights the indispensable role of wireless sensor networks in addressing these challenges.

Keywords: Vehicles, Wireless sensor networks, Traffic bigdata, Traffic monitoring.

1 | Introduction

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In today's modern world, transportation has become a crucial aspect of daily life, especially in densely populated countries like India. However, the rapid increase in the number of vehicles has resulted in a significant rise in traffic congestion and pollution levels [1]. Effectively managing this traffic and reducing pollution has become a challenging task, mainly when relying solely on human intervention to monitor traffic and collect statistics. To overcome these challenges, the implementation of sensor-based systems connected through Wireless Sensor Networks (WSNs) has proven to be highly effective. In this paper, we delve into the various methodologies and techniques employed to measure traffic flow and pollution rates using WSNs. By deploying sensors at strategic locations, such as intersections and highways, we can gather real-time data on traffic patterns, vehicle density, and pollutant levels [2]. These sensors are capable of wirelessly transmitting the collected data to a centralized system for analysis and decision-making.

One of the primary advantages of using WSNs for traffic and pollution monitoring is the ability to capture data continuously and in real time. This provides transportation authorities with up-to-date information to make informed decisions in managing traffic flow and implementing appropriate measures to reduce pollution. Furthermore, the data collected over an extended period enables the

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identification of long-term trends and patterns, facilitating better planning and resource allocation. The implementation of WSNs also allows for efficient data gathering and utilization. By leveraging the power of wireless communication, the collected data can be transmitted effortlessly to a central control center, eliminating the need for manual data collection and reducing human error. The centralized system can then process and analyze the data to generate valuable insights, such as identifying traffic bottlenecks, optimizing signal timings, and implementing traffic diversion strategies to alleviate congestion and reduce pollution levels.

Additionally, WSNs enable scalability and flexibility in the deployment of sensors. As traffic patterns change or new areas require monitoring, additional sensors can be easily added or repositioned to ensure optimal coverage. This adaptability ensures that the system can effectively handle dynamic traffic conditions and cater to the evolving needs of transportation management. In conclusion, the utilization of WSNs in traffic and pollution monitoring systems offers a promising solution to tackle the challenges posed by increasing traffic and pollution levels. By employing sensors connected through wireless communication, transportation authorities can gather real-time data, make data-driven decisions, and implement targeted strategies to manage traffic flow and reduce pollution effectively.

2 | Basic Concepts

In recent years, there has been extensive research on the application of WSN technologies in the field of Intelligent Transportation Systems (ITS), aiming to address the critical need for real-time and accurate traffic parameter monitoring [3]. WSNs have emerged as a promising solution due to their inherent advantages, including flexibility, scalability, and lower installation and maintenance costs compared to traditional surveillance systems. Various studies have focused on the effective acquisition of traffic information using WSNs, employing strategically placed sensor nodes to collect data on traffic flow, vehicle density, and other relevant parameters. However, it is essential to note that these studies have primarily concentrated on specific aspects of traffic monitoring, such as traffic flow analysis or congestion detection, without proposing a comprehensive system that can simultaneously monitor and manage traffic conditions [4].

To achieve a more holistic approach to traffic monitoring and management, it is necessary to develop a comprehensive system that addresses multiple aspects of traffic control, including data acquisition, analysis, and decision-making. While existing studies have made significant contributions in terms of data acquisition using WSNs, their focus has been primarily on collecting traffic-related information. However, effective traffic management requires not only the acquisition of accurate and real-time data but also the ability to analyze and interpret this data to make informed decisions.

3 | Proposed Work

Building upon the existing research, our proposed work seeks to overcome the limitations observed in previous studies and develop a comprehensive traffic monitoring and management system. While traffic sensors have been utilized in the past, they often require frequent battery replacements or recharging, leading to operational disruptions [5]. To address this challenge, we propose the integration of solar panels as a reliable and sustainable power source for the sensor nodes. By harnessing the energy of the sun, these sensors can operate continuously without the need for manual intervention, ensuring seamless data collection and monitoring [6]. In addition to traffic monitoring, our system incorporates the use of MQ-135 air quality gas sensors to assess pollution levels at different traffic signals. This enables us to identify areas with higher pollution concentrations and take necessary measures to mitigate the impact on public health and the environment. Furthermore, we propose the installation of actuators equipped with chemicals capable of absorbing carbon from the air, thus contributing to pollution reduction efforts [7].

To effectively utilize the data collected from the sensor nodes, we analyze and classify the city into zones based on air quality. This information is then presented to the government to facilitate the implementation of traffic prevention policies, such as congestion pricing or alternate transportation incentives [7]. To enhance the efficiency of data collection and ensure the functionality of the system, we introduce the concept of a mobile sink node. This sink node can move around the city, collecting data from sensor nodes and periodically checking the status and performance of the filtration systems, thereby ensuring accurate and reliable data collection [8]. By integrating solar-powered sensor nodes, air quality monitoring, and the implementation of a mobile sink node, our proposed system aims to provide a comprehensive solution for traffic monitoring and management. With the ability to continuously monitor traffic conditions, identify pollution hotspots, and actively implement measures to reduce pollution and improve traffic flow, our system has the potential to enhance transportation systems' efficiency and sustainability significantly.

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3.1 | Traffic Management

The proposed system comprises two subsystems aimed at efficient traffic management:

3.1.1 | Data acquisition subsystem

The primary component of this subsystem is the WSN technology. Sensor nodes installed at road intersections are responsible for collecting and transmitting real-time traffic data, including:

- *Vehicle speed.*
- *Vehicle count.*
- *Vehicle classification.*
- *Environmental data.*
- *Occupancy.*
- *Vehicle re-identification.*

In addition to traffic data, the nodes must be capable of re-identifying vehicles to create an original destination traffic map. To ensure reliable and fail-safe communication within the subsystem, it is essential to maintain a high level of Quality of Service (QoS) [9]. For our deployment, we will utilize the IEEE 802.15.4 standard, adapted by the ZigBee Alliance, as it offers advantages such as low cost, low power consumption, and simplicity. Other wireless technologies like Bluetooth or Wi-Fi, while providing high data rates, are disadvantaged by their higher power consumption, application complexity, and cost [10].

3.1.2 | Control and data analysis subsystem

The Control Station (CS), also known as the control center, plays a crucial role in this subsystem. It collects and processes the data received from the sensor nodes and takes appropriate actions to address or prevent traffic-related issues. The CS fulfills three main functions: collecting, compiling, and storing the environmental and relevant traffic data in a database accessible for further study and review purposes [11].

4 | Applications

The utilization of WSN for traffic surveillance offers several advantages over other sensor technologies, contributing to its widespread adoption. These advantages include:

Cost-effectiveness: a cost comparison between different surveillance technologies, considering device cost, installation, and maintenance expenses, demonstrates that WSNs are approximately half the cost of inductive loops. Furthermore, it is expected that the cost of WSNs will continue to decline rapidly with increasing volume [12].

High accuracy: wireless sensors have been proven to provide accurate vehicle count and speed measurements, comparable to the accuracy of inductive loops. Additionally, by employing a collaborative approach within the WSN, detection accuracy and reliability can be significantly improved. Studies have also shown that wireless sensors can achieve acceptable accuracy in vehicle classification [13].

Maintenance ease: wireless sensor nodes are equipped with intelligence that enables automatic diagnosis, simplifying maintenance procedures by promptly resolving any issues that may arise [14].

Flexibility: one of the significant advantages of wireless sensors is their easy deployment and removal in proximity to roads, making them suitable for both permanent and temporary traffic measurements. Wireless sensor configurations can be customized to adapt to different purposes, and environmental sensing can be combined with traffic surveillance [15].

Wireless communication: wireless communication capability is essential for road-to-vehicle communication. With the emergence of smart vehicles, the origin-destination matrix can be generated without relying solely on surveys. The communication logs between the sensing nodes and vehicles during their trips can be utilized to generate this matrix [15].

Object detection techniques, combined with machine learning, have gained significant prominence across various applications, from smart doorbells to military-level smart objects capable of detecting suspicious unidentified objects. This technique, along with machine learning, enhances the capabilities of traffic surveillance systems [11]:

- *Motion detection: this involves detecting moving objects or vehicles using a digital camera.*
- *Object detection: various algorithms are employed to detect and mark objects.*
- *Motion estimation: determining the motion vector of the moving objects.*
- *Object identification: identifying the type of vehicle to understand the pollution constraints associated with that particular model.*

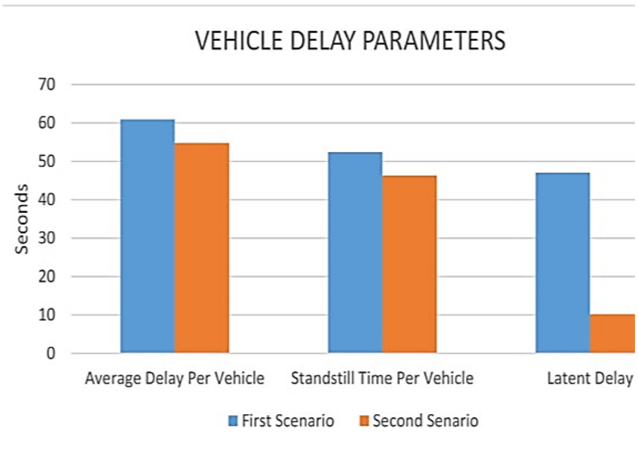

Fig. 1. Vehicle delay parameters in the network.

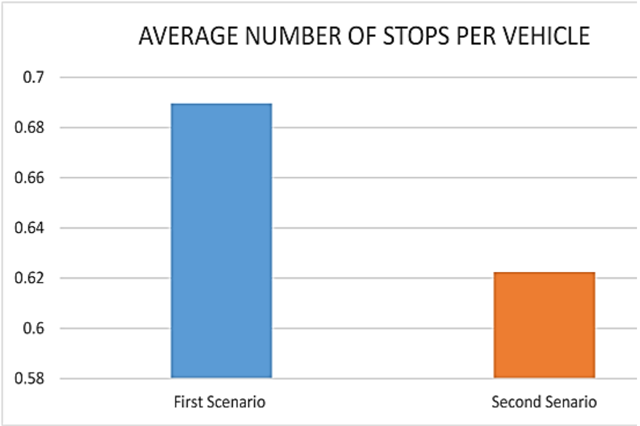

Fig. 2. Average no of spots per vehicle.

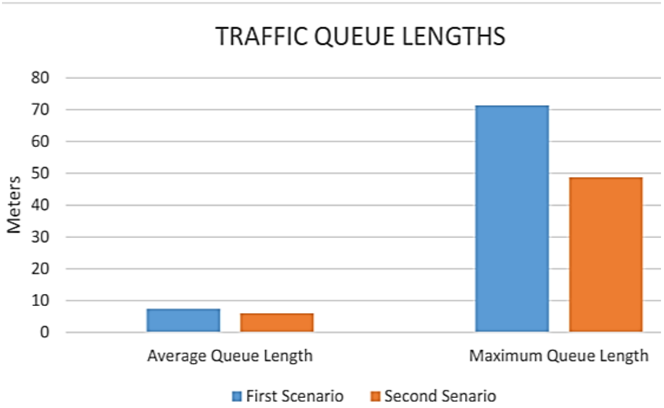

Fig. 3. Average and maximum vehicle queue length measured.

Advantages:

- *Facilitates real-time traffic monitoring and updates on the current situation.*
- *Enables the detection of highly polluted areas and facilitates their filtration.*
- *Allows for the division of areas into zones based on pollution levels.*
- *The MQ-135 gas sensor enables real-time detection of carbon levels in the air.*
- *Utilizes rechargeable batteries that can be charged using sunlight.*

Disadvantages:

- *Object detection during nighttime poses challenges.*
- *Pollution cleaners or air purifiers require regular maintenance and replacement.*
- *The sink node must move to all traffic points to gather data; otherwise, data collection is not possible.*
- *Traffic patterns are not consistent and change daily, making the division of zones difficult.*
- *Storing a large amount of sensor data and analyzing it to extract meaningful information can be time-consuming and computationally intensive.*

5 | Conclusion

This paper provides a comprehensive overview of a WSN-based traffic monitoring system and emphasizes its notable advantages in enhancing the performance of ITS. In contrast to conventional wired monitoring systems, WSN offers superior suitability for scenarios necessitating dense deployment and adaptability to dynamic road conditions. The wireless approach greatly enhances the flexibility and

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responsiveness of the monitoring network, rendering it an ideal technology for safety applications that are progressively crucial in the realm of ITS.

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