

Comfort and Danger Zone Boundary Prediction for Flying Car Safe Overtaking in Highways



S. Srithar, N. M. Saravanakumar

Abstract: Nowadays the road transportation system is enlarged much due to the population and fast-moving world. Due to human fault, vehicle accidents are quite unavoidable. The primary cause for accidents is the desecration of traffic rules such as over speed, unplanned overtake, etc. To increase the safety of vehicle rider the autonomous cars are coming into the picture. The autonomous vehicles can decide on their own for safe self-driving. But, the autonomous vehicles are still on the bench because lots of realistic considerations and predictions are needed to make the system more intelligence. The vehicular ad-hoc network acts an important role in autonomous vehicle building by considering various facts. The motive of the research is to give assistance message to the drivers for safe overtaking. In the literature, safety assistance is provided through the Road Side Control Units (RSCU). But the construction cost and maintenance for the RSCU is too high. Our methodology will give a sustainable solution for safety assistance when the vehicle tries to overtake. The proposed methodology uses Cooperative Overtaking Sight Assistance (COSAS) which predicts the comfort zone and danger zone boundaries for safe overtaking. The methodology greatly reduces infrastructure dependency. The experimental evaluations are carried out in SUMO and NS2.

Keywords: overtaking cars, one hop neighbor, Motion prediction, Greedy selector, Cooperative Overtaking Sight Assistance.

I. INTRODUCTION

Vehicular Networks mean the nodes are called vehicles, where each node different from the traditional wireless nodes. The intelligent system in a vehicular environment aims to increase the driver's safety, fuel consumption, and traffic monitoring, etc. Navigation device installed smart cars used to locate the vehicle's current place for cooperative safety-related assistance. In vehicular networks, the communication strategy is divided into three. They are car-to-car communication (C2C), car-to-Road Side Control Unit (C2R), Car-Car-Road Side Control Units (C2C2R). In C2C communications, the car can pass the message directly with other cars belonging to the communication range.

If the vehicle is too long from their radio range then they can communicate through the intermediate vehicles called 'relay car'. Intermediate vehicles can act as a relay node for forwarding the data from one another. Hence all the nodes are cooperative. A vehicle has own energy level, bandwidth, mobility, and speed, etc. In Car-to-infrastructure communication a car can communicate to RSCU as well as RSCU can communicate with the car.

Roadside control units are not moveable and they act like base stations. A Vehicle cannot send anything directly to other vehicles if they are away from the communication range. It can send it through the relay car or RSCU. RSCU will monitor the status of each vehicle and sent it to the decision-maker for processing the data. In Infrastructure communication, the roadside device sends data to another roadside device for data transmission. RSCU uses WiFi/WiMax technology for long-distance communication. Roadside control units are fixed for every 1 kilometer. Whenever the node is moving from one RSCU to another RSCU the information regards the vehicle is passed to adjacent RSCU for further processing. The routing protocols supported in mobile wireless networks not suitable in the vehicular network due to the fast-changing topology. C2C communication is done through the short-range communication protocol. In India road width for the single lane is 3.75m and for two-lane 7m. The minimum safe distance between the vehicles in front 10m, back 10m, left side 1m, and right side 1m.

II. RELATED WORK

VanQuang Nguyen[15] et al., proposed and investigated Lane change assistance system(LCAS) to assist for an immediate lane change. The smart car contains three cameras which are fixed in the left, right and front side of the vehicle. The pictures are captures in periodic intervals to detect the lanes and the vehicles. The filter names as Kalman used to filter out the vehicle's actual road coverage. Francesco Biondi [6] et al., investigated the reaction time of the pressing a break while using cell phones as well as in heavy traffic time. The reaction time of the driver varies depends on the age of the driver, type of vehicle and the environmental condition. The normal reaction time for the human is 0.2sec to 2 sec. Jordanka Kovaceva [8] et. al, examined the comfort zone for a car safe overtaking for a bicycle. In some situations, bicycles and cars may share the common medium for traveling. By the time, there should be a safe distance need to maintain by the car while overtaking. The enormous critical parameters like rural, urban, speed, road conditions were discussed. Susann Winkler [14] et al., experimented with a fidelity driving simulator to warn the drivers.

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The strategies such as Hill area, T junction, School Zone, Bicyclist, Speed breaker alert, etc. Michael Motro[11] et al., studied the traffic simulator named as VEINS. The objective of VEINS is to alert the driver who is not safe while driving. It uses the DSRC standard for C2C communication. The methodology will not give accurate safety assistance because the communication range of each vehicle is very limited and the message gets lost due to the nature of the network topology.

Meiping Yun[10] experimented with various lane change behaviors such as lane change position, steering angle, deceleration, angle and merging gap, etc. The simulation results are given positive results in high-density traffic scenarios. Besat Zardosht [4] investigated the prediction based rerouting algorithm. If there is an accident happens in a road the information regarding the same is intimated to the emergency vehicle as well as the neighbors. If any heavy traffic situation arises then the alternative and the more suited route is suggested to the predecessor vehicles. Andrea Gorrieri[2] et al. investigated the performance of a decentralized detection scheme for cluster WSNs. In the downlink phase, a novel clustering broadcast protocol is used and in the uplink phase, the vehicle performs clustered topology and decentralized detection. Hichem Sedjelmaci [7] et al., designed and implements an intrusion detection method to prevent dangerous attacks in the network. Sofiane Zemouri [14] et al., proposed distributed dissemination protocol "Road-casting protocol" for safety message in urban areas to cooperatively forward the data. K. Karuppasamy[9] et al., analyzed the various routing algorithms in a mobile network environment. But, the traditional routing protocol supported in mobile wireless networks does not suit for communication. S. Srihar[13] et al., briefly discussed the route cause analysis of the accident in TamilNadu region. This paper survey says that the second root cause of vehicle crash is unplanned overtaking. Our methodology gives a solution to this root cause.

III. PROBLEM FORMULATION

The primary motto of the research work is to provide safety assurance while overtaking. The crucial point here is there no collision with an opposite vehicle. It also ensures proper communication with the neighbor vehicle. There is no need for any fixed infrastructure unit for decision making in our methodology. Assume that, cars are cooperative where the vehicle can act as peer-to-peer connectivity. The comfort zone boundaries could be shared to the overtaking vehicle in prior. Based on the prediction the vehicle can make the decision. The methodology may not suffer from the line of sight with opposite vehicles. Also, the overtaking vehicle will intimate his overtaking message to the most dangerous zone vehicle if any. The system operates for flying overtaking behavior which means the front vehicle runs with low speed and the overtaking vehicle fly at a high speed.

IV. SYSTEM DESIGN

All the cars are fixed with a navigation device for vehicle movement monitoring. The vehicle periodically shares its current speed, location, and direction to all the neighboring vehicles. Based on the control packet information the prediction can be made. For safety overtaking, there are several factors to be considered. They are,

- Speed of the overtaking cars
- Speed of the overtaken cars
- Speed of the opposite cars

A. Network Formulation

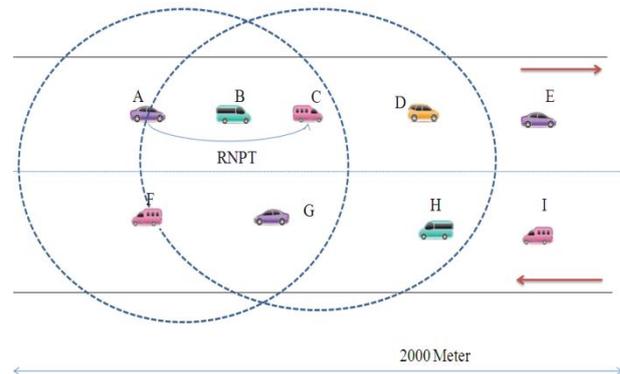


Fig 1: Initial configuration of vehicles

Let us assume, the experiments are carried out in the two-lane highway environment with 2KM coverage (Fig 1). There is a number of a vehicle which moves in different direction and speeds (Table 1). All the vehicles are mounted with a navigation device and the vehicles are assumed to be cooperative. The cars can send the messages to its nearby cars whose communication range is within the radio coverage. All the vehicles periodically send and receive control packets with one-hop peer vehicles. The vehicle who would like to overtake will send a "Request Neighbor Position Table (RNPT)" message to the farthest stable vehicle by applying the Motion prediction algorithm. In our example, the vehicle 'C' is stable and the farthest vehicle from the vehicle 'A'. The vehicle 'C' returns the surrounding vehicle <Neighbor_ID, Velocity, Location, Direction> to the vehicle 'A'.

Table 1: Vehicle C's RNTP

V-ID	Speed	Location	Direction	Time of Catch
A	90	X:X	→	10:12:01:101
B	72	Y:Y	→	10:12:01:300
G	80	Z:Z	←	10:12:01:504
D	70	A:B	→	10:12:02:002
H	90	C:D	←	10:12:02:789

The current vehicle will receive the RNTP message from the vehicle 'C'. Based on the vehicle ID and direction information the current vehicle will neglect the duplicate vehicle IDs.

B. Comfort Zone Overtaking Prediction

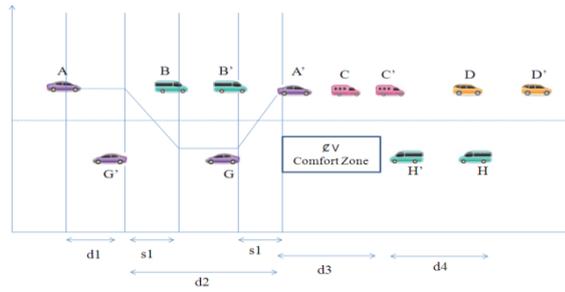


Fig 2: Comfort Zone Prediction Mechanism

In Fig 2, the vehicle A, B, C, D, G and H denotes the current location at time t_1 and the vehicle A', B', C', D', G', H' denotes the current location at time t_2 . The current vehicle (source vehicle) receives current neighbor entries and Greedy neighbor entries. By Cooperative Overtaking Sight Assistance (COSA) comfort zone mechanism. Whenever the speed of the Current vehicle is higher than the front moving vehicle then the current is eligible to overtake. The prediction algorithm will predict the Danger zone/ Safe zone boundaries prior then the intimation message is passed to the most critical zone vehicles.

$$d_1 = V_b \cdot t \quad (1)$$

Where,

V_b -Speed of slow-moving vehicle

t -Reaction time(Normally 2sec)

$$d_2 = b + 2S \quad (2)$$

Where,

$b = V_b \cdot T$

$T = \sqrt{(4S/a)}$

$S = 0.7V_b + 6$ (Spacing between the overtaking and overtaken vehicle)

$$d_3 = (V_s \cdot t) + (V_o \cdot t) \quad (3)$$

Where,

V_s =Overtaking vehicle speed

V_o =Opposite vehicle speed

$$d_4 = V \cdot T \quad (4)$$

Where,

V =opposite vehicle speed

The equation (3) indicated a Comfort Zone boundary distance in meters. If the comfort zone vehicle entry belongs to "Zero" then the overtaking begins. Before overtaking the intimation message is passed to its current neighbor entries and its greedy visitor nodes.

C. Danger Zone Boundary Limit

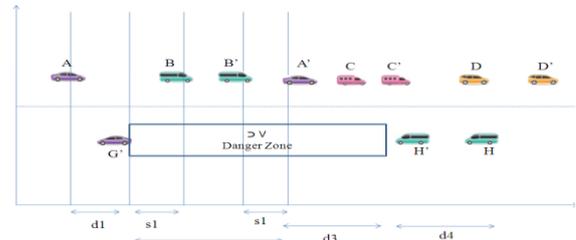


Fig 3: Danger Zone Limit

At the time of overtaking if any vehicles found in the comfort zone boundary limit then the overtaking decision can be a snooze for a while (Fig 3). The cumulative distance for the current vehicle $d_2 + d_3$ (Equation 3,4) indicates the 'danger zone' boundary. After the expiration of Time to Freeze (T2F) the vehicle can follow the same procedure to obtain a comfort zone.

V. COSA PROCEDURAL METHODOLOGY

1. Start
2. Let,
 $\forall \leftarrow$ Receive, Send Hello packets
 $V \ni \{V_{Loc}, V_K, V_R \text{ of OHNs} \}$
3. Let,
 $Overtaking \leftarrow V_s$
 $Overtaker \leftarrow V_N$
4. If (Velocity(V_s) > Velocity(V_N))
 Yes: $V_s \rightarrow$ Apply Greedy Motion Guess
 $V_N \rightarrow$ Send RNTP (Goto 5)
 No: Snooze Overtake
5. Reject: unwanted Entries
6. Inject: Cooperative Overtaking Sight Assistance (COSA)
7. If (Comfort Zone == $\emptyset V$)
 $V_s \rightarrow$ Assistance message, Safe overtake Else:
 Activate \rightarrow Time to snooze (Goto 1)

VI. RESULTS AND DISCUSSION

The COSA algorithm is examined with Network Simulator 2.34. The simulation is taking place in the 5km highway lane. The MAC protocol used here is IEEE 802.11P whereas the propagation model is TwoRayGround. The range of communication is assigned heterogeneous in which the vehicle communication range is assigned as 200 meters to 300 meters (Fig 4). The Vehicles acceleration is randomly distributed as 50km/hrs to 100 km/hrs. A source will try to send a maximum of 1052 packets from the source to the destination. The minimum connectivity Fine Threshold (F_T) with the source is assigned as 10 seconds. The message type CBR is used for the packet transmission. The packet interval rate is assumed as 0.05sec. The entire process is simulated with 150 seconds (Table 2).

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Table 2: Simulation Parameters

Parameters	Value
Simulator	NS 2.34, SUMO
Package	Vanet Mobisim
Simulation Area	5000m*5000M
MAC protocol	IEEE 802.11P
Propagation model	TwoRayGround
Hello packet interval	1sec
Minimum Vehicle speed	50 km/hrs
Maximum vehicle speed	100 km/hrs
Max Transmission Range	300m
Min Transmission Range	200m
Number of lanes	2
Packet Size	1052 bytes
Number of vehicles	50,75,100,125,150
Fine Threshold(F_T)	10 sec
Traffic Type	CBR
Packet interval	0.05sec
Routing Protocol	GPSR
Methodology	COSA
Highway Simulation time	150 sec

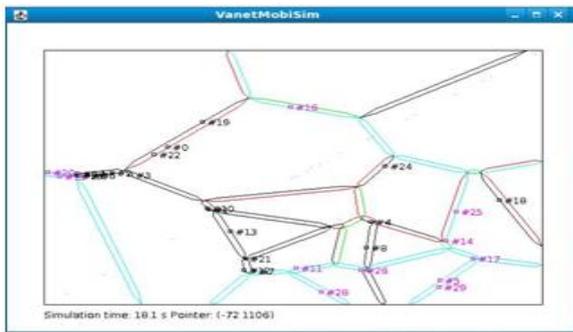


Fig 4: Vanet MobiSim Road scenario

Our new approach will greatly reduce the collision rate during the autonomous overtaking. Our simulation randomly chose 10 cars for overtaking with heterogeneous speeds. Fig 5, shows the 89.2% collision-free overtaking success rate. Whenever the number of the vehicle is less, the source-to-destination message delivery time increased. Because the assumption we made is the velocity of the vehicle varies. If no Greedy forwarder contains stable speed then, by selecting a choice will take time (Fig 6). If the number of neighbor vehicles is high then the choice of alternative selection becomes easier, so the delay time also minimized.

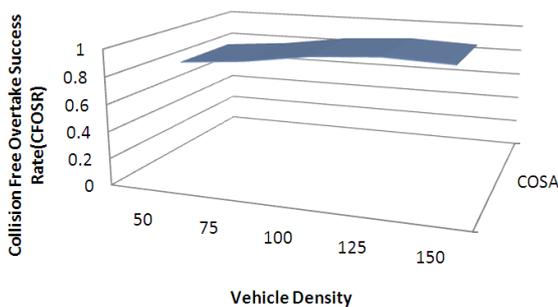


Fig 5: Collision Free overtake success Rate

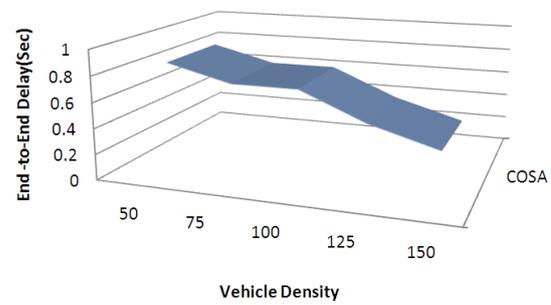


Fig 6: End-to-End delay

Our proposed strategy is compared with VEINS [11]. In some situations, the forwarder node may not present which leads to packet failure. The approach COSA has an improvement over VEINS for reduced packet error rate with 8.7% (Fig.6, Table 3).

Table 3: VEINS vs COSA Packet loss

No. of Vehicles	VEINS	COSA
50	27	20
75	29	17
100	31	20
125	44	28
150	49	34

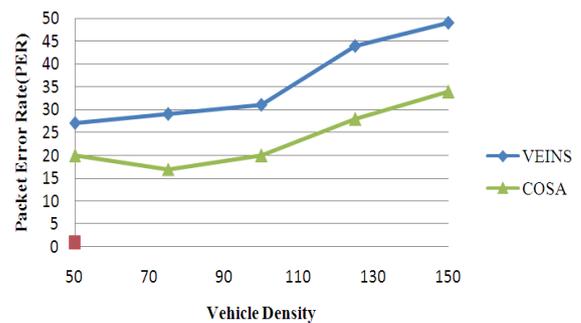


Fig 7: Packet Drop Rate Comparison

VII. CONCLUSION

The vehicular systems came into the picture for safety-related applications. One of the most trivial situations is to guide the driver at the time of overtaking. There are many things to consider before overtaking a vehicle such as the current node's speed, overtaken vehicle speed, and opposite vehicle speed. The existing literature survived various solutions but not suited due to the short communication range of the vehicles. Our methodology will incorporate the feature of motion prediction algorithm and Cooperative Overtaking Sight Assistance (COSA) to identify the Comfort Zone. Our methodology considers heterogeneous vehicle facts such as its type, speed, and range, etc. The simulation result shows a good collision-free overtaking success rate.

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