Intelligent transport system by assisting driver

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Abstract—The growing number of vehicles on the roads worldwide, lead to increase in the number of road traffic accidents. These are recognized as a major public safety problem. In this context, connected vehicles are considered as the key enabling technology to improve road safety and the emergence of next generation cooperative intelligent transport systems (ITS). In ITS, network services and applications (e.g., safety messages) will require an exchange of vehicle and event location information. Effective lane changing and routing in Vehicular Ad hoc Networks is a challenging task. This paper aims to propose a solution to ensure the safety of drivers while changing lanes on the highways. Efficient and faster routing protocols could play a crucial role in the applications of ITS, safeguarding both the drivers and the passengers and thus maintaining a safe on-road environment. In this paper we propose a Driver Assistance System in Intelligent Transport System based on the speed of vehicles, for effective lane changing in the dynamic mobility model. In our approach we present the lane changing based system on speed and minimum gap between the vehicles. The paper focuses towards the development of an Intelligent Transportation System that provides timely, reliable information to the drivers and the concerned authorities. The test bed is created on the techniques used in the proposed system where the analysis takes place in the On Board Embedded System designed for Vehicle Navigation. The designed system was tested on a Four Lane road at Neemrana in India. Successful simulations have been conducted along with real time network parameters to maximize the QoS (quality of service) and performance using SUMO and NS-2. The system implementation together with our findings is presented in this paper. To illustrate our approach we present some results of the simulation using NS-2 (Abstract).

Keywords—GPS; RSU; smart cities; V2V; V2I; VANET

I. INTRODUCTION (HEADING 1)

Intelligent transport systems (ITS) are considered as the key enabling technology to improve road safety, traffic efficiency and driving experience. It helps to communicate not only with hotspots, but also with other nearby entities through direct short-range communications (DSRC), such as vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I), vehicle-to-pedestrian (V2P) and vehicle-to-anything (V2X). The new market forecasts [1] clearly indicate that the connected vehicle market will be worth 39 billion USD in 2018, up from 13 billion USD in 2012, and that more than 50% of the vehicles sold worldwide in 2015 will have communication capabilities.

It is envisioned that every new vehicle will be connected in multiple ways by 2025. This new reality of intelligent transport systems will help in different types of vehicular communications (VC) and also enable the emergence of innovative active road safety applications, and traffic management services.

Research and standardization activities on intelligent transport systems had significantly started, worldwide, more than a decade ago [2,3] and encompasses various multidisciplinary areas, including radio channel modeling, data link protocols, wireless communications, networking protocols, security and localization.

In the United States, proposed a novel Wireless Access in Vehicular Environments (WAVE) V2X protocol stack [4] for enabling future ITS applications. It relies on the IEEE 802.11p standard [5], which extended the PHY and MAC layers of the IEEE 802.11-2007 standard [6] to cover vehicular environments and the IEEE 1609 family of standards [4] to provide high level features (above the MAC layer), such as routing, addressing, security and resources management. In Europe, the European Telecommunications Standards Institute (ETSI) TC ITS working group [7] is working on a global standard for cooperative ITS systems, which adapts and optimizes ongoing ITS proposals at IEEE and ISO [8]. The ETSI TC ITS defines reference architecture [7] for cooperative V2X communications, including the support for the IEEE 802.11p standard [4]. However, there is still a lack of experimental deployment and comprehensive performance evaluation of these standards under realistic environments, traffic load and application use cases, especially regarding the security of vehicular communications and the safety of ITS applications.

Taking the upcoming model of driverless cars and smart cities into consideration, it is very important to build up mobility models and algorithms for safe and efficient environment. With the introduction of vehicular ad hoc network (VANET) in the field of transportation, a new area for research has evolved out of it. VANET is basically a subset of mobile ad hoc network (MANET) where all the moving nodes behave as vehicles.
The Vehicle-to-Infrastructure (V2I) and Vehicle-to-Vehicle communications (V2V) [1] play a very important role in this aspect. In the Vehicle-to-Infrastructure model, the information of the traffic is collected at the Road Side Unit (RSU) and is broadcast to the receiver vehicles and then sent to the central server for monitoring the vehicles. In the Vehicle-to-Vehicle model; the exchange of information takes place between the vehicles itself. This exchange of information among the vehicles and the RSU’s may influence the movement of these vehicles. The communication between the vehicles, RSU and the central server follow the Dedicated Short Range Communication Protocol (DSRC). In the system, the vehicles on the road communicate with each other and then the information is sent to the RSU. The RSU further exchanges information with the central traffic-monitoring server with the help of the Internet. The communication here is bidirectional.

We have taken up a scenario where we have five different lanes on a road with the speed limit increasing from the left most lanes to the right most one. The model is therefore like 120Kmph > 80Kmph > 40Kmph > 0Kmph (stop) lanes. The vehicles have to move according to the speed limits set above. While moving on these lanes, the vehicles can increase or decrease their speed and change the lane accordingly. Changing the lane will be possible only when the minimum gap between the vehicles is as set in the algorithm (SBLS). But if any particular vehicle is not doing so, the hardware implemented OBU (On Board Unit) in the vehicle will display a warning message to the driver to either change the speed or change the lane. If the default vehicle does not follow the speed rules then the emergency warning message will be broadcast to the vehicles and the RSU’s in the communication range of this vehicle so as to maintain a safe environment. The other vehicles will also receive this information that will influence their movement in a particular fashion. As soon as the number of defaulter’s messages increase, the RSUs transmit the information to the nearest traffic monitoring system. Now the traffic monitoring authority will penalize or bound the faulty vehicle by analyzing the data. In this algorithm based model we are using the concept of lane changing with respect to speed, with the help of the information received from the GPS receiver. The latitude and longitude data will be parsed and then we will check the current position of the vehicle with respect to the lane and then check the correct speed of the vehicle with the lane speed limit. If the driver does not drive at the correct speed then the driver will be warned first in terms of alarm and displaying message on the LCD, this process will repeat for some duration. After the elapsed time the warning message will be broadcast to the nearby vehicles and RSU’s. The information received about the GPS coordinates and velocity readings allows the software implementation for collision detection or accident prevention system by giving an audible warning tone whenever a vehicle is over speeding or driven in the wrong lane. ‘Prioritized’ and ‘timely’ transmission of warning messages for safety applications is crucial in VANETs to prevent fatal accidents and warn the drivers beforehand, hence, a SBLS algorithm is presented which is based on the appropriate routing algorithms such as AODV and GPSR as well as Priority Queue and are compared under the given scenario to provide the better Quality of service (QoS). The rest of this paper is organized as follows: In section II we have taken a brief description on the concept of VANETs and the related work done in this field. In section III, the system design and problem formulation has been discussed. In section IV, we have defined our protocol. In section V we have shown the performance evaluation, taken a look at the applications of GPS and the hardware implementation of the protocol, traffic model generated with the help of SUMO-MOVE followed by the simulation of the VANET network in NS-2. Section VI, concludes this paper and gives a glance of future work to be done in this model. Lastly, we have ended up giving the references without which writing this paper would be very difficult for us.

II. RELATED WORK

VANET (Vehicular ad hoc networks) is a very vast area for research and has opened gates for new possibilities and better technology in the field of transportation both in terms of safety and efficiency. In VANET, cars are defined as mobile nodes in a mobile ad hoc network to create a mobile network [6]. C.-F. Chiasserini, E. Fasolo. [5] the paper discusses about the short broadcasting of the messages in VANET. This will help in improving the efficiency and also security up to some extent.

In [7] Rajendra Prasad Nayak the thesis proposes a method to calculate the speed of the vehicle based on the position of the vehicle. The vehicles exchange information with RSU and then the RSU sends it to the central monitoring server.

Nehal Kassem, Ahmed E Kosha [8] presented the paper proposes a method of vehicle detection and speed estimation based on RF. The main drawback is that a vehicle can proceed to any speed in case of a miss, which can cause an error in the accurate estimation of speed.

In [9] Ram Shringar Raw, Manish Kumar presented the paper throws light on various technical applications, advantages, challenges and issues in VANET and methods to improve the network system. The paper also discusses about the techniques involved in secure message transmission, which will help us in our future work foe data authentication.

Tanveer Kausar, Priyanka Gupta [12], the authors have proposed an approach for the collision avoidance system in VANETS based on the lane changing using GPS based hardware with trans receivers for data exchange.

Yong Zhou, Rong Xu [13], the paper discusses about the lane changing and safety warning system based on virtual lane boundary. The safety system alerts the driver based on the width of the lane and the time required to cross that point.

In [14, 15], the authors have discussed about the safe lane change assistance system to drivers with the help of cameras and proximity sensors. The basic terminology is to detect the presence of any vehicle in the blind spot region and change the lane based on the speed and the driving style of the driver.

In [16, 17], the authors have proposed an approach for lane change tracking and vehicle detection in VANET with the help of cameras mounted on the vehicles. The basic process involved is, the camera takes a recording of the surrounding of the vehicle and then image processing is done. The lane changing and vehicle tracking is done by using Hough transform on the results of the image processing.
III. SYSTEM DESIGN AND PROBLEM FORMULATION

While driving a vehicle the behavior of a driver will depend on factors like speeding, traffic density and fast lane changing, etc.

Hence, reckless driving recklessly causes accidents and also affects the movement of traffic. Now if a faulty driver does not follow the proper lane changing protocols and crosses the speed limits then immediate warning actions are required to be taken.

So what can be a possible solution to check the abruptions like over speeding and lane changing mechanism of vehicle and what ways can be deployed to minimize it?

How can we possibly deploy techniques to send faster warning messages for the neighbor vehicles in order to warn them about the situation? Can the latency be minimized and the quality of service is increased by using suitable routing algorithm?

IV. PROPOSED SYSTEM

The protocol was developed to implement the efficient lane changing based on the speed of the vehicle for the sake of safety and an efficient environment in VANET. In this section we have discussed about the SBLS algorithm to study the behavior of the vehicles with its implementation and later on in section VI we have implemented the SBLS algorithm in the hardware module and the appropriate routing protocol with the mobility model generation is checked with the help of SUMO-MOVE and the simulation of the algorithm in NS2.

A. Hardware

In our system we have used Ali3d3 board as the primary hardware board for the implemented VANET system. It comprises of a 500 MHz AMD Geode LX800 CPU with two network card interfaces and it is also interfaced with a Unex DCMA86P2 mini-PCI card using ath5k driver when connected to an ordinary WIFI network card using ath9k driver. The ath5k driver can be changed for this wireless card to be able to use the IEEE 802.11p protocol as the Atheros AR5414 wireless chipset of DCMA86P2 wireless card supports radio operation in dedicated short range communications (DSRC) range of 5.85GHz - 5.92GHz with seven available bands of 10MHz. The system board peripheral also connects a LTE module and two antennas used for WIFI and IEEE 802.11p. We have used an external GPS module to acquire the location information and an OBU-to-RS232 interpreter, to collect the information about the status of the vehicle. We have used STN1110 module for transmitting the vehicle status information to the surrounding vehicles with Bluetooth interface.

Fig 1: Ali3d3 board used in our Hardware

B. Assumptions

The SBLS is based on the following assumptions:

[10] Every vehicle is capable of determining its own location and mobility information with the help of GPS. The information being exchanged between the vehicles and RSU’s is authentic.

The hardware installed in the vehicles is running on the power provided by the vehicle itself.

All the vehicles moving on these lanes are VANET approved and have the hardware installed in them. Before we start with the algorithm, here are a few definitions [11]:

Definition 1 (Road Segment): A road segment is defined by R where \( R = \{ s(x, y), e(x, y), l, v_l, v_u \} \). Here \( s \) and \( e \) are the starting and end points of the lane respectively with \( (x, y) \) as the location \( (x=\text{latitude}, y=\text{longitude}) \). \( l \) is the number of lanes (5 according to our scenario). \( v_l \) is the speed of the lane. The length of the road segment and the width of the lanes can be estimated with the help of the location of \( s \) and \( e \).

Definition 2 (Road Network): Road network is a graph \( Rn=(j, s) \). Here \( j \) is the set of all road segment junctions and \( s \) is the set of all road segments.

Definition 3 (Minimum Gap): It is the minimum gap to be maintained between two vehicles on any particular lane on the road. In this algorithm it is denoted as \( min_{gap} \).

Parameters: Assume that there are 3 lanes \( L_i = \{ L_1, L_2, L_3 \} \) with speed limits \( (V_{li}, V_{ui}) \) respectively with a tolerance of 10%. \( L_{Bi} \) is the lane buffer ID which will help us in storing the previous lane ID in which the vehicle was moving.

\( V_{li} \) and \( V_{ui} \) are considered as the lower and upper limits of the lane \( L_i \). (Each lane has its own upper and lower limit.) The vehicles at the start point initiate the entire path planning process travelling in various lanes \( L_1, L_2, L_3 \) at different speeds \( S_i = \{ S_1, S_2, S_3 \} \) (speed of the vehicles). GPS will monitor \( L_{Bi} \) and helps to locate the ID of the last lane, the current position and speed to store in a Buffer of the monitor system. Now suppose that a vehicle is travelling with speed \( S_{ext} \) in lane \( L_3 \) having a upper and lower speed limit lane at a particular point, the GPS based monitor system will check the speed of this vehicle with lane speed limits and give an alert message to the driver to either reduce/ increase the speed or to change the lane, if driving at wrong speed. The system continuously monitors the driving style of the vehicle for a particular time. If the vehicle changes the lane or reduces the speed in the time \( t \) the monitor system gives an OK status to the driver and to the RSU.
If the vehicle does not respond to the warning and change the speed or the lane, then the OBU monitoring system broadcasts the emergency message to neighboring vehicles to alert the other nodes and also transmits emergency data packet to nearby RSU by using the affective Greedy Perimeter Stateless Routing (GPSR) protocol.

C. SBLS Algorithm

Taking the above assumptions and definitions into consideration, we have the SBLS algorithm as follows:

Position Verification:
Obtain the values of $S_{est}$, $V_{li}$, $V_{ul}$, w.r.t $L_i$.

Pos-label

if $(S_{est} < V_{ul})$ AND $(S_{est} > V_{li})$
	hen
  Alarm Status: OFF;
  Display “Speed Under Limit”; 
elseif ($S_{est} > V_{ul}$)
  Display “Reduce speed or Change Lane”; 
  Alarm Status: ON;
  Timer ON:
  Check for Deceleration/lane change subroutines;
  Update System Variables;
  Timer ends;

GPSR based forwarding of the warning message to RSU and nearby vehicles;

goto Pos-label
elseif($S_{est} < V_{li}$)
  Display “Accelerate or Change to a Lower Lane.”
  If($S_{est} == 0$)
    Update Engine State = OFF if (Engine State == OFF)
then
  Display “Vehicle not in motion”; //At the base station else
  Display “Vehicle in motion”; //At the base station
  Alarm Status: ON;
  Timer ON;
  Check Acceleration/lane change subroutines;
  Timer ends;

GPSR based message forwarding to RSU and surrounding vehicles;

goto Acceleration/Acceleration:

Deceleration:\n
1. if $(S_{est} < V_{li})$
  Warning issue: “Accelerate”
  Check and update $S_{est}$ Check
min$\bar{g}$

goto Position Verification
2. if
  $(S_{est} > V_{ul})$
  Warning issue: “Decelerate”
  Check and update for $S_{est}$
  Check $\min_{gap}$

goto Position Verification

Lane Change:

1. if $(S_{est} < V_{li})$ OR $(S_{est} > V_{ul})$
  Check $\min_{gap}$
  If $(\min_{gap}$ condition not satisfied)
    Display “Lane changing not allowed”
  Else
    Display “Lane changing allowed”

The IEEE 802.11p is used for V2V for transmission of warning messages and data from one vehicle to another. It requires the ath9k driver for compatibility with the hardware. The IEEE 802.11abgn is used for intra-vehicular communications. However it requires the ath9k drivers with the hardware. We are using only 802.11p in this system.

V. PERFORMANCE EVALUATION

In this section we have discussed about the working of the on board navigation unit (OBU), the simulation of the algorithm using NS2 and the comparison between the AODV and the GPSR protocols for smart and efficient transmission of the data packets in the network with respect to the average end to end delay and packet loss ratio.

The hardware installed in the vehicle will be able to parse the data from that of the data received by the GPS receiver and compare, save them for vehicles and lane ID identification purposes. For example, the location, speed and time information will be sent to the RSU in order keep proper track of the faulty vehicle and pass on information further to the central traffic monitoring server.

A. OBU- GPS enabled monitoring system

The hardware processes the data received by GPS with respect to the moving vehicle. The GPS receiver receives the data packets and this data is used by the micro-controller. The microcontroller further processes the required data, stores the lane information and checks the values with the thresholds pre-set in it. In cases of mismatch, the microcontroller immediately alerts the driver three times. If these warnings are ignored an alert message is then broadcasted to the other vehicles and RSU’s in range. The block diagram and implementation of the OBU described above is as shown in the Fig.2.

![Fig. 2 Block Diagram and implementation of the Hardware Circuit](image)

In hardware of this model uses an LCD display and an alarm for displaying the warning message and alerting the driver respectively. Fig. 3 shows the response rate of the system while testing in the real test bed. The graph shows the delay after the driver has committed an error with its lane speed, the driver’s response time after the warning has been issued and the time taken to reach the warning message to the neighboring vehicle in 5 instances.

The following are the parameters involved for the on board GPS based system.
Fig 3. Graph to show the response time in real test bed

TABLE II

<table>
<thead>
<tr>
<th>Data format from the GPS and OBU modules</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Latitude</td>
<td>Degree (upto 4 places of decimal)</td>
</tr>
<tr>
<td>Longitude</td>
<td>Degree (upto 4 places of decimal)</td>
</tr>
<tr>
<td>Speed</td>
<td>m/s (upto 4 places of decimal)</td>
</tr>
<tr>
<td>Direction</td>
<td>Degrees</td>
</tr>
<tr>
<td>OBU module</td>
<td></td>
</tr>
<tr>
<td>Average speed</td>
<td>km/h</td>
</tr>
<tr>
<td>Maximum speed</td>
<td>km/h</td>
</tr>
<tr>
<td>Acceleration</td>
<td>m/s</td>
</tr>
</tbody>
</table>

B. SUMO and MOVE

Fig. 4 shows the mobility model which we have used in our scenario. We have used a specific segment of Neemrana, India to show the simulation in a 4-lane road and also have implemented the system. The simulation results have been recorded. Fig.4 shows the roadmap of a segment used for simulation in Neemrana. Each lane in the 4-lane road has been assigned with different upper and lower speed limits. Each vehicle has been limited within these speed limits. The vehicles shown in the figure are bounded to move according to that particular lane speed limit. If a vehicle is not maintaining the lane speed, it will change its speed or its lane based on the minimum gap between the vehicles moving on the road as stated in the SBLS algorithm. The car number 2 shown in red car as shown in the scenario figure, wants to change the lane and hence has reduced the speed. When the minimum gap requirement between the vehicles (nodes) is met, it attempts to change its lane.

The lane number 1 is for the use of only emergency vehicles like ambulance, fire brigades etc., and can move in case of mishaps or emergencies.

The lane 2 has its upper limit speed of 120Kmph and lower limit 70Kmph, similarly lane 3 and 4 has the pre-set speed limit set of 80Kmph and 40Kmph and lower limits to be 30Kmph and 0Kmph respectively.

If due to any reasons the normal lanes are blocked maybe due to road blockages like in accident cases, the emergency lane will be opened for all the vehicles to use in order to avoid traffic congestion.

The vehicles have their specific range of communication. They communicate with each other and other vehicles in their range and the exchange information among themselves. The entire scenario for the system implementation is simulated in NS2 [3] and the SBLS was implemented. The results of the simulations are described and explained in the next section.

The .tcl and sumo.tr files imported from SUMO-MOVE are the requirements for simulation to be done in NS-2. This scenario is then imported in NS2 where we have implemented our algorithm.

C. NS2

The mobility model which was generated using SUMO and MOVE simulators is simulated in NS-2 with the help of the .sumo.tr and .tcl files which we got earlier. The simulation results have been discussed in this section using Fig. 5. In nodes -> 1,2,3,4 are the 4 vehicles on 4 lanes that are present in the lower two lanes of the road.

In Fig. 5 the vehicle no. 2 shifts it lane based on the speed change. Initially it starts from the second lane and then shifts to the first lane based on the protocol. The min\textsubscript{gap} estimation is also shown in Fig. 5.

![Fig. 5 min\textsubscript{gap} and speed estimation based lane changing](image)

In Fig. 6, the calculation of the minimum gap required between the vehicles to change the lane is shown.

![Fig. 6 min\textsubscript{gap} and speed estimation based lane changing](image)
VI. CONCLUSION AND FUTURE WORK

The speed-based lane changing protocol implemented within the on board system will play a very important role in VANET and will create a semi-automatic environment, in the concept of smart cities and smart transportation. The drivers will get full and authentic information of their surrounding without much effort. In the previous works done in this field, the major papers have focused on using cameras followed by image processing for the lane change assistance and safety warning systems. The use of GPS based system is more reliable as it is more accurate and the data being provided is real time data. Thus this system is more reliable and efficient in terms of safety and accuracy. In this paper, we have explained the protocol and the first level implementation of the algorithm with the help of SUMO-MOVE, NS-2 [19] and some field trials with the hardware prototype. Further, we will use different packet forwarding strategies for different connection states. As we are transmitting information like the location, speed etc. from the hardware, there may be a case where the data can be manipulated. We intend to improve our protocol in such a way that it takes care of these issues.

REFERENCES