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Intelligent Traffic Signal Control System For Vehicle-To-Infrastructure Communication In Vehicular Ad-Hoc Network

T. Hamsa Valli [1], J.Jeevitha [1] , V.Nandhini [1] , M.Siva Sangari [2]
[1]*Final Year Students , Department of Information Technology , Sri Ramakrishna Engineering College, Coimbatore*
[2]*Assistant Professor (Sr.Grade), Department of Information Technology, Sri Ramakrishna Engineering College, Coimbatore*

Abstract

Vehicular Ad hoc Network (VANET) is a promising approach for Intelligent Transport Systems (ITS). VANET has been widely used to reduce traffic congestion and delay experienced by the user. Traditional automated traffic signal control systems normally schedule the vehicles at intersection in a pre-timed slot manner. This pre-timed controller approach fails to deal with dynamic traffic. To overcome this problem an adaptive and intelligent traffic control system is proposed. It collects and aggregate real-time speed and position information on individual vehicles to optimize signal control at traffic intersections. Once the vehicle enters into the boundary of traffic area, they broadcast their positional information as data packet to the traffic signal controller. The controller at the intersection receives the transmitted packets from all the legs of intersection. The Platooning algorithm is implemented to group the vehicles approximately into platoons. The platoons are formed on the basis of data disseminated by the vehicles. Then the controller runs Oldest Job First algorithm which treats platoons as jobs. The algorithm schedules jobs in conflict free manner and ensures all the jobs utilize equal processing time i.e. the vehicles of each platoons cross the intersection at equal delays. The proposed approach is evaluated under various traffic volumes and simulation results show that, this algorithm reduces the delay by 36% and increases the throughput by 8% when compared with pre-timed signal control methods.

Keyword: Vehicular Ad-Hoc network (VANET), Pre-timed slot, platoons, Oldest Job First (OJF).

Introduction

Vehicular Ad-Hoc Networks

Vehicular Ad-Hoc Network (**VANET**) is an emerging technology in the modern world .This technology uses moving vehicles as nodes in a network to create a dynamic network. VANET can be viewed as main component of the Intelligent Transportation Systems (**ITS**). VANET turns every participating vehicle into a wireless router or node, allowing vehicles approximately 100 to 300 meters of each other to connect and, in turn, create a network as shown in Fig 1.1. As vehicles fall out of the signal range, it gets disconnected from the network.

Vehicular networks are composed of mobile nodes, vehicles equipped with On Board Units (OBU), and stationary nodes called Road Side Units (RSU) attached to infrastructure that will be deployed along the roads. Both OBU and RSU devices have wireless/wired communications. capabilities. OBUs communicate with each other and with the RSUs in ad hoc manner.

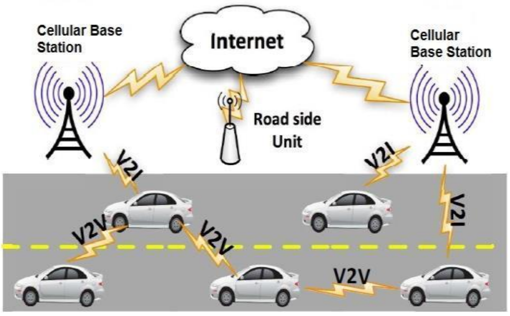

Figure 1.1: VANET Architecture

Vehicular Networks are expected to employ variety of advanced wireless technologies such as Dedicated Short Range Communications (DSRC), which is an enhanced version of the WiFi technology suitable for VANET environments. The DSRC is developed to support the data transfer in rapidly changing communication environments, like VANET, where time-critical responses and high data rates are required.

Vehicular Communication

There are mainly two types of communications scenarios in vehicular networks

- Vehicle-to-Vehicle (V2V)
- Vehicle-to-Infrastructure (V2I).

Vehicle-to-Vehicle (V2V)

It allows direct vehicular communication without relying on a fixed infrastructure support and can be mainly employed for safety, security, and dissemination applications. The communication is shown in Fig1.2.

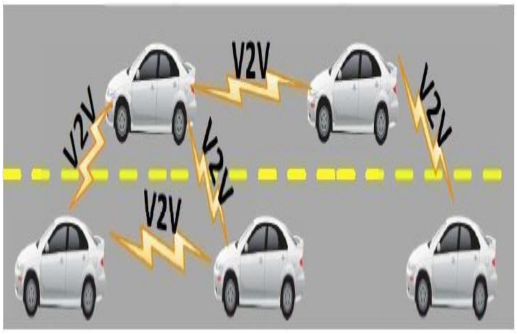

Figure 1.2: Vehicle-to-Vehicle(V2V) Communication

Vehicle-to-Infrastructure (V2I)

It allows a vehicle to communicate with the roadside infrastructure mainly for information and data gathering applications. The communication is shown in Fig 1.3.

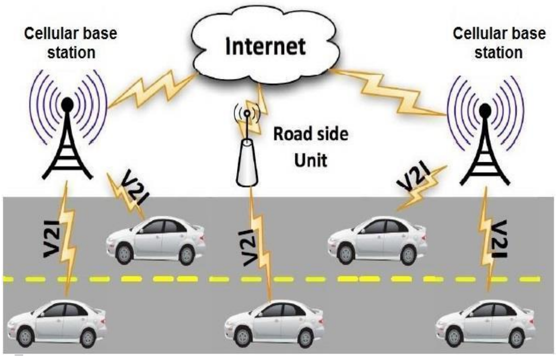

Figure 1.3: Vehicle-to-Infrastructure (V2I)

Intelligent Transport System (ITS)

Intelligent Transport System (ITS) aims to provide innovative services relating to different modes of transport and traffic management and enable various users to be better informed and make safer and 'smarter' use of transport networks as shown in Fig 1.4. ITS is at the heart of what keeps us road safe in our city's roads. ITS provides solutions to make roads safer and keep traffic flowing smoothly .ITS allow timely dissemination of traffic information which is the key to help motorists take the best route to their destination. It has emerged as an efficient way to improve the performance of the flow of vehicles on the roads. The goals of ITS is to provide road safety, driving and distribution of updated information about the roads. Traffic signals are adjusted according to the level of risks on different road sections.

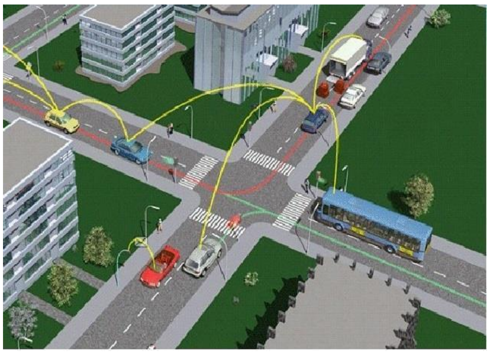

Figure 1.4: Intelligent Transport System Network

ITS vary in technologies applied, from basic management systems such as car navigation, traffic signal control system, container management system, variable message signs, automatic number plate recognition or speed cameras to monitor applications, such as security CCTV systems and to more advanced applications that integrate live data and feedback from a number of other sources, such as parking guidance and information systems and weather information. Additionally predictive techniques are being developed to allow advance modelling and comparison with baseline data.

Literature Survey

More than thirty years now, many efforts have been made to create traffic light systems that can be able to dynamically schedule the vehicles at intersections. In the existing system, roadside sensors such as loop detectors [2] and traffic monitoring cameras are used. The loop detectors can only detect the presence or absence of vehicles, which is a serious limitations. These loop detectors are physically connected to the traffic signal controller, and this connection is used to communicate the information gathered from the loop detectors to the traffic signal controller. The traffic signal controller then uses the data to schedule traffic through the intersection by cycling through pre-set phases and assigning appropriate amounts of GREEN time or skipping phase's altogether. More recently, video based traffic detection systems employing traffic monitoring cameras have been considered for traffic signal control. While these have been effective, particularly to coordinate traffic conditions with known events, they require a high degree of human intervention. Most of the signal control systems rely on pre-timed slot manner in which vehicles arrival time can be known before the vehicles reaches the stop line. Some of the important ones are Webster method that can be used to calculate delay minimizing cycle time. Then Split, Cycle, and Offset Optimization Techniques (SCOOTS) [3] method which uses a loop detector as a sensor that is placed at the entry point of every link to an intersection. Then Sydney Coordinated Adaptive Traffic System (SCATS) [4] also rely on loop detectors, which are placed before the stop line of the intersection. The adaptive signal control system includes other online algorithm called 2-compitative algorithm [7] which has the problem of pre-emptively scheduling jobs with unspecified resource requirements so as to minimize the average waiting time of jobs in the system. This non clairvoyant scheduling problem is the task typically faced by an operating system in a time-sharing environment where as many users as possible should get fast response from the system. The other technique make use of wireless communication and GPS [8], it enables vehicles to collect and disseminate traffic information and, finally, to provide meaningful data to the driver. It uses one-hop broadcasts to avoid a broadcast storm. Each record consists of a position, identification number, speed, direction, state and a timestamp of the moment when the information was created. Adaptive traffic light system in the context of the Traffic View platform relies especially on wireless communication with the approaching vehicles. The traffic light controller listens to all the information the cars are exchanging, thus finding out how crowded the intersection approaches are. In a city environment, controllers in adjacent intersections may communicate through a wired network, in order to provide each other with additional information. The upstream signal controller forwards to the downstream signal controller packets about the cars that enter the link between the two. Thus, the downstream intersection can decide its timing based on information known in advance.

Proposed Methodology

Intelligent traffic control system explores the idea of using vehicle information to enhance efficient traffic signaling. This system mainly focuses on controlling the traffic light based on the platooning and scheduling of vehicles at the intersection .The goal of this system is to enhance safe and smooth driving environment for drivers. The smart traffic system uses vehicle information to efficiently schedule the traffic. This system also considers scheduling of emergency vehicles such as ambulances.

List of Modules

1. Dissemination of information to traffic signal
2. Platooning Algorithm for grouping vehicles
3. OJF Algorithm for scheduling vehicles
4. Collision avoidance
5. Emergency vehicle scheduling.

Dissemination of Information to Traffic Signal

The real time information about the vehicles in the intersection is disseminated from the on-board sensors embedded in the vehicles to the wireless sensors embedded into the traffic signal control system by periodical broadcasts. A simple information dissemination is shown in Fig3.1. The speed and location information on vehicles that can be disseminated to the traffic signal controller using VANET are both spatially and temporally fine-grained. Such precise per-vehicle speed and location information can enable additional capabilities such as being able to predict the time instance when vehicles will reach the stop line of the intersection. This is in comparison with roadside sensors such as loop detectors that can only detect the presence or absence of vehicles and, at best estimate, the number of vehicles in the queue. Furthermore, it is cheaper to equip vehicles with wireless devices than to install roadside equipment.

The real time information of the vehicles include vehicle ID, current time, and speed and location information. The speed of the vehicle is calculated from the speedometer, location information from the Global Positioning System (GPS) fitted to the vehicle. GPS is a satellite-based navigation system that provides reliable time and location information. Today most of the vehicles are fitted with in-built sensors to collect real time information. It reduces the complexity of embedding sensors in the vehicle to collect the real time information from the vehicles.

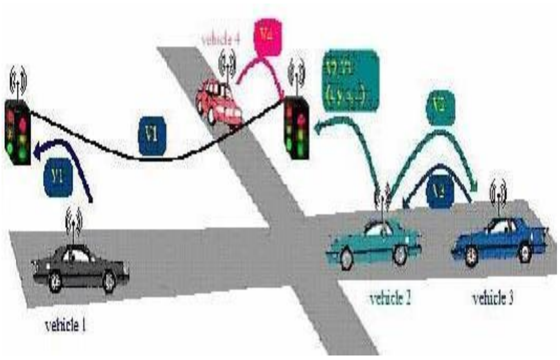

Figure 3.1: Dissemination of Information

Platooning Algorithm for Grouping Vehicles

Vehicle platooning is a promising concept in dealing with traffic jams. Vehicle platooning aims to increase the current road capacity. The key in achieving this goal is the organization of vehicles in tightly controlled groups, also called platoons that operate close together. As a result, a highway can accommodate more vehicles when vehicles drive in platoons compared to the manual conditions. The algorithm reduces traffic delays at intersections by minimizing the interruptions to vehicle platoon movements on the major roads.

Group the vehicular traffic into platoons as shown in Fig 3.2. A Platoon is a group of vehicles within a specified range. The vehicles within a certain boundary range of 100-300m is grouped into a platoon. It is ensured that the platoons are of equal size. The vehicles in the same platoon cross the intersection with same delay time. The different platoons are scheduled at different time. Each platoon is differently colored for differentiating and easy recognition of platoons.

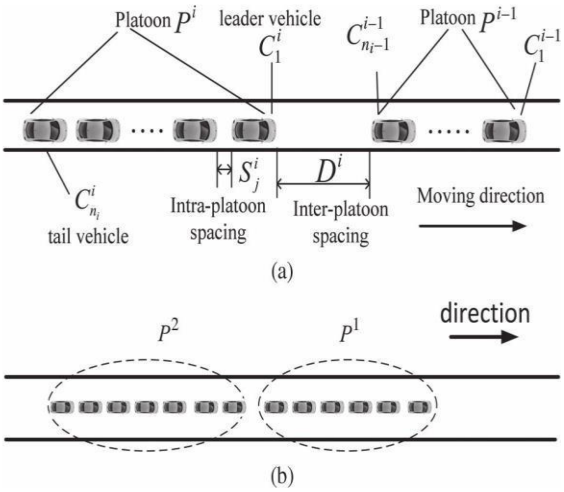

Figure 3.2: Example of Platoon formation

OJF Algorithm for Scheduling Vehicles

Oldest Job First (OJF) algorithm is an online algorithm where there is no prior knowledge about the arrival time of the vehicles. It makes use of the per-vehicle real time position and speed data to do vehicular traffic scheduling at an isolated traffic intersection with the objective of minimizing delays at the intersection. An important requirement for the OJF algorithm is that all vehicles in the intersection require equal processing time. Conflict graphs which indicates all the movements that consists of conflict threats is created to reduce the conflicts and increase the efficiency of all vehicles in the intersection.

The traffic signal controller then use the conflict free schedule from the OJF algorithm to schedule platoons of vehicles in a safe conflict-free manner. The platoon of vehicles that has early arrival time is scheduled first.

Collision Avoidance

Improving intersection collision avoidance systems will lead to the avoidance of many road accidents; this system is based on V2I communication. The sensors at infrastructure (Road Side Units) gather, process and analyze the information from the vehicles moving close to the intersection depending on the analysis of data; if there is a probability of an accident or a hazardous situation, a warning message is sent to the vehicles in the intersection area to warn them about the possibility of the accident so that they can take appropriate action to avoid it. The drivers on intimation can take a different route or change the lane path to avoid accidents. Lane changing is the functionality to steer a vehicle from the current lane to an adjacent lane. This aspect of lateral control is considered to be the most challenging as it involves more vehicle dynamics.

Emergency Vehicle Scheduling

This system is designed to satisfy the requirements to provide a clear road to allow emergency vehicles to reach their destinations without waiting in traffic. The system disseminates alert messages relying on one way V2V communication between vehicles travelling on the same route in an attempt to clear the road clear for the emergency vehicle. Available infrastructures at each intersection support emergency vehicles by sending messages to all traffic lights on the route to the destination using V2I communication. The emergency vehicle such as ambulance provides an alert message to the vehicle in front of it which then transfers the message to the front-line vehicles. The vehicle near the traffic signal controller sends the emergency vehicle information to the controller. This sets all the lights to green when the emergency vehicle arrives at the traffic signals, minimizing the response time for the emergency vehicle, and reducing the possibility of an accident occurring involving it.

Performance Evaluation

In this section, the existing and the proposed methods are compared. In the existing system, in order to minimize the delay experienced by the user the Webster's method is implemented. In this method, simulation tools are used to generate random vehicle arrival times to the intersection at a given average arrival time. In the proposed system, in order to reduce the delay and increase the throughput, an online algorithm called Oldest Arrival First (OAF) algorithm is used. This algorithm is based on the real time information collected from the vehicles, which are arriving to the stop line. Based on the information available a group of vehicles, called platoons are formed using platooning algorithm and vehicles are dynamically scheduled by using Oldest Job First (OJF) algorithm.

Performance of Platooning Algorithm

The effectiveness of the platooning algorithm is tested, which is part of the OAF signal control algorithm. The performance of the OAF algorithm depends on the ability of the platooning algorithm to divide the vehicular traffic on the approach into platoons that require equal amounts of GREEN time. For example, at an arrival rate of 400 vehicles, 33% of the platoons were platoons of size 4, 45% were platoons of size 5, and 22% of the platoons were of size 6. This implies that the platooning algorithm produces approximately equal-sized platoons, which is a necessary condition for the OAF algorithm. At relatively heavy traffic arrival rates, platoons containing approximately equal number of vehicles, and they take approximately equal amount of GREEN time to pass through the intersection.

Performance of OJF Algorithm

The performance of the OJF algorithm is compared against the other fixed-time signal control. This algorithm depends upon the vehicle speed, arrival time and position data to schedule the vehicle dynamically. At light traffic rate, this algorithm recovers from congestion much faster, hence the delays experienced decreased much faster. This is because the OJF algorithm is able to take advantage of the gaps that occur among vehicles and create platoons, and then, it minimizes the maximum delay that each platoon experiences. Moreover, it is efficient in discharging the queues. The performance parameter that measured was the average delay per vehicle, handover delay, handover traffic, message delay and packet delivery ratio which proved this algorithm is better than all other pre-timed control method.

Graph 1: Packet Delivery Ratio

Packet Delivery Ratio is the measure of delivery rate of a packet. In this graph packet delivery ratio is compared with other pre-timed signal control method.

Delivery Ratio= Number of packets received * 100 Number of packet sent

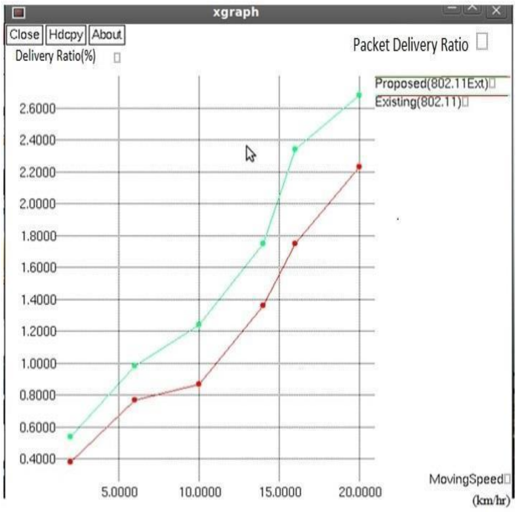

Figure 4.1: Packet Delivery Ratio

Graph 2: Message Delay

Message Delay is the measure of delay incurred by a packet during transmission.

Message Delay= Inter Arrival Time Between first And Second packet

Simulation Time

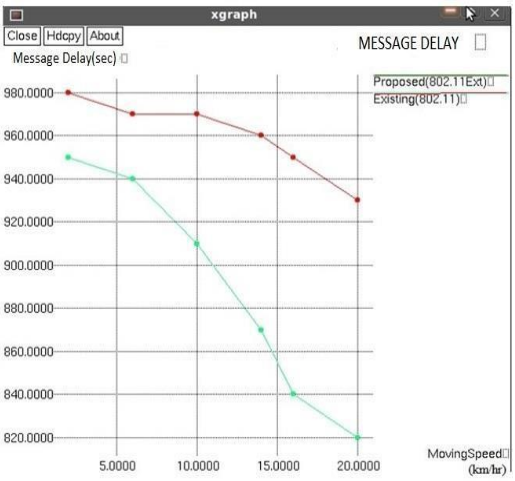

Figure 4.2: Message Delay

Graph 3: Handover Delay

Handover Delay= Inter Arrival Time of First and Second packet ____________________
Total data packet Delivery Time

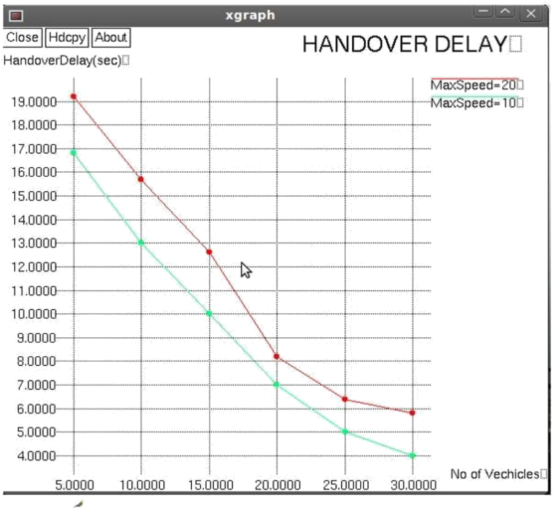

Figure 4.3: Handover Delay

Graph 4: Handover Traffic

Under various transmission rate, Handover Traffic is compared. It is inferred that at higher transmission rate, the packet reaches faster to the traffic signal control unit

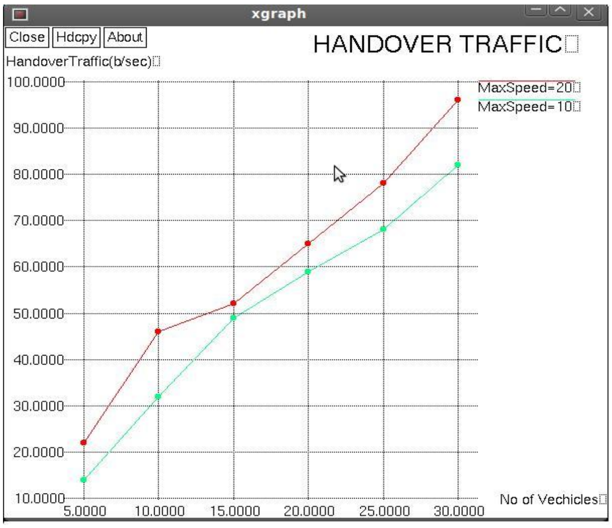

Figure 4.4: Handover Traffic

Comparative Analysis

When compared with other pre-timed signal control method, the Packet Delivery Ratio is increased by **8%** and Message Delay is reduced by **36%.**

Table 4.1: Comparative Analysis

Parameter	**Pre-timed signal control method(Existing)**	**Dynamic scheduling method with CAR Protocol (Proposed)**
Packet Delivery Ratio	0.88	0.96
Message Delay	1.58	1.22

Conclusion and Future Work

Conclusion

This system shows how VANET can be used to aid in traffic signal control. It implements adaptive traffic signal control algorithm that reduces the delay experienced by the vehicles as they pass through the intersection. OAF algorithm produces lower delays, compared with other method and the pre- timed signal control method. This approach is used to reduce the problem of traffic congestion at the intersection. This is used for smooth flow of vehicles without congestion. The adaptive traffic signal control algorithm also provides emergency services at critical conditions like fire brigade vehicles, ambulance or police on pursuit by using priority based signaling. The dynamic scheduling method is evaluated under various traffic volumes and simulation results show that, this algorithm reduces the delay by 36% and increases the throughput by 8% when compared with pre-timed signal control methods.

Future Work

The future work includes, the GREEN signal notification can be sent to the vehicles that are not in the platoon. Consider the case of sub lanes connected with main lanes. The vehicle which are at the head of platoon sends information to the vehicles near to sub lanes indicating that GREEN signal is ON in V2V communication. It helps the vehicles to use main lanes itself rather than using sub lanes.

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