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# Smart road traffic control system for traffic overcrowding

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## ABSTRACT

An Intelligent Transportation System (ITS) is an advanced application which, without embodying intelligence as such, aims to provide innovative services relating to different modes of transport and traffic management and enable users to be better informed and make safer, more coordinated, and 'smarter' use of transport networks. Although ITS may refer to all modes of transport, ITS as systems in which information and communication technologies are applied in the field of road transport, including infrastructure, vehicles, and users, and in traffic management and mobility management, as well as for interfaces with other modes of transport. [1] ITS may improve the efficiency of transport in a number of situations, i.e. road transport, traffic management, mobility, etc.

***Keywords***— *Intelligent transportation systems, Sensing, Wireless technologies, Traffic control*

## 1. INTRODUCTION

The transportation system is important in everyone's life. Traffic congestion is a major issue in our daily life. There are several reasons for the sudden surge in the traffic, in many regions. The main reason can be defined as, to increase in the population which in turn has caused a rise in the number of vehicles on the road. Also, there are several other issues for traffic congestion like insufficient infrastructure, ineffective management of capacity (i.e. poor traffic timing), work zone, special events, emergencies, unconstraint demands etc. In the past few years, development in wireless communication technologies and the development of vehicular network standards tiled the way for the implementation of ITS. ITS is defined as the application of advanced sensors, computer, electronics and telecommunication technologies and management strategies in an integrated way to improve the safety and efficiency of the transportation system [1]. The major goal of ITS is to evaluate, develop, analyze and integrate the sensors, information communications technologies, and concept to make efficient traffic flow to improve environmental quality, save energy, conserve time such that enhance the comfort of drivers, pedestrian, and other traffic groups[2].

We can say that the purpose of ITS is to take advantage of the appropriate technologies to create "more intelligent" roads, vehicles and users. Several ITS technologies were developed and started to use in the 80s in many countries. Zero-Sum Ltd. Japanese firm who expertise in ITS along with Ahmadabad Municipal Corporation launched its pilot project on real-time traffic information in the city of Ahmadabad. This was the first ITS Solution with the integrated commercial system in India. One of the big milestones for ITS measure was carried out during "2010 Asian Games" at China for parallel traffic control and management [3].

An ITS application must detect, control and reduce congestion based on online data that describes traffic patterns such as, density, speed, travel time, the geographic position of vehicles and the current time. To accomplish this goal, however, the main challenge is how to forecast congestion and re-route vehicles appropriately by considering the time impact on future traffic in an area of interest [4]. Inadequate capacity or density and unrestrained demand are interconnected but signal delays are hard coded and do not depend on the amount of traffic density. Therefore there is a need to optimize the traffic control system and make it more dynamic so as to accommodate the varying traffic density. This paper provides reviews of the various techniques are proposed by different authors to automate and optimize the traffic signal for traffic flow. The paper is organized into many sections, in which section II will give the historical perspective and an overview of the state of the art on worldwide ITS. Section III highlights a comparative study of all the existing methods used with advantages and disadvantages. Section IV describes the challenges and issues of worldwide and Indian ITS. Finally, section V concludes the study and some future work.

## 2. ITS BACKGROUND


**Fig. 1: Architecture / Overview Structure of ITS**

 

Intelligent Transportation Systems is a global trend, attracting worldwide interest from transportation professionals, automotive industry, and political decision makers. ITS is related to advanced communication, information, and electronics technology to solve transportation problems such as traffic congestion, safety, transport efficiency and environmental conservation. As per the figure, 1 component of ITS can be defined as:

**(a) Automated Data Collection:** It needs extensive and precise strategic planning through hardware and competent software. Automatic vehicle identification, GPS based vehicle locator, cameras, sensors etc. are some of the hardware used for data collection. With this large amount of data the analysis can be done like traffic count, surveillance, travel speed, time, location, delay etc.

**(b) Data Transmission:** It is a key aspect of rapid and real-time information communication in ITS implementation. Information can be communicated by a traffic-related announcement to the traveler through SMS, internet, on-board units of vehicles etc.

**(c) Data Analysis:** It contains adaptive logical analysis, error rectification, data cleaning, and data syntheses. The processed data analyzed further to forecast traffic scenario. Real-time information like travel time, delay, accidents on roads, change in route, work zone, diversions etc. is the gain after data analysis [4].

**(d)** With respective above points ITS covers and improves almost all the aspects of transportation engineering. There are many auxiliaries of the ITS out of which most significant and extensively used all over the world to solve the traffic and transportation problem are as follows:


**Fig. 2: Subsidiaries of ITS**

**(e) Advanced Traveler Information System (ATIS):** It implements a broad range of technologies, such as internet, telephones, cellular phones, television, radio, etc. to help travelers and drivers in making informed decisions regarding trip departures, optimum routes, and available modes of travel.

**(f) Advanced Traffic Management System (ATMS):** It is used by the traffic police department and traffic regulation authorities as a tool to manage and control traffic by monitoring the flow of traffic and making appropriate decisions in a timely manner. Traffic management systems optimize the movement of vehicles, by using real-time information to interfere with and adjust controls such as traffic signals to improve traffic flow.

**(g) Advanced Public Transportation System (APTS):** It is concerned with increasing operational efficiency of all public transportation modes and increasing condition by making the transportation system more reliable. With the help of APTS, the way public transportation systems functioning is transformed and the nature of the transportation services that can be offered by public transportation systems are changed.

**(h) Emergency Management System (EMS):** It is the newest research field in the intelligent transportation system. EMS is mainly concerned with the application of different intelligent transportation system technologies to develop a transport system which can provide help in the emergency conditions [5].

The architecture and different developed models over the years of four major branches of ITS have been considered by researchers in their studies using Vehicle to Infrastructure (V2I) or Vehicle to Vehicle (V2V) communications, for ease of life quality in metropolitan, urban areas complex management strategies with network-wide traffic control needed. As determined the goal of efficient traffic control using design process and investigation of algorithm and infrastructure with proper traffic planner is done in [10] [57].

### 2.1 Worldwide ITS

Now a day's many countries have accepted applications of this ITS not only for traffic congestion control but for road safety and proper utilization of infrastructure too. Many organizations are coming with multiple solutions related to the ITS issues. Because of ITS has become a multidisciplinary conjunctive field of work, between public, private and academic sectors.

In the U.S., the Department of intelligent transportation system focuses on automation, connected vehicles, emerging capabilities, enterprise data, interoperability and accelerating deployment [18].

European ITS has taken a major step towards deployment and use of road transport since 2008. Other public-private partnership programs aim at safety applications of ITS like connected automated driving, deployment, and use of intelligent safety [43].

United Kingdom has done some remarkable executions of ITS as follows-electronic toll collection, cameras are installed to observe the traffic activities etc. Intelligent speed adaption is also implemented using GPS [48].

ITS features in Dubai are traffic jam alerts, parking, parking guidance, dynamic onboard navigation system for car users [53].

Canada is the first country that introduced ITS. ITS has a traveler information system, public transport services consisting of transit, management, real-time passenger information etc [49].

A few cities in India have implemented ITS projects such as automatic parking, highway toll collection, traffic signal management, and public transportation management. Chennai city authorities have initiated traffic management by installing surveillance cameras at intersections and supervise the traffic flow. Being a part of the project FM radio station played a very good role in transmitting traffic jam in Chennai. With the help of radar, accelerometer gun and smart cameras traffic control, as well as vehicle number detection, is implemented in Mumbai. A pilot project was implemented in Hyderabad and Delhi by initiating SMS based system for road users and BRT

 

system implementation in Pune [50]. Also, because of inefficient management of traffic and increasing vehicle count creating inconsistencies reported [52].

## 3. STUDY OF EXISTING METHODS

The papers reviewed based on the following points:

- Approaches used to make traffic routing and a signal controlling decisions, i.e. adaptive (learning) versus non-adaptive, simulation versus real-time and hybrid strategies.
- Types of parameters (input and output) such as traffic quantity, waiting time, previous and current traffic data information/knowledge to make traffic routing.
- Traffic data collection methods used and communication methods applied/considered.
- Smart Traffic Control (STC) at a single intersection or multiple intersections or both.
- The way of improvement in the performance of traffic control to avoid congestion.

### 3.1 Video analytics deployed in traffic domain for traffic congestion control

Generally, the problem of vehicle counting is mostly done using deploying inductive loops. These loops provide high accuracy but are very disturbing at the roadway, that's why it comes with high maintenance cost. Most of video analytics system on traffic congestion focuses on counting and doing classifications for more statistics. The vehicle identification is used with self-adaptive windows to estimate the mean travel time under traffic demand and supply uncertainty (i.e recurrent traffic congestion, bottleneck etc) [46]. In [8], demonstrated motion-based tracking with trajectory analysis method is to improve intersection behavior analysis for accurate turning movement count at the intersection. There is a major problem with mixed vehicle (e.g. cars, scooter, heavy vehicle etc.) traffic flow that has been tackled in [5]. Image processing algorithm is used to estimate traffic density using cameras. Based on analysis of traffic images from live traffic evidence of congestion collapse which lasts for the extended time period shown in [9]. Many ITS applications rely on lane-level vehicle arrangement (positioning) that requires high accuracy, bandwidth, availability, and integrity. Lane-level positioning methods must reliably work in real time in a wide range of environments demonstrated in [16]. There are many lighting and weather conditions effects on vision-based systems. Such a system must adopt all these lighting conditions. The different cues are given related to this kind of situation in [21] [25] [28]. Because of uncertainty in the traffic flows with the machine-vision algorithm an autonomous fuzzy control system also used in [39]. All representative of vision-based approaches that were analyzed in details is highlighted in table 1.

**Table 1: Video analytics deployed in traffic domain for traffic congestion control algorithm**

| Algorithm | Outcome |
|---|---|
| An optimization model for signaling time at an intersection under mixed heavy traffic | The investigation provides queue length, the queue clearance time |
| The vision-based Vehicle tracking system | Estimate turning movement count, speed profile and waiting time |
| Road traffic congestion with image mosaicking technique | Intelligent decision making for traffic controlling |
| Computer vision and differential pseudo range global positioning system with kalman filter | Inertial navigation |
| Vision-based automatic vehicle detection under lighting conditions | Vehicle detection |
| Detecting and tracking of traffic shockwaves | Vehicle tracking |
| Traffic Signal density and duration image processing of each traffic light | Automatically estimation of Controlling using traffic |
| Machine vision algorithm and fuzzy expert system | Vehicle detection |
| The vision-basedintelligent traffic management system | Vehicle detection, density estimation |
| Vehicle Reidentification time System | Estimation of mean travel |

### 3.2 Machine learning framework

Machine learning and intelligence are being practical in numerous ways for tackling difficult confronts in many fields including transportation, energy etc. A good machine learning-based system requires all elements like sensors and data analytics capability to generate good results. A better understanding of the new technology is also important before system implementation to achieve high order performance for traffic monitoring and management. For a correct prediction of traffic information in real time such as flow, density, speed included intelligent traffic control systems to optimize the vehicle operations. Neural network, reinforcement learning techniques/frameworks used for efficient traffic signal policy, see [11] [13] [17] [27] [31] [33]. For road network management the optimization techniques are given in [14].

All representatives of vision-based approaches that were analyzed in details are highlighted in table 2.

**Table 2: Machine learning framework algorithm**

| Algorithm | Outcome |
|---|---|
| Multi-agent system and reinforcement | learning framework, a Q-learning algorithm with feedforward |
| Trip modeling system | Predict the traveling speed profile for the selected route based on the traffic information |
| Distributed unsupervised traff responsive signal control w hybrid computational intellig techniques fuzzy neural network hybrid multi-agent system | Simulation on multi-agent system provides effective control of large- scale traffic network |
| Generalized Beta-Gaussian Bayesian Network | Predicated traffic variables like:link travel time link flow link densities and their time evaluation in a real network |
| Discrete-Time Hidden Markov Model with classical Baum- Welch or Bayesian learning algorithm | Inferring the traffic signal phases from sequences of maneuvers |
| An intelligent decision-making system with Artificial Neural Network (back propagation) Expert System (Fuzzy Expert system for decision making) | The integrated system gave an efficient performance for adaptable traffic control problem |

### 3.3 Smart technologies for traffic control

To improve safety and efficiency many research groups focus their attention on emerging technologies as a feasible alternative to solve the traffic problem. The flexibility and increasing capacity of emerging technologies help to create cooperative automotive systems and reduce investment as well

 

as operational cost and then making more well-organized transport system. Communication technologies are also helping to build a vehicular network to reduce traffic congestion given in [11]. In order to enable the deployment of the system, the vehicle must be equipped with wireless radios and communication devices must be placed at the roadsides. In this sense, the advanced technology, particularly in the area of mobile computing, wireless ad-hoc network (VANETs), is emerging and these vehicles can communicate with other vehicles and infrastructures, i.e. V2V, V2I as observed in [6][12][15][32]. Using inductive loop base traffic signals are analyzed in [36]. The traffic prediction is done with VANETs for traffic prediction [38]. The historical traffic pattern is also a great asset in the maneuver of the transportation management system [45]. Wireless Sensor Networks (WSNs) gain more attention to traffic detection. Taxonomy of different schemes for avoiding congestion with a number of sensors given in [41]. All representatives of smart technology approach that were analyzed in detail are highlighted in table 3.

**Table 3: Smart technologies for traffic control algorithm**

| Algorithm | Outcome |
|---|---|
| Used vehicle to infrastructure communication and approximate dynamic programming with the simulation parameters like vehicle dimension, vehicle acceleration profile, vehicle braking profile, driving behavior | Travel time Estimation and adaptive traffic signal control |
| Make use of the mobile phone for accelerometer-based vehicular movement detection, map- matching for the traveled road segment, using cellular signal traffic congestion estimation of traveled road | Detection of road traffic congestion |
| Understanding of Internet of Things infrastructure in the bus transportation system in Singapore | Predict the arrival time of buses and crowded inside the bus |
| Using Taxi GPS tracing for the human mobility pattern in the city using a two-phase approach for night bus route planning :<br>Phase I- cluster hot areas with dense passengers for identifying a location in the cluster as a candidate bus stop<br>Phase II-Given the bus route origin, destination, candidate bus stop, maximum total travel time and bus operation frequency builds a bus route graph. | Automatic bus route generation |
| Using low-frequency data probe manuscript for pre-time traffic signals | Estimated collection of Signal Phase and Timing information |
| Smart traffic control system to make a traffic routing decision | Traffic control and management |
| Fuzzy expert system<br>Artificial Neural<br>Network Wirelesses sensor networks | |
| Inductive traffic loop detection for | Automation of traffic signal |
| Functional data analysis | Recognizing patterns of daily traffic profiles |

## 4. ISSUES AND CHALLENGES

Several attempts were made for traffic optimization by researchers. One of the challenges is to integrate the predictions for upcoming traffic conditions. Another challenge is to design a flexible model to deal with objectives like time, financial cost, convenience and environmental pollution etc. From the technical point of view, correct detection of vehicle density on road by keeping high accuracy including improved algorithmic solutions for multiple cues, for statistical and learning methods, sensors and telematics (e.g. V2X communication, GPS). One of the key aspects in ITS is the proper collection of the dataset can carry out by employing more powerful sensors or developing sensor fusion to handle software and hardware issues coming at the algorithmic level. In the Asian nation like India, the National Development Policy Committee (NTDPC) was legitimate by the government of India in 2010 to formulate long run ITS policy. It identifies methodologies to unravel current ITS issues and targeted towards a too long run vision in 2032 by introducing multi-model structures [26].

Because of people's demand and expectation of service quality has changed due to the availability of maps, GPS, etc. People plan their routes based on distance, time and cost. Therefore Information and Communication Technology' (ICT) enabled transport is stressed nowadays. This functionality will help to collect more efficient data and analytics will lead towards better decision making in systematic execution of ITS applications [54].

For the ITS implementation the key aspects that India is facing are given by world bank study report : improper developed road networks, economical restriction observed in the government, uncontrolled population growth, lack of resources for function and maintenance of roads, less requirement for automation, less interest in decision making and lack of user awareness. At the same time, the number of small scaled ITS pilot projects are being implemented that are given in the previous section. So far there is hardly any fully implemented ITS application present in India.

In India, ITS applications must focus on emergency management, congestion management, advanced traffic management system, advanced traveler information system, commercial vehicle operations, advanced vehicle control system etc. This probably can be achieved by implementing proper road network. Following are some specific challenges in the implementation:

- Evolving an ITS standard for its different essentials and applications
- To monitor, regulate and document the current and future ITS projects, the formation of ITS authority combined with the Ministry of Road Transport and Highway and Ministry of Urban Development.
- Fully functional Traffic Management Center coordinating urban and regional ITS activities.
- Surfacing and applying the good methodologies for data collection techniques in Indian traffic conditions.
- Setting up national data records
- Promoting involvement or interaction between academia, industries, and government agencies developing ITS projects and decision making.
- To achieve all the above in ITS applications in wide area current infrastructure has been made proficient as much as necessary for its successful functioning.

## 5. CONCLUSION

With the advancement of emerging technology, industrial and educational development there is more opportunity for employment and better scope of education as well as research in developing cities. The life style of people in metro cities with a large volume of the population is equally affected by various application and service systems. Therefore currently

 

most of the cities are in the process of transforming into smart cities by adopting automated systems in all possible sectors. With an objective of developing a new transport system for vehicles in a smart city, this article proposed a modern traffic control system using connected vehicle technology under VANET configuration with an integrated approach of solving general traffic related issues in a high volume traffic gateway. For the overall benefit of the traffic system, various modules like video monitoring, smart traffic control system, signal system and smart devices are included in the presented approach with the detailed structure of their smart functionality. Simulation results show that it has an improved rate of congestion control in traffic points as it uses the advanced technology of automated vehicles, mobile agent and big data analytic tools.

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