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A study on intelligent traffic management using IoT for urban congestion control

Channappa A *

Department of Computer Science Engineering, Government Polytechnic, Kudligi, Karnataka, India.

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Abstract

Intelligent Traffic Management Systems (ITMS) play a vital role in enhancing the efficiency, safety, and sustainability of urban transportation networks. The research explores the integration of artificial intelligence, IoT, and data analytics in traffic management, highlighting their impact on congestion reduction, accident prevention, and environmental sustainability. Additionally, it discusses the future directions and potential avenues for further research in this domain.A smart city must have an intelligence-based traffic management system for the movement of vehicles. Traffic jams and vehicle parking problems are the most dominant problems that arise with increasing vehicles. The development of cities into better and smarter cities is through effective management and better traffic planning. Developing countries adopt better technologies, like smart traffic management systems, to cope with traffic-related problems and efficiently handle the same. One effective solution to the traffic-related problems is the green corridor passage for emergency vehicles. However, the usual traffic is hampered when a green corridor is a setup. Detection of traffic congestion and managing the real-time traffic flow is the most challenging task because it needs integration of real-time traffic-related data with the traffic control system. Only when this is achieved, one can think of finding a solution for the clearance of any emergency vehicle.

Keywords: Intelligent Traffic Management Systems; Traffic planning; Congestion reduction; Real-time traffic-related; urban transportation networks

1. Introduction

In the rapid development of the urban area, the volume of vehicles has greatly increased which creating issues such as trafficcongestion, economic losses, environmental pollution and excessive fuel waste. Intelligent Transportation Systems (ITS) is an interdisciplinary field that uses data analytics from different mathematical models, and is also seen as an important technology to alleviate congestion in urban traffic. Better estimates of dynamic travel demand together with improved sensor data also makes it possible to calibrate and estimate boundary conditions to more advanced traffic models in real-time.Accurate traffic forecasting and traffic light regulation are important steps in the development of an ITS and are essential for transport system efficiency. Traffic lights at multi-way junctions in most medium-sized cities function by allowing entry into the junction using predetermined timing, giving each entry the same duration of time allowed based on historic data but not taking account of the prevailing situation. There is a need for an efficient traffic management system to forecast and control traffic flows in urban areas. Prediction of traffic helps to avoid traffic before there is congestion. Typically, the urban traffic forecast uses historical and current traffic flow data to predict future moments of road conditions. The overall cost of traffic is calculated in various ways, including but not limited to, assessing outlay needed to reduce traffic volumes to optimal road capacity. Consider that in the morning, heavier traffic is flowing towards the city with less flowing in the opposing direction.With the development of technology mobile phones, sensors are widely used to analyze the traffic condition. Big data analytics plays an essential role in the intelligent traffic management system reach. Data Analytics helps us to predict Traffic before congestion and the occurrence of traffic can be avoided[1].

* Corresponding author: Channappa A

2. Literature Review

Sadhukhan, Pampa [2]Traffic congestion is one of the major issues with the public transportation system in recent time. The traffic congestion has a negative impact on the productivity, competitiveness and economic growth of a country. Hence traffic congestion control has become an important area of research and significant number of solutions to this problem came out of various research efforts in the said field over the past few decades. Among these, vehicle-to-vehicle (V2V) communication-based approaches cannot accurately estimate the density of traffic congestion. On the other hand, the traffic signalling systems having predetermined fixed operation time cannot manage the traffic volume changing over time and thus, long traffic queues are generated at the road crossings[3].

Sabeen Javaid et al [4] Traffic management system is considered as one of the major dimensions of a smart city. With the rapid growth of population and urban mobility in metropolitan cities, traffic congestion is often seen on roads. To tackle various issues for managing traffic on roads and to help authorities in proper planning, a smart traffic management system using the Internet of Things (IoT) is proposed in this paper. A hybrid approach (combination of centralized and decentralized) is used to optimize traffic flow on roads and an algorithm is devised to manage various traffic situations efficiently. For this purpose, the system takes traffic density as input from a) cameras b) and sensors, then manages traffic signals. Another algorithm based on Artificial Intelligence is used to predict the traffic density for future to minimize the traffic congestion.

Mahesh Lakshminarasimhan [5] In the contemporary world, urban mobility is one of the unprecedented challenges to be tackled in the administration of a big city. This paper analyses the ever-growing urban population around the globe and discusses about the traffic systems in densely populated cities like Los Angeles and Amsterdam. Further, an advanced traffic management system is proposed, implemented using Internet of Things (IoT). The system is supported by a circuit embedded in the vehicle, which operates using RFID with clustered systems. The functionalities of the system include efficient traffic light control, parking space identification and anti-theft security mechanism.

Ninad Lanke, Sheetal Koul [6] Traffic congestion is a major problem in many cities of India along with other countries. Failure of signals, poor law enforcement and bad traffic management has lead to traffic congestion. One of the major problems with Indian cities is that the existing infrastructure cannot be expanded more, and thus the only option available is better management of the traffic. Traffic congestion has a negative impact on economy, the environment and the overall quality of life. Hence it is high time to effectively manage the traffic congestion problem. There are various methods available for traffic management such as video data analysis, infrared sensors, inductive loop detection, wireless sensor network, etc. All these methods are effective methods of smart traffic management. But the problem with these systems is that the installation time, the cost incurred for the installation and maintenance of the system is very high.

3. IoT Architecture for smart traffic system

By executing this architecture planning the congestion level in traffic will reduce and helps in traffic free roadways in urban area. After implementing smart traffic, the result of traffic congestion level will be automatically reduced because the level of accuracy input helps to identify and detect the vehicle in perception layer. After transmitting the data into cloud and analyse through prediction algorithm in middleware layer then final result output will display in application layer. Smart traffic congestion control model working with four layers. First layer is Perception Layer second layer is Transmission Layer, next is Middleware Layer and final stage is Application Layer. Perception layer gathers the sensor input from the environment or physical object, using sensors and react based signal received from upper layer through actuator. It is also called as data gathering layer and physical components are managed by this layer. In transmission layer communication technologies used to collect data from end devices and pass it to access point and gateway nodes, includes Bluetooth, WIFI or Zigbee. Main role of this layer is to transmit the information from one place to other. Storing data in cloud linked model from middleware Layer, mediate between cloud storage and network devices like gateways. Their roles are pre-processing the data for removal of redundant information, store the data in cloud Database and its processing. Prediction algorithms are used to make decisions on data set received from environment. Data mining process perform under algorithmic calculation such as Time Series decision making as like prediction.

3.1. Towards Intelligent Traffic Flow Prediction

Road Traffic Congestion is a persistent problem worldwide. With huge growth of population, number of vehicles is increasing at a larger rate. India is the second largest country in terms of growth in population and economy. Most of the cities in India are facing road congestion problems. There are practical difficulties in maintaining Intelligent Transport Management Systems (ITMS) in developed countries towards metropolitan cities in India. This is due to slow

growth in infrastructure compared to the rapid increase in the number of vehicles, space and cost constraints. The Traffic flow information is needed for travellers to help them to make better travel decisions on congestions and to improve traffic operation efficiency. Predicting short-term traffic flow will be more helpful in managing freeway networks. This traffic flow prediction makes use of real-time data in predicting the traffic status in the subsequent five to twenty minutes. All countries in the world are trying to improve their traffic management system to be more efficient. Researchers have used different methods to predict freeway traffic in urban areas[7].

3.2. Real-time traffic updates

Real-time traffic monitoring systems play a key role in the transition toward smart cities. A considerable amount of literature has been published on intelligent traffic management systems based on the IoT paradigm. Autonomous traffic sensing is at the heart of smart city infrastructures, wherein smart wireless sensors are used to measure traffic flow, predict congestion, and adaptively control traffic routes. Doing so effectively provides an awareness that enables more efficient use of resources and infrastructure. Identifying and measuring congestion is the very first step in the traffic management process. The flow, occupancy, density is the widely used traffic congestion measures, which are mostly obtained from images or videos captured by vision systems initially. Based on these measures, the traffic warning messages are broadcasted through smartphones, radio, televisions, light signals, dynamic variable message signs, or display units. Among them, the mobile-based web applications received much attention among researchers. Most of the recent developments in delivering real-time traffic updates used the congestion estimates to dynamically control the traffic signal.

3.3. Existing Intelligent Traffic Management System

The existing Intelligent Traffic Management System represents a significant advancement in urban infrastructure technology. It integrates various smart technologies and data driven approaches to optimize traffic flow, enhance safety, and improve the overall efficiency of urban mobility. Unlike traditional traffic management systems, the existing ITMS leverages real-time data analytics, predictive modelling, and adaptive control mechanisms to dynamically adjust traffic signals, manage lane configurations, and provide commuters with up-to-date traffic information. By harnessing the power of artificial intelligence, internet of things devices, and connected vehicle technology, the existing ITMS offers a more proactive and responsive approach to managing traffic, ultimately leading to reduced congestion, shorter travel times, and a better commuting experience for city residents

- Technological Integration:
    - The existing intelligent traffic management system integrates various advanced technologies such as Artificial Intelligence (AI), Internet of Things (IoT), and data analytics.
    - AI algorithms analyze real-time traffic data to optimize traffic flow, predict congestion, and dynamically adjust traffic signals.
- Live Monitoring and Control:
    - Traffic cameras, sensors, and other IoT devices are deployed across road networks to collect real-time data on traffic conditions, vehicle speeds, and congestion levels.
    - This data is continuously monitored and analyzed to provide traffic managers with insights and control over traffic flow.
- Adaptive Traffic Control:
    - The intelligent traffic management system utilizes adaptive traffic control strategies to dynamically adjust traffic signals based on current traffic conditions.
    - This adaptability allows for optimized traffic flow and reduced congestion, especially during peak hours or unexpected events.
- Improved Commuter Experience:
    - Commuters benefit from real-time traffic updates, alternative route suggestions, and personalized travel recommendations through mobile applications and digital platforms.
    - Access to timely and accurate information enhances the overall commuting experience and reduces travel times.

- Improvement of Safety and Sustainability:
    - Integration with advanced technologies such as autonomous vehicle systems and connected infrastructure improves road safety by reducing the risk of accidents and minimizing human error.
    - By optimizing traffic flow and reducing congestion, the intelligent traffic management system contributes to environmental sustainability by reducing fuel consumption and greenhouse gas emissions.

4. Methodology

Descriptive research was implemented in which observations were recorded and later analyzed. There is no known literature regarding some of the subjects of interest in this study. No literature was found that discussed congestion and its impact on the city and its citizens. The sample size needed to be large in order to reduce the sampling error but remain manageable. This method of data collection was selected because it permits the solicitation of a large number of opinions. In this study the population was all road users whose total number is unknown and assumed to be large. As a result, a sample was used to gather data, a sample being a smaller but representative subset of a population. Possible responses from questionnaires were coded using SPSS. Descriptive functions were also run on the data, the results of which were graphs and charts that showed frequencies given variables had assumed. The applications also capture the time each car 'passed', thus facilitating easier analysis. To validate the questionnaires, a pilot study was run and collected data was used to ascertain if questions were clear and would be helpful in meeting objectives. Analysis is the activity of examining presented data with the goal of gaining a deeper understanding. In addition, no current data was found that discussed vehicular traffic in the city. A population is a collection of all entities involved in a study on which a researcher wants to generalize findings. The populations as well as sampling techniques that were used during data collection were also discussed.

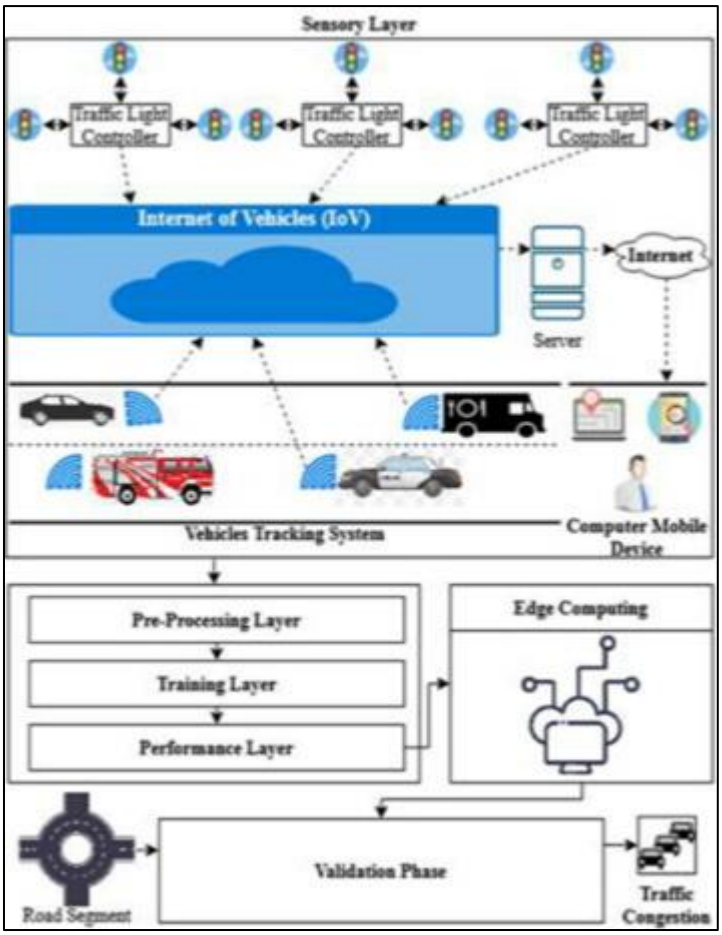

Figure 1 Intelligent traffic management using IoT for urban congestion control

5. Results and Discussions

The number of cars was counted using TallyTimed Counter and the results exported to a spreadsheet, the resulting graph is presented in graph 1. The graph shows the average number of cars that were observed per day for 30 days

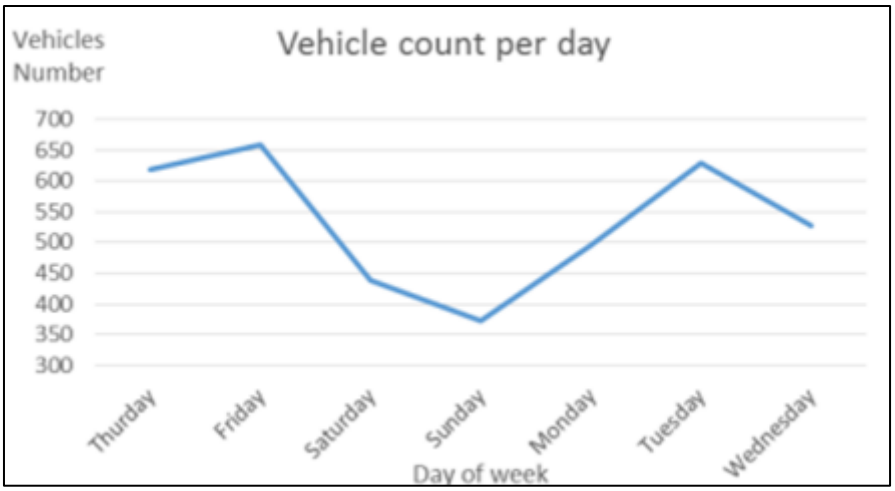

Figure 2 Count of cars per day

The total number of cars was recorded to be higher on Fridays and lower on Sundays compared to other days. In contrast, graph 2 shows the number of vehicles recorded against time.

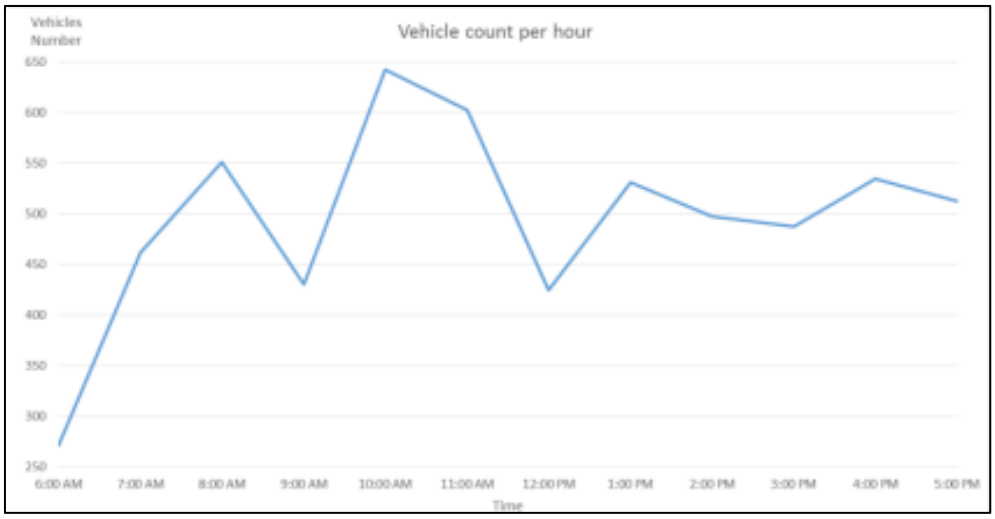

Figure 3 Count of cars per hour

The graph shows that concentration of the gas was at it maximum in the evening. The gas was at its minimum in the morning hours and steadily increased from then on.

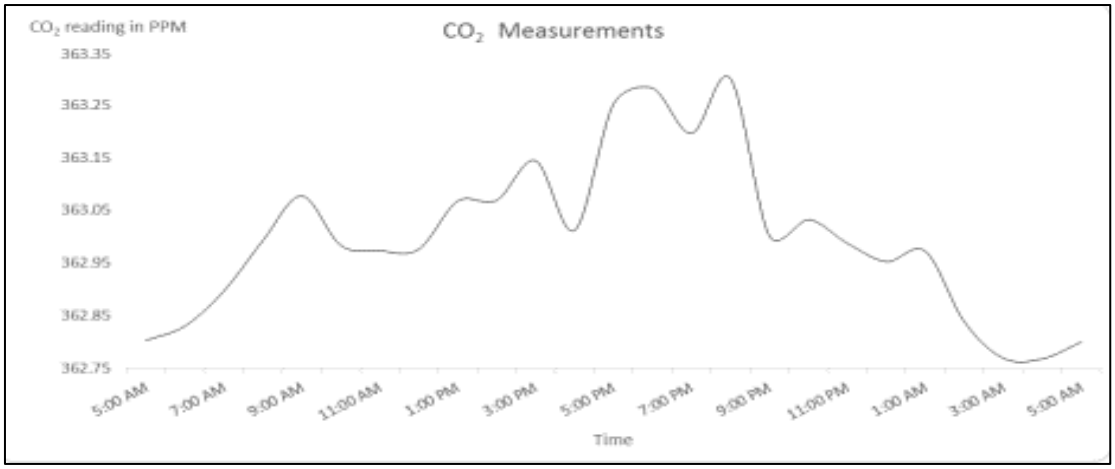

Figure 4 Carbon dioxide measuring

The results of the car counting experiment and CO_2 monitoring were combined to establish whether there was any relationship.

Table 1 Correlation of CO_2 and count of cars

Correlations	**Carbon Dioxide**	**Vehicle Count**
Carbon Dioxide	Pearson Correlation	1
	Sig. (1-tailed)	
	N	12
Vehicle Count	Pearson Correlation	0.286
	Sig. (1-tailed)	0.183
	N	12

These results are presented in Table 1: the correlation between the two parameters was found to be 0,286, which is very low but positive; a higher correlation had been expected.

6. Conclusion

Traffic congestion is a significant problem, especially in growing nations; to encounter this, many models of traffic system were proposed. Traffic management is one of the prominent areas where the IoT application is used. Due to the lack of proper and smart traffic management, developing countries face various traffic issues. The situation is even worse in densely populated poorer nations. Developing countries adopt better technologies, like smart traffic management systems, to cope with traffic related problems and efficiently handle the same. One effective solution to the traffic-related problems is the green corridor passage for emergency vehicles. For a smart transportation system, a new framework is traffic prediction is recommended to avoid congestion. The parameters of interest are the number of cars and the speeds at which the cars are travelling. The system is able to relay traffic information to motorists on multiple platforms. An intelligent traffic light control system is deployed to prevent traffic congestion before it occurs and based on an alert signal traffic route will be deviated. This can help travellers to have free-flow traffic. This system proposes to predict traffic congestion based on the arrival time of vehicles, thereby helping to reduce traffic congestion before occurrence. By diverting the vehicles through another route, traffic can be reduced. It involves the smart building of the intelligent transport system with the ability to tackle real-time issues. To minimize the traffic problems typically faced by ambulance, an intelligent transport system is proposed.

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