Driver Assistance System Towards Overtaking in Vehicular Ad Hoc Networks

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***Abstract*—The large number of accidents caused by unsuccessful motor vehicle overtaking manoeuvres on roads is a significant problem with much public debate and concerns. In addition, one accident might cause another follow on accident when there is no signalling/reporting of it occurring, thus causing obstructions and further accidents in the vicinity. This can seriously affect the traffic flows, generating traffic jams and sometimes resulting in more unwarranted accidents, which can be avoided with the application of technology. The emergence of wireless ad hoc and sensor technologies and their adoption in vehicular networks can provide smart solutions to mitigate the probability of accidents and avoidance of dangerous traffic flow situations. This paper presents some important concepts for an application development to assist the driver in overtaking manoeuvres with prior knowledge of oncoming traffic, even when the road curvature has blind spots. In order to do that, the application must indicate whether it is safe or not to perform the overtaking manoeuvre. To propose this application, concepts of kinematics techniques are used to model the overtaking manoeuvres and the successful simulation results show this technique to be promising as expounded in this paper.**

***Keywords*-Driver Assistance System; Overtaking; VANET; Kinematics**

I. INTRODUCTION

Vehicular Ad Hoc Network (VANET) [1] is a new mobile communication system which promises many possibilities for a new range of applications in road traffic systems. Although VANETs are a newly introduced breed of innovative network concepts and technology application, many articles have been published about them, mainly from the point of view of safety applications [2], entertainment [3] and driver assistance applications [4].

These kind of applications can facilitate the human environment interaction in avoiding unwarranted mishaps/accidents. The driver assistance applications may be used, for example, to find parking spaces [5] and report on car accidents [6]. In the entertainment area, the human environment interaction application can quickly configure and harness players within a vicinity to join a multi-player on-line game [7].

In this paper, we present a driver assistance system for overtaking using VANET. We analyse the overtaking behaviour scenarios found in the literature [8] in order to capture our fundamental requirements to define our proposed maneuvering and overtaking model based on kinematic principles. This model decides through various algorithmic conditions when the overtaking manoeuvre is safe to be performed by a driver. This analysis is a very important cornerstone for designing a smart overtaking assistant, and it is the starting point of the first step for a complete and comprehensive VANET Driver Assistance System (VANET-DAS).

We also propose an intelligent message transmission technique in order not to overload the transmission medium since time is of the essence in VANET-DAS real-time activities with very tight threshold conditions and values. The decision-making for overtaking and maneuvering must be performed only in a real situation and the application must be able to identify a real overtaking situation as and when the events unfold. We also developed a rapid report message protocol which exchanges coordinates within the VANET vicinity for the surrounding vehicles to be context-aware of what is happening in a near instantaneous manner.

The remainder of this paper is organized as follows: Section II discusses the related work, Section III gives the theoretical analysis of the overviews the overtaking manoeuvre scenarios, Section IV describes the message broadcast system used by the applications within the VANET-DAS. In Section V, the experimental environment and the simulations results are presented and discussed; and finally, the conclusion and future works are given in the last section.

II. RELATED WORK

Nowadays, there are several proposed vehicular ad hoc network applications for safer driving and road traffic management, particularly concerning overtaking [9][10][11]. However, most of them related to overtaking do not consider the entire overtaking and maneuvering process. These applications mainly focuses on vehicular lane changing process, which in our work we regard as one of the many phases in an overtaking manoeuvre. Besides, not all of these related works do this in VANET environments.

Toledo et al. [9] developed a federated cooperative system to assist in overtaking on a cellular network. The overtaking is predicted after passing through filters that have applied kinematic information based on the vehicles and road topology format. The main purpose of Toledo's work is to estimate the risk in the overtaking manoeuvre. Similarly, our work also uses kinematics to predict a favourable overtaking manoeuvre situation, but with much more precision an explicitly in VANET environments and scenarios.

The main advantage of using VANET is that it can be formed either with or without physical infrastructure other than the air waves and frequency spectrum. Furthermore, in the application developed [9], vehicles exchange messages so that the manoeuvre can be authorized to be safe. During this operation many problems can arise such as sending replying messages transfer/transmission failure; lost message updates due to time-outs and vehicle traffic reconfiguration; loss of vehicle identification; and lack of updated management information about the VANET vicinity area in question. In this developed application, the messages are transmitted through broadcasting in a non-periodic manner and also when there is a change in the speed of the vehicle.

Ruder et al. [10] developed a system using wireless sensors in vehicles to assist the lane changing process in overtaking manoeuvres. The overtaking model in this system considers two lanes flowing in the same direction and an approximating vehicle system algorithm developed for predicting safe versus unsafe overtaking manoeuvres. Different from Rude's approach, we developed a coordinated positioning message broadcast protocol among the vehicles without the use of approximating wireless sensors. In our proposed VANET-DAS, there is the advantage of knowing the position of adjacent vehicles in advance even if they are a relatively long distance away since distance is defined by the transmission range.

Hrri et al. [11] developed an overtaking maneuvering application system which handles three different ways of area information recording and maintenance:

1) Constant Degree Detection: Every node tries to keep a constant number of neighbours. When a node detects that a neighbour actually left its neighbourhood, it tries to acquire new neighbours by sending a small advertising message.
2) Implicit Detection: A node i entering node $j's$ transmission range has a high probability to have a common neighbour with j.
3) Adaptive Coverage Detection: Every node sends an advertising message when it has moved a distance equal to a part of its transmission range.

In our proposed VANET-DAS, we developed a modified version of the Adaptive Coverage Detection technique. In Hrris scheme [11], it works by sending area messages reports at each $\frac{2}{3}$ (two thirds) [11] of the transmission range from the focal point. In our VANET-DAS version, the application checks in advance if an updated positioning message is necessary to be sent while comparing the real distance travelled and the predicted one. The calculations of the predicted distance is based on the last positioning message sent.

III. THEORETICAL BACKGROUND AND ANALYSIS

According to Olsen [12], a lane change is defined as a deliberate and substantial shift in the lateral position of a vehicle, that is, when the vehicle leaves its original lane to manoeuvre towards another lane. According to Winsum et al. [13], a lane change happens in three sequential phases, considering the direction of the vehicle:

1) In the first phase, the car's steering wheel is turned to a maximum angle so that car can perform the the lane change.
2) The second phase starts when the wheel is turned in the opposite direction and ends when that angle reaches zero (always ahead).
3) During the third phase, the steering wheel is turned to a maximum angle in the opposite direction to establish the vehicle in the former lane.

Given the above definitions we can conclude that at least a minimum of two lane changes are involved in an overtaking manoeuvre. The first one shifts to one side to avoid colliding with the vehicle straight in front of it and the second one returns to the car's original lane.

According to Hegeman et al. [8] and Wilson et al. [14], an overtaking manoeuvre can be classified as:

1) Normal: The overtaker follows a vehicle and waits for a safe sufficient gap to perform an overtaking manoeuvre.
2) Flying: The overtaker does not adjust its speed to the speed of the vehicle that is to be overtaken but continues at its current speed during the overtaking manoeuvre.
3) Piggy backing: The overtaking vehicle follows another vehicle that overtakes a slower vehicle.
4) 2+: The overtaker performs the overtaking manoeuvre of two or more vehicles.

In our VANET-DAS, the overtaking scheme is based on the flying overtaking method. In the flying overtaking method (see Figure 1), the overtaking vehicle is travelling faster than the vehicle (leader) being overtaken. The faster vehicle changes lane, passes the leader and returns to its original lane without changing its speed except to ensure any distant vehicle coming from the opposite direction has sufficient distance to travel to avoid a collision (accident).

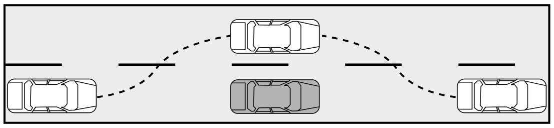

Figure 1. Overtaking using flying method

A. Kinematic-based Decision-Making

The overtaking decision takes into account the various combinations of collision possibilities with surrounding vehicles. That is, there is an appropriate and inappropriate scenario for performing the overtaking when the manoeuvre should or should not be performed according to a set of safety measures and criteria. Two characteristics of surrounding cars must be identified:

1) Position: The current position of the vehicle.
2) Mobility: The direction and speed of the vehicle.

The first characteristic, position, allows us to obtain a brief view on the network topology of the surrounding cars. In the second characteristic, mobility, it is possible to go beyond the area knowledge of the topology, so that a network actor can predict a more precise topology configuration with more detailed information.

The task of mobility prediction is a challenge that has been solved through several techniques over time:

1) Adaptive Strategy: The predictions are corrected at the end of the average predictability interval.
2) Reactive Strategy: The node notifies the neighbourhood when a criterion changed (maximum predicting error).

Hrri et al. [11] details the evolution of such mobility prediction techniques and presents several schemes/models which are currently used nowadays in overtaking and maneuvering vehicle transport systems.

1) Deterministic Models: Only considers the position and a fixed velocity.
2) Stochastic Models: They do not aim at obtaining an exact prediction, but rather a correct one with high probability.

In our VANET-DAS, the trajectory of the car is obtained through a deterministic model, which is basically first order kinetics. Our application, having knowledge of a car, at the time (t), and in the present position (x,y) can show the vehicles future position using (1) [11].

$$Pos_i(t) = \begin{bmatrix} x_i + v_x^i.t \\ y_i + v_y^i.t \end{bmatrix} \tag{1}$$

This equation (1) calculates the distance between a vehicle and every other surrounding vehicle in the vicinity at an arbitrary time t, as given in (2):

$$\begin{aligned} D_{ij} &= D_{ji} \\ &= \|Pos_j(t) - Pos_i(t)\| \end{aligned} \tag{2}$$

The development of a high mathematical fidelity model can be very complex, depending on the various variables/coefficients involved, such as speed, acceleration, air resistance, weather condition, road condition, other drivers behaviour patters and the driver's reaction time. In a real, practical, overtaking manoeuvre scenario, several factors must be considered. In our work we focus on a few essential variables and conditions namely, position and mobility, resulting in a simplified model but with equally valid outcomes.

The scenario in which the overtaking model was developed involved three vehicles, C_1, C_2 and C_3 as shown in Figure 2.

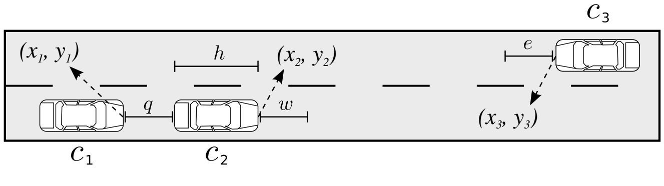

Figure 2. Scenario used in the simplified overtaking model

C_1 is travelling faster than the speed of C_2 and C_3, and their individual speeds are non-zero values. Looking at Figure 2, q, w and e are constants, and given the relative speeds, they refer to the safe distances of the respective vehicles, while h refers to the average length of an arbitrary vehicle. The current position of each vehicle is typically represented by (x_i, y_i) as shown in Figure 2 and their velocity is represented by (v_{xi}, v_{yi}), with the index i identifying each vehicle.

For overtaking decision making, it is necessary to calculate the travelled distance of the whole overtaking manoeuvre. At the end of the manoeuvre, the current car position is validated for its position and verified to identify if the manoeuvre can take place successfully within the time constraints or threshold value bounds.

As previously mentioned, in the flying model, the vehicle does not accelerate for overtaking, although in practice this would be deemed necessary if either the vehicle being overtaken decides to accelerate or the oncoming vehicle is travelling faster than expected/predicted. In our scenario, the overtaking car has a higher maximum speed than the leader and performs the overtaking manoeuvre with a constant speed. The manoeuvre itself is performed in two stages.

First Stage: there are four steps in this stage. The first step is when the C_1 vehicle is behind the leader and its first manoeuvre is positioning itself to perform lane shifting as they travel in tandem. In other words, it must travel l distance on y-axis in a somewhat diagonal lane shift manoeuvre as shown in Figure 3.

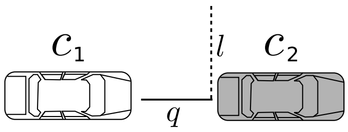

Figure 3. Distance travelled on lane shift

The second step is to move up for overtaking, C_1 needs to rotate the vehicle steering wheel making a relative angle θ between the wheels and the x-axis as shown in Figure 4. The vehicle drifts to shift into the adjacent lane. Knowing this information, the velocity components v_x^{c1} and v_y^{c1} are calculated using equations 3 and 4 respectively:

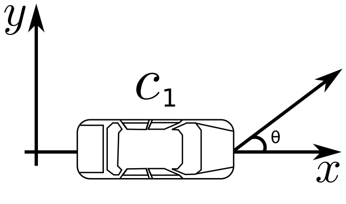

Figure 4. Angle between the wheels and x-axis on lane shift

$$v_x^{c1} = v_{c1} \cdot cos(\theta) \tag{3}$$

$$v_y^{c1} = v_{c1} \cdot sin(\theta) \tag{4}$$

The 3rd step is to calculate the time (t_1) and distance travelled (s_1) by C_1 during the lane shift. This is calculated using 5 and 6 respectively:

$$t_1 \quad = \frac{l}{v_y^{c1}} \tag{5}$$

$$s_1 \quad = v_x^{c1} \cdot t_1 \tag{6}$$

In the final step, it is necessary to calculate the remaining C_1 vehicle's distance (r) so that the C_1 vehicle's front is paired with the C_2 vehicle's back as shown in Figure 5. This is calculated using 5.

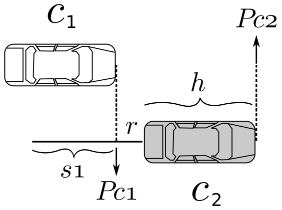

Figure 5. Remaining distance of C_1 so that C_1's front is paired with the back of C_2

$$r = \|Pos_{c2}(t_1) - Pos_{c1}(t_1)\| - h \tag{7}$$

Second Stage: C_1 must pass C_2. In order to achieve this, C_1 has to travel a minimum of $2 \cdot r + 2 \cdot h$ distance as shown in Figure 6.

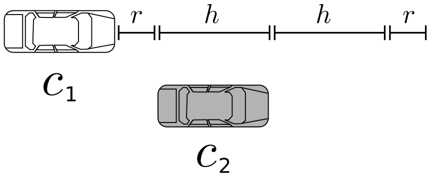

Figure 6. Distance travelled by C_1 to safely pass C_2

The time spent in the second stage overtaking manoeuvre (t_3) is calculated using (8):

$$t_3 = \frac{2 \cdot r + 2 \cdot h}{\|\vec{v}_{c1} - \vec{v}_{c2}\|} \tag{8}$$

and the travelled distance (s_3) is calculated using 9:

$$s_3 = \vec{v_{c1}} \times t_3 \tag{9}$$

For C_1 to return to its original lane side, the same values are used (time and travelled distance) that are calculated during the first stage overtaking manoeuvre move (Figure 7).

After obtaining s_1 and s_3, the total travelled distance by C_1 during the overtaking manoeuvre is calculated by using $s_t = 2 \cdot s_1 + s_3$.

To check if the overtaking can be performed safely, the time must be calculated so that C_1 will be in a safe position with sufficient leeway to move into the original side of its lane with a drift of θ degrees as shown in Figure 8.

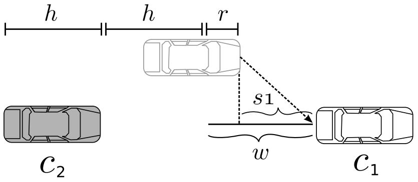

Figure 7. Travelled distance for C_1 returns to its original lane

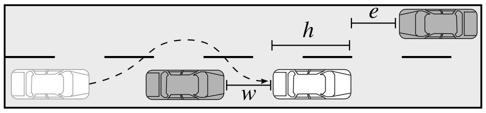

Figure 8. Desired position of C_1 after it complete the whole overtaking manoeuvre

To achieve this drifting position in a safe manner with collision avoidance, the following equation (10) must be solved:

$$t_4 = \frac{\|Pos_{c2}(0) - Pos_{c3}(0)\| - w - h - e}{\|\vec{v_{c2}} + \vec{v_{c3}}\|} \tag{10}$$

such that the distance travelled by vehicle C_1 is calculated (s_4) during the overtaking manoeuvre in t_4 seconds.

For making the kinematic-decision for safe collision-free overtaking manoeuvre, s_t and s_4 are compared. If the s_t value is lower than the s_4 value, overtaking is allowed to proceed safely within the threshold bounded values of all the other related variables/parameters.

B. *Overtaking Situation Detection*

The detection of the overtaking situation is important in our VANET-DAS. It is a trigger for the calculating process to validly detect the overtaking situation using the kinematic decision-making principle based on three conditions:

1) Overtaking intention.
2) Passing vehicle is really behind the leader at a safe distance.
3) Check if the vehicles are travelling in the same direction.

The first condition refers to the overtaking intention value represented by γ (gamma). For each vehicle in our VANET-DAS, there is an associated value for the overtaking intention over a period of time. The γ value is represented by a real number in the interval $[0, 1]$, where 0 denotes null overtaking intention and 1 denotes maximum overtaking intention.

A vehicle overtaking intention γ_i at time t is calculated using (11).

$$\gamma_i(t) = \frac{E}{D_{ij}(t) + E} \tag{11}$$

where $D_{ij}(t)$ refers to the distance of vehicle i to the closest vehicle j and E refers to the sum of the safety distances q and the length h of a vehicle, in other words, $E = q + h$.

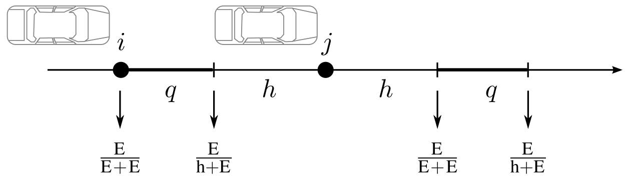

Figure 9. Range of values for overtaking intention

This condition is true when $\frac{E}{E+E} \leq \gamma \leq \frac{E}{h+E}$ holds, and it is equal to the line in bold represented in 9.

When the vehicle i is at a safety distance of E meters from vehicle j, the overtaking intention will be $\frac{E}{E+E} = \frac{E}{2E} = 0.5$ and when i is at h meters of j the overtaking intention will be the maximum safety limit allowable. For example, when when $h = 8.0$ and $q = 33.3$, $\gamma = \frac{33.3+8.0}{8.0+33.3+8.0} = 0.83$.

The second condition is used to ensure that the overtaking is really behind the leader at a relatively safe distance. For this condition, it is necessary to calculate the angle between the vehicles as shown in Figure 10.

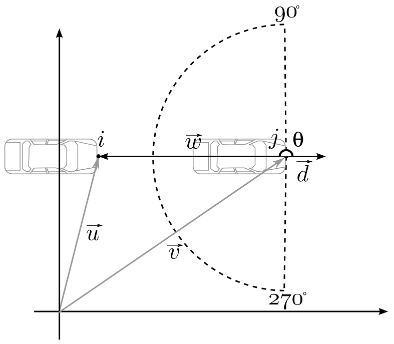

Figure 10. Angle between direction vector of j and vector w

In Figure 10, $\vec{u}$ and $\vec{v}$ are positioning vectors of vehicles i and j respectively and $\vec{w}$ (vector difference) is derived from $\vec{w} = \vec{u} - \vec{v}$. Therefore, to ensure that vehicle i is behind vehicle j, the angle between $\vec{w}$ and $\vec{d}$ should be in the 90 to 270 degree range, i.e., $90 \leq \theta \leq 270$.

The third (last final) condition is used to check if the vehicle i and j are travelling in the same direction. For this condition, it is sufficient to check the angle between the direction vectors of i and j as illustrated in 11.

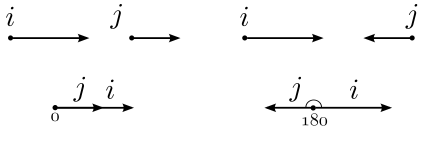

Figure 11. Angle between vector direction of vehicle i and j

If the angle between direction vectors of i and j is between the interval $[\theta, 360 - \theta]$, as shown in Figure 12, the last condition is satisfied.

Finally, it can be stated that if all three of the above mentioned conditions are fulfilled, then a valid safe overtaking maneuvering situation holds true.

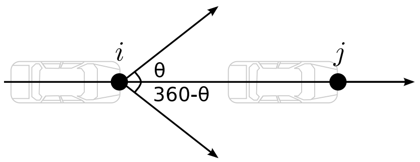

Figure 12. Interval for identifying when two vehicles are travelling in same direction.

C. Positioning Messages

In a vehicular safety application in a VANET environment, the message exchange among vehicles is an important operation, which itself must be very explicit to avoid any misrepresentations and misinterpretations. Each device within the vehicle must be able to predict a safe situation for an overtaking move. For this to happen without overloading the network with unnecessary network transmission traffic, it is necessary to ensure that the transmission medium is used in a smart and efficient manner. In other words, the application should use the transmission medium only when necessary within very stringent/tight command and response round-trip delay threshold value bounds. For this, we are using a scheme in which the predicted position is compared periodically to the real-life position. If there is a significant difference between these values, a new message is broadcasted to all surrounding vehicles with in its vicinity range.

When a vehicle is moving, the distance to be covered before broadcasting a mobility message (since vehicles are typically dynamically moving) is defined how $\frac{2}{3}$ (two thirds) of the transmission range. With this distance and the vehicle speed, one can easily predict the time during which a new broadcast should be performed (that is predicting t). The interval between the initial time and the predicted time is divided into seven equal time intervals as shown in Figure 13.

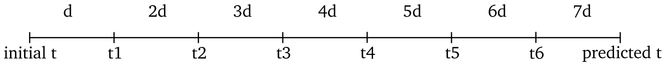

Figure 13. Intervals of time for checking if it is necessary to send a new positioning message.

After each interval t_i, a comparison between each vehicle's real position (P_a) and its predicted position (P_p) is performed, and if the absolute difference between P_a and P_p is greater than a sufficiently small value, ϵ (epsilon, $\epsilon = 0.5$), a new message is broadcasted to all the vehicles in the vicinity. This scheme of the broadcasting method has been devised to ensure that our VANET-DAS does not broadcast unnecessary messages by consuming transmission and device processing capacities. In overall system and network management terms remain efficient within the constraints of the dynamic real-time environment of a VANET.

IV. SIMULATIONS AND RESULTS

The experiments were performed using Network Simulator ns2, version 2.34 [15] using an Intel Core i3 CPU 2.13 GHz computer with GNU-Linux Ubuntu 11.04 [16]. Our VANET-DAS application was modelled and developed as a set of mobile agents to reflect the vehicles in a transport environment as shown in Figure 14. Each device in then simulation used Nakagami propagation model [17] and $1,000$m transmission range.

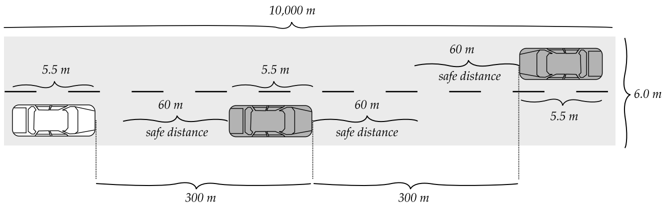

Figure 14. Simulated real-life like environment

The surrounding vehicles data is stored in an optimized table-lookup data structures, which provide both rapid searchs and update using C++ programming with the Standard Template Library (STL) [18] functions for it.

The mobile agents representing the vehicles (devices of a VANET) were established through a common higher-level controlling meta-agent which generates a log file that provides data about safe and unsafe overtaking situations for each of the vehicles in the experiment. This log file is filtered to identify the devices in each vehicle during the overtaking maneuvering and inter message exchange operations being simulated.

We analyse and evaluate the data collected from the simulation runs to assess the vehicles' behaviour for two functionalities of our VANET-DAS:

1) Broadcasting
2) Overtaking Situation Detection

And finally, we also analyse the reliability of the VANET-DAS application itself. The results are given below.

A. Broadcasting Results

As shown in Figure 15 it is possible to identify that the VANET-DAS application works well, for example, when a vehicle moves with a constant 20 m/s speed during 100 s and $1,000$ m transmission range, the application sends a report message at each 666.67 m.

In this case, three messages are sent when the vehicle is at 666.67 m, $1,333.33$ m and $2,000$ m respectively, stating from an initial position and a single last message is sent in the initial simulation point, totalling four messages. Similarly, behaviour is also identified in our other simulation runs. Therefore, the VANET-DAS application has an expected behaviour because it sent positioning messages at expected positions.

B. Overtaking Situation Detection Results

In this experiment, we observed and checked the overtaking detection operation using our VANET-DAS simulated scenario where a vehicle (C_1) is 155 m from another vehicle (C_2) and they are 32 m/s and 14 m/s apart respectively. C_1 is approaching C_2 position and is approximately 41.3m behind when C_1 starts the overtaking manoeuvre in three stages:

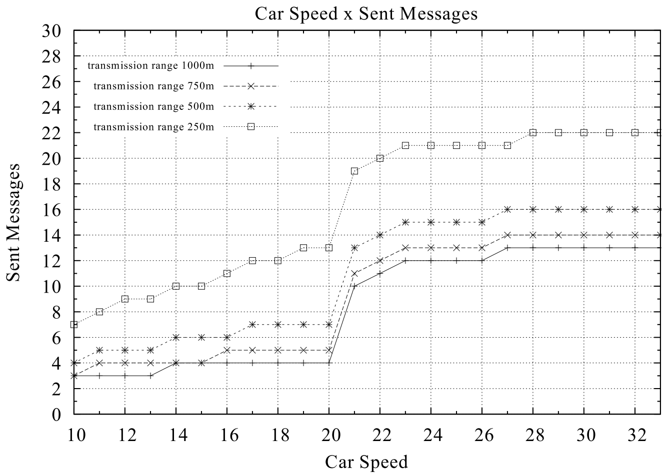

Figure 15. Amount of sent messages as a function of vehicle's speed and transmission range

1) Lane shift;
2) Overtaking; and
3) Returning to the original lane

Figure 16 shows the detection of time of the overtaking manoeuvres. At x-axis, its pointed is determined as 0 when the method does not detect an overtaking, and it will be 1 when an overtaking is detected.

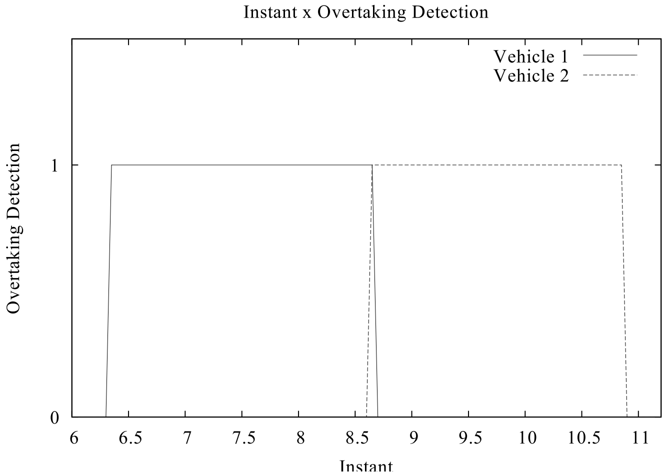

Figure 16. Instants which has detected overtaking situation

In order to demonstrate and validate if the results obtained in the experiment are consistent, as illustrated in Figure 16, we used 14 to calculate the instant (horizontal axis) when the vehicle C_1 is q meters close to vehicle C_2:

$$S_{C1}(T) = S_{C2}(T) - q - h \tag{12}$$

$$x_1 + vx_1T = x_2 + vx_2T - q - h \tag{13}$$

$$T = \frac{x2 - x1 - q - h}{vx_1 - vx_2} \tag{14}$$

Defining $q = 33.3$ and $h = 8.0$, we get $T = 6.31$ seconds, we notice in Figure 16 that at this point an overtaking situation was detected.

C. Reliability of the Application

The main goal in this experiment is to validate the application operation in different scenarios of our VANET-DAS. In each scenario, the vehicle C_1 is placed randomly behind C_2 and C_3 placed randomly in front of C_2 as shown in Figure 17.

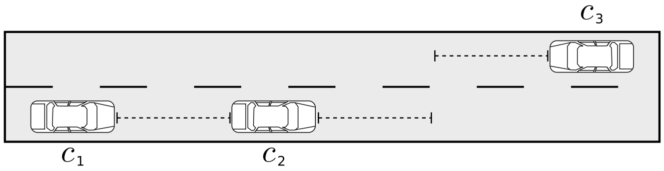

Figure 17. A random placement of vehicles simulation scenario

The vehicle's speed is chosen randomly as follow:

1) C_2's speed is chosen between the range of 16 m/s and 25 m/s.
2) C_1's speed is chosen between the range of C_2s speed plus 5 m/s and 30 m/s.
3) C_3's speed is chosen between the range of 16 m/s and 30 m/s range.

Using these parameters, $1,000$ different scenarios were created and in each scenario the time in which C_1 passes C_3 (t_c) is checked. To confirm the application accuracy, two times are identified in the overtaking manoeuvre. The first time detection happens when C_1 is behind C_2 at a distance of $q+h$ meters (t_1) and the second time detection when C_1 is in front of C_2 at the distance of $h+q$ meters (t_2) as shown in Figure 18.

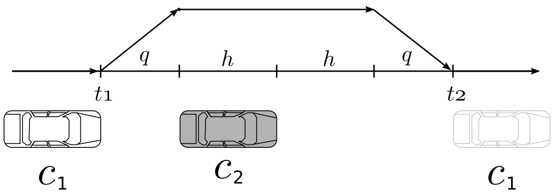

Figure 18. The times t_1 and t_2 times in overtaking manoeuvre

Thus, we can safely conclude that the VANET-DAS application should work correctly when any one of the following conditions are met:

1) If t_c is lower than t_1 it is expected that the application will not send any message because it has not detected an overtaking situation.
2) If t_c is between t_1 and t_2 the application is expected to indicate that an overtaking cannot be performed safely.
3) If t_c is greater than t_2 one can expect that the application indicates that overtaking can be safely performed.

At each iteration of the experiment, we compared the instant t_c with times which the application generates alerts of overtaking permission or prohibition. We found that the application returned the expected messages in 99% of the cases in our experiments.

V. CONCLUSION AND FUTURE WORKS

The research work discussed in this paper presented some fundamental concepts for an application development in the VANET environment to assist drivers in overtaking manoeuvres safely. Using kinematics and a positioning mechanism with an efficient messaging communication protocol, it is possible to develop a real-life application system capable of predicting safe overtaking manoeuvres with minimum near collision or no accident risk and without overloading the VANET data transmission medium.

Despite using controlled scenarios and without considering the driver's unpredictable behaviour pattern, the application has promising characteristics for an actual application development to assist overtaking in real-life systems for modern traffic systems. In particular, as shown from the result, the application can detect an ongoing overtaking manoeuvre operating in an efficient message data transmission VANET environment with a near 99% reliability.

As shown from the result, the application can detect an ongoing overtaking manoeuvre saving CPU processing. Moreover, the system could predict 99% of simulated situations.

In our future research work, we intend to improve the broadcast mechanism analysing the balancing act between position checking interval and the positioning errors in which the checking intervals are not constant but dynamically set according to the vehicle positioning and vehicle space prediction error margins and travelled distance between message broadcast periods. It is considered a difficult problem to solve because it is desirable to increase the travelled distance by the vehicle before sending a new message report to save on transmission overheads. This requires a critical balancing act between the two conflicting goals of safe distance between vehicles and active communication (without loss of message communication) in the VANET vicinity transmission range. It is also necessary to reduce the positioning error between the predicted and real vehicle positions.

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