Intelligent traffic management system: A systematic survey

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Abstract:
The inferior transportation system of any country directly affects its socio-economic development, human health and environment. In this regard, Intelligent Transportation System (ITS) has been developed in order to deal with these growing problems of traffic congestion. ITS is a promising technology which makes the road transportation system intelligent with the use of computing, electronics and communication technologies. Therefore, the success of ITS in managing the traffic flows depends on the communication technologies and algorithms used. This review provides the insight of various types of communication technologies and algorithms used in ITS and an assessment of their effectiveness. The paper highlights the conclusions extracted from studies of different communication technologies and algorithms and besides suggests the future directions considering the challenges of presently used systems.

Keywords: - Intelligent Transportation Systems, Algorithms, Communication Technologies, Traffic Management.

1. Introduction:

Now days, traffic congestion is a major issue of urban areas owing to increasing population which resulted into rapid growth of traffic demand. In spite of many efforts in last decades and spending billions of dollars to ease congestion, day-by-day, this problem seems to be getting shoddier [1]. The inferior transportation system of any country directly affects its socio-economic development, human health and environment. For instance, significant outcomes of the 2015 Urban Mobility Report (471 U.S. urban areas) estimates the total annual congestion cost nearly 160 billion dollars, delay in travel time as 6.9 billion hours and 3.1 billion gallons of fuel was wasted only because of traffic congestion. The Travel Time Index (TTI), which is the ratio of travel time taken in the peak periods to the time taken during free flow conditions, was estimated as 1.23 [2]. In this regard, Intelligent Transportation System (ITS) has been developed in order to deal with these growing problems of traffic congestion. ITS is a promising technology which makes the road transportation system intelligent with the use of computing, electronics and communication technologies. Significant reduction in traffic congestion and environment pollution can be achieved through the effective use of ITS [3]. ITS works as an integrated system that uses various types of communication technologies (Wireless Sensor Network (WSN) [4], Radio-Frequency Identification (RFID) [5], Vehicular ad hoc networks (VANETs) [6, 7], Bluetooth [8], WiFi, Road Side Unit (RSU) [9, 10], ZigBee [11], and MANETs), control and several vehicle sensing techniques which further helps to efficiently monitor and manage traffic flow. With the use of these technologies, ITS improve the overall performance of road transportation in several ways such as improvement in average speed, reduces delay time and harmful emissions and enhances road safety. Thus, with the help of these sophisticated technologies, ITS dealing with traffic congestion since 1980s [12].

As stated above, largely the performance of ITS as per its application, depends upon the type of communication technology used. Mainly, the wireless communication technology has been used where several devices are connected using wireless networks and thereby transfer the data through signals. This data has been transferred and shared among nodes using different mediums such as radio wave and microwave [13]. VANET is another application of wireless networks for traffic management [20] where every partaking vehicle transformed into a wireless router or mobile node through VANET. This facilitates the vehicles to connect to each other to build a network with wide-ranging [21]. Though, VANET cannot offer complete and justifiable application due to some specific problems associated with VANETs such as interference that can occur when one node communicate to another node through a direct connection [22].

In addition to the communication technologies used for the intelligent transportation systems, several algorithms are also designed to schedule the phases of the cycle time of traffic light signals so as to allow the competing traffic flows to share the road intersection effectively. The new era of Internet of Things (IoT) technology could provide an answer to today’s traffic management problems in large cities. The IoT uses
Internet, wireless network, sensing and detection technologies to monitor and process data automatically. IoT mainly deals with the installation of sensors for acquiring the required data related to the traffic congestion and thereafter connecting this to the internet using precise protocols for data sharing and communication so as to achieve intelligent monitoring and management of traffic flows [30].

1.1 Motivation and background

In recent years, ITS has gradually incorporated smart technology which helps to dynamically control the traffic lights after analysing the real-time traffic data over the particular road network. Thus, in order to understand the role of technology in managing the traffic flows to ease traffic congestion and reduce delay time and environment pollution, one has to keep dynamic traffic control in mind. The developed ITS has used various types of communication technologies, scheduling algorithms, computer simulations and real testbed. This paper gives a complete description of the communication technologies used for ITS along with different algorithms developed to calculate the green light phase time. Further, the role of real-testbed and computer simulation is also described with related problem and then their individual importance for ITS is explored. The comprehensive literature has been categorized and represented in numerous tables under different headings. For instance, the references related to the type of communication technologies (Table 1) and type of algorithms used (Table 2) are represented in respective tables. Besides, the role of IoT has explored in this paper with reference to ITS.

1.2 Contribution of survey article

In spite of vast literature available on ITS in reference to various communication techniques, algorithms, simulation software and numerous other scenarios to optimize the traffic flow, yet, the consolidated survey report concerning the role of ITS related to traffic management system has not been presented. Consequently, an insightful study of the role of ITS pertaining to optimizing the traffic flow to mitigate the problem of traffic congestion through several techniques needs to be explored and a comprehensive literature review must be done that give a better understanding and a concise view to the reader about function of ITS regarding dynamic traffic control. In this paper, authors made an attempt to give a succinct report regarding ITS with reference to traffic flow management and suggests novel directions for research and development.

1.3 Review of related survey articles

Maimaris and Papageorgiou [3] has focused solely on communication technologies used in ITS, however Mangiaracina et al. [31] has described the role of ITS for urban Smart Mobility bearing in mind both people and freight transport. Similarly, Xiong et al. [32] briefly reported the history of ITS and besides, explored its forthcoming applications which provide some insight into ITS. Further, Qureshi and Abdullah, [13] review mainly refers to the applications of ITS. Chen and Cheng [33] discussed about the scope of agent-based technology in traffic and transportation systems comprising roadway, railway and air transportation. There is significant research on the type of communication technologies, different scheduling algorithms, simulation software and real-testbed concerning ITS, nevertheless a comprehensive review of these computing, scheduling and information sharing techniques related to ITS has not been presented. Hence, in this paper, an effort has been made to describe the role of ITS in traffic management system.

2. Communication technologies used in ITS

Various types of communication technologies are used in ITS (Table 1). There are several issues and challenges for their working efficiency and reliability. These challenges comprise medium access control, routing protocols, distance factor, time/emergency situation, bandwidth, security and privacy. In the last few years, efforts have been made to develop a range of Vehicle Automation and Communication Systems (VACS) [34] to solve the problems related to traffic flow and safety. Similarly, for this purpose, key developments have been made in the field of intelligent autonomous vehicles [35]. Therefore, it has been learnt that the development in the field of communication technology directly affects the performance of the traffic management systems or in more general terms of ITS. The use of efficient communication techniques further helps to reduce congestion and gas emissions and thereby leads to substantial improvement in safety.
The efficiency of any ITS depend on the effectiveness of communication technology used. Presently, a lot of communication technologies are adopted in ITS applications such as RFID, WiFi, Bluetooth, WAVE DSRC, Wimax, 2G/3G/4G/5G Cellular, GPS and Zigbee.

RFID techniques has been used for small distance (~ 10m) communication between vehicle and infrastructure [14]. Major applications of this technology include the identification of vehicles at automated toll collection; simplifying parking as well as RFID based e-plate for vehicle’s identification and tracking [16]. Through, RFID technology, ITS can be benefited in several ways, even with the limited communication range of this technology. Further, owing to the low cost, RFID is considered as one of the main technologies used in ITS.

3. Algorithms used for traffic control

Algorithms play a very important role for the effective implementation of ITS to dynamically control the traffic flow over a designated road network. These algorithms are designed to optimize the traffic light phase time (sometimes also called Green Light Phase Time (GLPT)) at the signalized intersection [51, 71]. Typically, the ITS algorithms have been developed for isolated traffic light signals, where, the algorithm schedule the traffic light phase time without considering the adjoining signalized intersections. While, few algorithms have also been designed, where, the algorithm schedule the signal phase time after considering both the neighbouring traffic lights as well as the real-time traffic features of competing traffic flow.

This segment of the paper discuss about the algorithms, used for real-time studies pertaining to ITS. In these kinds of studies real-time traffic data has been collected using numerous data collection approaches and further, this data has been used to find the dynamic programming solution through different algorithms to solve the dynamic traffic light control problem under real-time scenarios.

This technology is precisely used for correctly predicting the nearby future traffic situations and accordingly effective choices were taken to efficiently control the traffic light sequences within a specific area for the smooth flow of vehicular traffic. Four different algorithms such as Adaboost, LPBoost, TotalBoost and Bagging were compared and found that TotalBoost algorithm is the most suitable for this problem. Encouraging results have been obtained and all are validated through computer simulations for a group of 16 road intersections in a busy central zone of Timisoara-Romania. A total set of 105 different traffic situations are considered for the validation through computer simulations. The suggested methodology could be customized as per the needs of any available urban zone and implemented with a radius of 4 km for normal or abnormal traffic conditions. Chandan et al. [53] proposed a real-time adaptive traffic signal control algorithm which uses a connected vehicle signal control (CVSC) approach for an isolated intersection. The real test bed data has been collected using the connected vehicle technology from a four-legged isolated intersection located at Castle Downs Road, Edmonton, Canada.

3.1 Algorithms used for computer simulation studies

In this section, author investigates some intelligent scheduling algorithms used in the past for computer simulation studies to schedule the different traffic light scenarios. Vilarinho and Tavares [61] designed an adaptive signal control model which can be easily used for existing fixed signal control system. In this paper, the employed algorithm helps to find new signal groups and besides, calculate the green time duration for every signal group so as to handle the periodic traffic fluctuations. Borg and Scerri [69] also developed an adaptive traffic light signal scheme that used a dynamic programme to control the traffic dynamics. Further, the proposed algorithm adapt to vast change in incoming vehicle density and geographical limitations which validate the use of developed dynamic controller in real time situations. Similarly, Yousef et al. [38] suggested an adaptive traffic signal time scheduling algorithm for single and multiple intersections using WSNs. Algorithm adjust the red/green light duration with the help of conflict directions matrix for each traffic signal. The traffic signal duration has been so adjusted by the designed algorithm that the average queue length and average waiting time reduced to minima. The effective dynamic control further supports the green wave process.

Fuzzy logic technology has also been used by many researchers [127, 128, 129] to develop the intelligent traffic lights control system since this technology has the capacity to imitate the human intelligence for controlling the traffic lights. Pappis and Mamdani, [130] first used a fuzzy logic controller for a single intersection and observed significant reduction in average delay of vehicles in comparison to a conventional effective vehicle-actuated controller. Askerzade and Mahmood, [127] developed a fuzzy logic control algorithm to calculate the optimum extension time of traffic lights which further be added to the fixed time of
The performance of an algorithm has been compared with a comprehensive literature of different communication technologies and algorithms. This review can be further extended to involve more categories of communication technologies and algorithms. In future, all the benefits of ITS arises when there is appropriately large number of vehicles using these systems and maximum number of cities implement these systems. This paper is an effort towards exclusion as well as consolidation of types of communication technologies and algorithms. The communication range and bandwidth are the major factors concerning communication technologies which must be considered while selecting these for latest ITS. Similarly, the algorithms must take into account the above findings. Further, all issues related to the presently used communication technologies and algorithms. The communication range and bandwidth are the major factors concerning communication technologies which must be considered while selecting these for latest ITS. Similarly, the algorithms must take into account the above findings. Further, all the benefits of ITS arises when there is appropriately large number of vehicles using these systems and maximum number of cities implement these systems. This paper is an effort towards exclusion as well as consolidation of types of communication technologies and algorithms. In future, this review can be further extended to involve more categories of communication technologies and algorithms.

4. Summary

In this paper, author has reviewed a comprehensive literature of different communication technologies and algorithms used in ITS. As a result, author has recognized various prospects, challenges and issues related to the presently used communication technologies and algorithms. The communication range and bandwidth are the major factors concerning communication technologies which must be considered while selecting these for latest ITS. Similarly, the algorithms must take into account the above findings. Further, all the benefits of ITS arises when there is appropriately large number of vehicles using these systems and maximum number of cities implement these systems. This paper is an effort towards exclusion as well as consolidation of types of communication technologies and algorithms. In future, this review can be further extended to involve more categories of communication technologies and algorithms.

References


