CHAPTER ONE

INTRODUCTION

1.1 Introduction

Road accidents have become a common occurrence today. Every year thousands of people die in road accidents, some people are lucky to get away with few scratches and some people tend to suffer serious injuries due to road intersection collision. Vehicular Ad hoc Network (VANET) is a special kind of network that focuses on the safety of users and to reduce the accidents. VANET provides many potential applications that are used to fulfill basic user safety requirements.

Vehicular ad-hoc network is subset of Mobile Ad hoc Network (MANET) in which vehicles could communicate with each other on the road and the intention of this network is to solve traffic problems. Motivation behind the V ANET is to provide safety to users.

Pure vehicle to vehicle ad hoc network (V2V) communication is a first type of communication in VANET, in which vehicle communicates to another vehicle. It is a kind of standalone communication and there is no support of proper infrastructure. In second type of communication vehicles depend on permanent infrastructure for sending and receiving safety or non safety messages, it is called vehicle to infrastructure (V2I) communication.

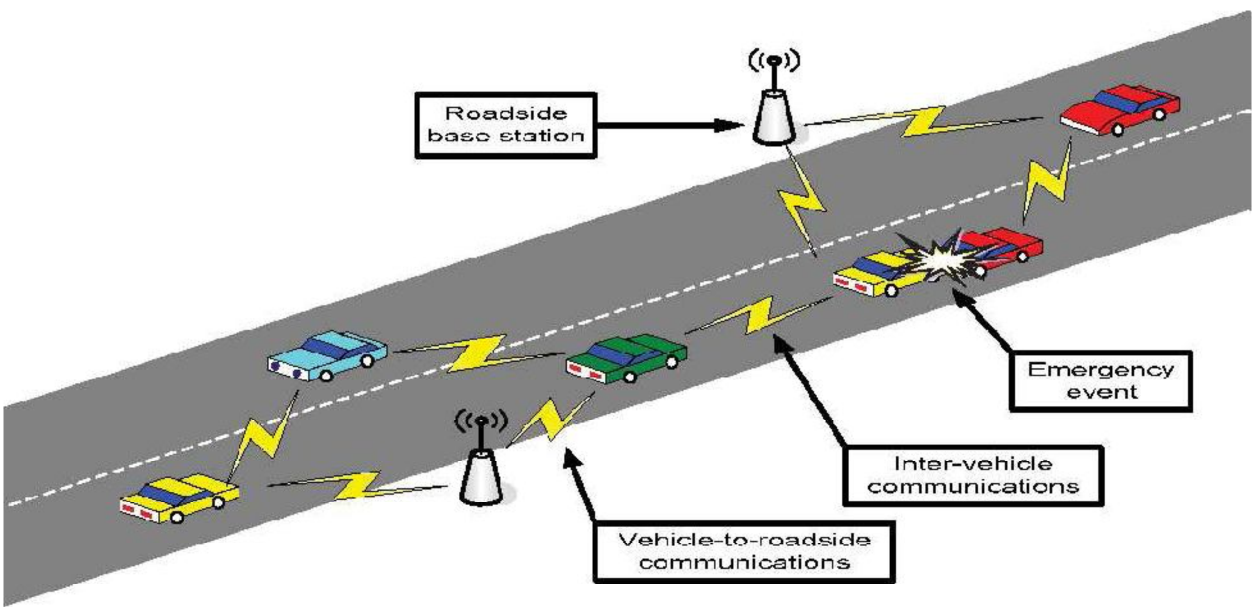

Figure 1.1: Basic Architecture of VANET.

Every year, approximately 1.27 million people are died over the globe in traffic accidents and about 50 million people are seriously injured [1]. According to National Highway Traffic Safety Administration, figure 1.2 indicates some of the consequences of recent car accidents. [2]

• 6.3 million Police reported traffic accidents

• 43,000 people were killed

• Millions of people were injured

• The economy effects caused due to these accidents were more than $230 billion

	Fatal		Serious		Minor		Without-Injury	Total No.Of Acciden d
Year	No.Accidents	No. of Dead	No. of Accidents	No. of Injured	No. of Accidents	No. of Injured		
2001	260	202	210	241	1479	1019	242	
2002	293	309	186	201	1331	1714	171	
2003	305	324	168	214	1360	1478	94	1927
2004	348	364	270	303	1383	1529	112	2113
2005	334	344	284	209	1215	1342	146	1979
2006	360	372	309	338	1257	1408	197	2123
2007	403	414	406	462	1352	1575	186	2347
Up To 30 Sep 2008	303	343	413	487	792	937	153	1688

Figure 1.2: Motor Accidents statistic from 2001 to 2009.

1.2 Problem statement

Overtaking maneuver is the most dangerous road maneuver because of its serious consequences which cause vehicle damages, serious injuries and even life lost. These vehicle road accidents caused by overtaking maneuvers are increasing especially in high ways. The main reasons for such type of accidents are, 1) deriver miss estimation to the distance between vehicles and 2) lack of visual coverage that the driver can't see vehicles approaching from reverse direction especially in curves. To solve this problem, a safety-overtaking application will developed to help in overtaking decision making.

1.3 Objectives

The main objectives of this research are:

1. Finding mathematical equations that can help reducing overtaking accidents.
2. Design an algorithm that can decide whether the overtaking is safety or not.
3. Implement the safety algorithm in VANET simulation environment.

1.5 Importance of research

The importances of this research are:

1. Improve overtaking decision making in order to avoid overtaking accident and save live.
2. Save from monetary lost that happened when car damaged by collision.
3. Save time and resources needed that will be needed to remove collide vehicles.

1.4 Scope

This research will cover the overtaking maneuver situations when there is only one vehicle ahead the overtaking vehicle with fixed length and do not take in its considerations when there are:

1. More than one vehicle to overtake.
2. Long vehicles like buses.
3. Variable length vehicles like trucks, which it may have single or double trails.

1.6 Research organization

This research will contain six chapters; the first chapter is an introduction. Chapter two is background for VANET protocols and different applications types in VANET. Chapter three is related work and chapter four is the methodology used for solving the problem. Chapter five is a result for different simulation scenarios, and chapter six is conclusion and future works.

CHAPTER TWO

BAKGROUND

2.1 introduction

This chapter will provide a background in VANET's protocol stack and its architecture and the different types of VANET applications.

2.2 VANET architecture and protocol stack

Intelligent transportation system (ITS) provides a set of standard for vehicular communications which describe how vehicle to vehicle (V2V) and vehicle to infrastructure (V2I) takes apart. It used for developing safety, non-safety/traffic efficiency and infotainment related applications.

The components of a VANET enabled vehicle include computer controlled devices and radio transceivers for message exchange. The protocol that has been standardized for communication in VANET is DSRC, which has a communication range of 300 meters to 1 km. The roadside base station provides information to the driver throughout his journey so that he can find a best route to his destination. The information is periodically exchanged.

2.2.1 Dedicated Short Range Communication (DSRC)

In 1999, the U.S. Federal Communication Commission (FCC) allocated 75MHz of Dedicated Short Range Communications (DSRC) spectrum at 5.9 GHz to be used exclusively for vehicle-to-vehicle and infrastructure-to-vehicle communications. The primary goal is to enable public safety applications that can save lives and improve traffic flow. Private services are also permitted in order to spread the deployment costs and to encourage the quick development and adoption of DSRC technologies and applications. DSRC is a free but licensed spectrum. It is free since the FCC does not charge for usage of that spectrum but it is licensed which means that it is more restricted in terms of its usage [3].

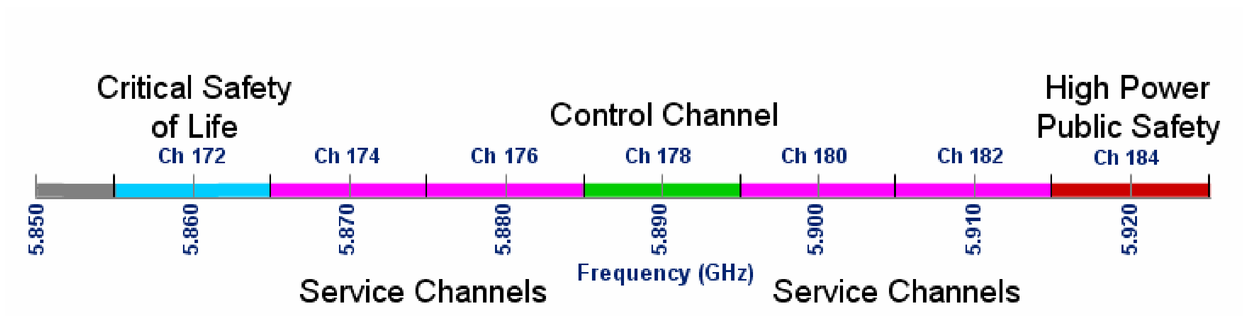

Figure 2.1: DSRC spectrum band and channels [4].

The DSRC spectrum is structured into seven 10 MHz wide channels. Channel 178 is the control channel (CCH), which is restricted to safety communications only. The two channels at the ends of the spectrum band are reserved for special uses. The rest are service channels (SCH) available for both safety and non-safety usage.

2.2.2 IEEE 802.11p WAVE

IEEE introduced a complete protocol stack of 1609 protocol family and named it as WAVE (Wireless Access in Vehicular Environment). There are six sub-standards under 1609 family named as IEEE 1609.1,2,3,4,5,6. Each one handles different issues at different layers. Fig. 1 provides an insight into the six sub-standards and their relationship with respect to the tasks at the various OSI layers.

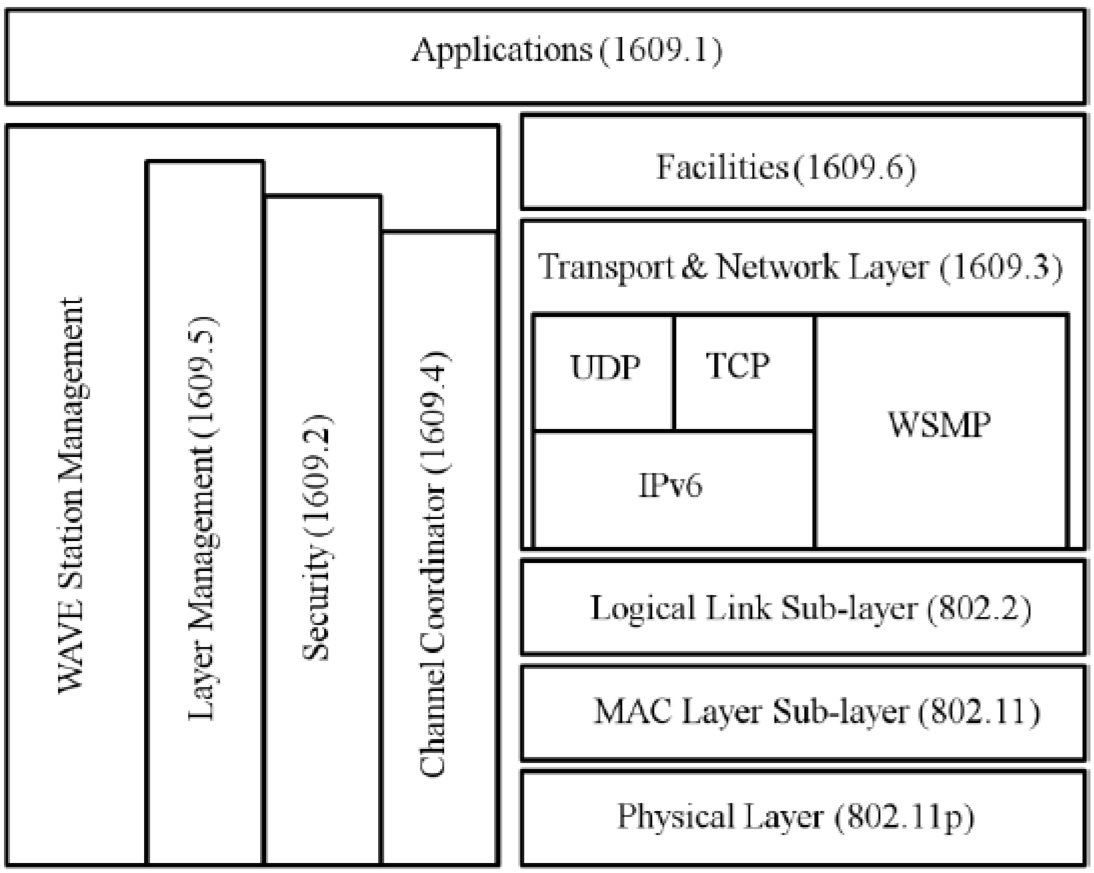

Figure 2.2: WAVE Architecture [4].

The types of applications are divided into two main categories as defined by IEEE 802.11p [4]:

i. Safety
ii. Infotainment.

IEEE 1609.1 details the management activities required for the proper operation of the applications. 1609.2 describe the considerations to be taken into account for communication security. For Transport and Network Layer handling of traffic safety related applications, 1609.3 provide a dedicated single protocol, named as WSMP (Wave Short Messages Protocol). 1609.4

define the coordination between the multiples channels of the spectrum. 1609.5 deals with Layer Management while 1609.6 offers an additional middle layer between transport and application layer, for handling of additional facilities at the Applications Layer.

IEEE 802.11p details the MAC Layer operation of the WAVE architecture. Vehicular nodes in VANETs can move very fast, leading to fast topological changes. WAVE uses two available services sets for network topology handling. WAVE Basic Service Set (WBSS) is defined for communication between RSUs and OBUs and closely resembles the 802.11a specifications for communication of nodes with the Access Points (AP). After listening to a beacon message, any new user can join WBSS without authentication process. The second service set is called WAVE independent basic service set (WIBSS). This service set supports the communication between two nodes in a mesh network i.e. V2V communication without the involvement of an RSU.

IEEE WAVE allows only one option at the MAC layer, i.e. 802.11p. Though this restricts the degree of freedom of research activities, open source simulators, like NCTUns, often provide extended protocol stack support, which assist researchers to use other options at the MAC layer as well. However, here it must be noted that 802.11p is based on a time tested standard (802.11a) which has proven its suitability for short range communications.

2.3 VANET applications

There are different types of VANET applications but they are mainly divided into two main categories, safety and non safety applications.

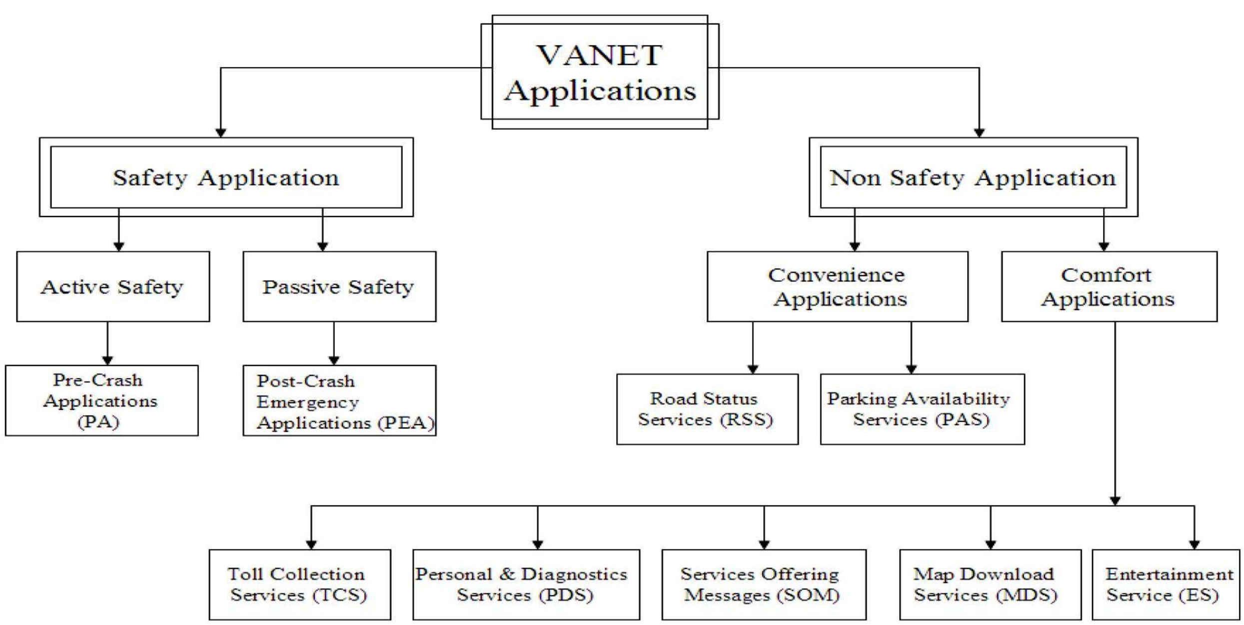

Figure 2.3: VANET Applications [5].

2.3.1 Safety Applications

The VANET is very important part of intelligent transport system (ITS). Safety application is the most important application of V ANET because it is directly related to users and its priority is high due to human life saving factor. The main goal of safety application is to provide safety of vehicles and its passengers from road accidents. Safety application is divided into two types that are active and passive safety applications [5].

1) Active Safety Applications

   Today active safety application can help to prevent accidents and work as pre crash applications. Active safety applications are based on control functions and the purpose of this to exchange the sensor data or status information between the vehicle to vehicle (V2V) and vehicles to infrastructure (V2I) communications. The goal of sending this kind of information to users is to react accordingly and avoid the accident. Antilock Brake System (ABS) and Electronic Stability Program (ESP) are examples of active safety system. Safety application provides a vehicle advisor called stop/slow vehicle advisor (SVA) in which stop or slow vehicle will broadcast waning message to its neighborhood or communicated to all other vehicles in case of any accident or congestion. Using of these information we have divided into three parts that is give below.

   a) Assistance

      It provides support by sending of following information.

      - Navigation Information
      - Collision Avoidance on the road
      - Lane Changing of Vehicles

   b) Information

      It provides information about speed limit on the road and work zone area on the highway.

   c) Waning

      This kind of application provides waning related information to drivers such like that post crash notification, obstacle waning and also give waning about the condition of the road. Vehicle Safety Communication Project was classify the intelligent safety applications and divided into following five major parts.

      - Intersection Collision Avoidance
      - Public Safety
      - Sign Extension
      - Vehicle Diagnostics & Maintenance

- Information from the other Vehicles

2) Passive Safety Applications

   Passive safety applications work inside the vehicle and protect the passengers against injury in the event of accident. Safety belt and air bags are the examples of passive safety applications. Passive safety applications cannot provide help to avoid accidents. But these kinds of applications are very useful in case of accident, criminal attacks, find the exits location of the users and provide services to effected peoples. Post crash emergency applications are a subset of passive safety applications.

2.3.2 Non Safety Applications

Non safety application can be divided into two major parts that are given below.

1. Convenience Applications
   Convenience applications are consist of two parts which is given below.
   a) Road Status Services (RSS)

      It provides an information about the road if any kind of problem on the road. Basic task is to detect and notify about the congestion on the road and sends this information to other users. Using this kind of information, other users on the road can adopt alternative route. This is very important application of V ANET, using these information people can save their time and also fuel.

   b) Parking Availability Services (PAS)

      It provides the clear picture of the empty slot for parking in specific geographical area. It provides the safety of your vehicle and save your time by finding an appropriate parking place in the shopping malls, restaurants and sport complexes.

2. Comfort Applications

   Comfort applications are related to user entertainment and these applications should not interfere with safety applications. The role of non safety applications is to comfort the passengers and to improve the traffic system. These applications also provide the opportunities to setup their business near the highway such as announcement of services. These applications are divided into the following five classes.

   a) Toll Collection Services (TCS)

      Toll collection is the time consuming task on the road. V ANET makes it easier as one can pay toll without stopping your vehicle. Toll collection mechanism is so easy; node passes from the toll point and toll collection point scans the Electrical License Plate (ELP) of the vehicle and issues the receipt message. Toll amount, time and location are mentioned in the receipt message.

b) Personal and Diagnostics Services (PDS)

It provides help to users to download or upload personalized vehicle setting or vehicle diagnostics to infrastructure (V2I) or from the infrastructure (I2V).

c) Services offering Messages (SOM)

It provides services in a specific range and passes messages to near users about the restaurant, shopping mall, gas station, and hotel while traveling on the highway. Stationary gateway will be developed for sending such kinds of marketing information (restaurants, shopping mall) to highway users.

d) Map Download Services (MDS)

It is type of portal that provides valuable information about a certain area where you are driving. Maps are available and can be downloaded from mobile hotspots area or home station about the specific location. This service is very helpful for the tourist to find some tourist places in specific region.

e) Entertainment Service (ES)

During your journey if you are interested to watch any movie or favorite program you can ask for ES of his favorite movies or any other program. These types of V ANET applications make your journey more enjoyable than in the past. Fig 4 shows the summary of all safety and non safety applications.

CHAPTER THREE

LITERATURE REVIEW

3.1 Introduction

This chapter will review some papers that related to the subject of the research and the differences between these works.

3.2 Real-time Video Stream Overtaking Assistance

Alexey Vinel, Evgeny Belyaev, Karen Egiazarian and Yevgeni Koucheryavy they provided a paper in IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY (JUN 2012) titled by "An Overtaking Assistance System Based on Joint Beaconing and Real-Time Video Transmission". In this paper they provide a model that enhanced the overtaking assistance system by combining between real-time video streaming and the exchange of status message (beacons). The first system, real-time video streaming, its assist the overtaking vehicle by provide the driver by a live video stream from alive camera attached to the front vehicle/overtaken vehicle. The second system it use beaconing, it send beacons that include position, speed and direction, that from it the overtaking vehicle can find out if there is any vehicle came from reverse direction. The drawback of the beaconing system that is provide less information, and in the real-time video stream the drawback is if there is many VANET-enable vehicle that increase the load of the multiple access channel used. So they will combine between the two overtaking assistance systems by use the beacons information to guarantee acceptable quality of video stream.

"In this paper, we propose a joint overtaking assistance system, which relies on the fact that the information about the oncoming traffic obtained from the beacons and received on the CCH is available on the encoder before the SCH degradation occurs. This way, the system is able to provide low end-to-end latency and acceptable visual quality, even during the period when platoons are approaching, which is the most critical time from the overtaking assistant application perspective.

The contributions of this paper are summarized as follows.

1) We introduce the novel concept of a coupled overtaking assistance system based on beaconing and real-time video transmission.
2) We develop a mathematical framework for evaluation of the performance of the system.
3) We characterize the benefits of the proposed approach for the H.264/AVC video coding and IEEE 802.11p/WAVE communication standards.

Operation of the proposed joint beaconing and video-based system is shown in Fig. 10 for the typical case shown in Fig. 1. It consists of the following steps:

1) Vehicle 1 receives from vehicle 3 the beaconing information, which contains its velocity V and current distance x. This information is used by vehicle 1 to predict the changes of the SCH throughput during the approach of the platoons, as explained in Sections IV-B and C. From Figs. 11–13, one can see that the SCH throughput rapidly decreases with the

decrease in distance x. Independently of the propagation model, the SCH throughput of the leading vehicle is decreased by a factor of two, which makes it important to adapt the video rate according to the channel load. As illustrated in Section III, this can be done well in advance by the use of beaconing information.

2) The video rate controller selects quantization step $\Delta(k)$ N for each slice to minimize the expected end-to-end distortion, as discussed in Section IV-D. The influence of the quantization step on end-to-end distortion is shown in Fig. 14. One can see that improper choice of the quantization step leads to serious visual quality degradation.
3) Video information captured by vehicle 1 is compressed by video encoder using the selected quantization step and transmitted to vehicle 2, where it is displayed to the driver. The visual quality in vehicle 2, for the cases when beacons from vehicle 3 are successfully received by vehicle 1, as well as without beaconing information, are shown in Figs. 15–17. One can see that when beaconing information is not used, the video quality becomes unacceptably low. If the beacons are available and the video rate is adapted according to the channel throughput early enough, then this guarantees acceptable quality during the overall time period of the approach of the platoons.

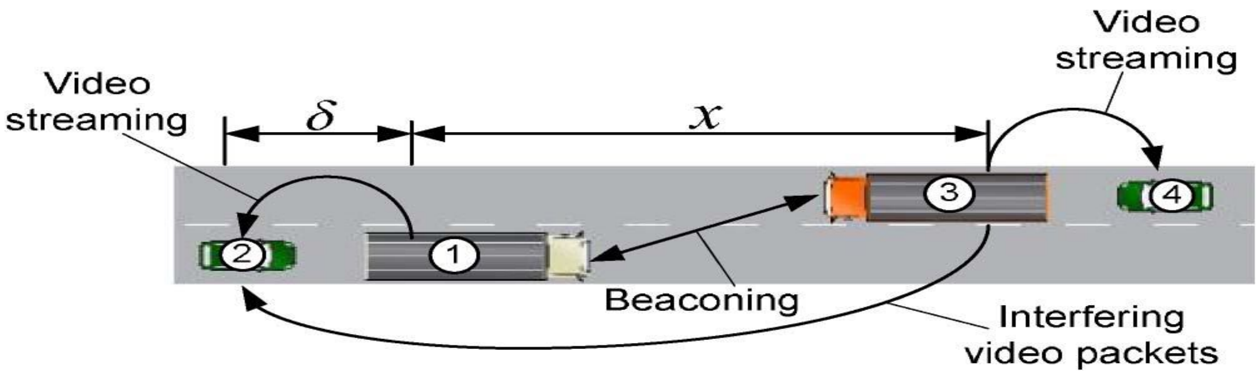

Figure 3.1: Overtaking scenario studied.

Figure3.2: Sudden danger scenario studied.

Up-to-date proposals for cooperative overtaking assistance systems rely on either the beaconing of status messages or real-time video transmission. The beaconing-based system provides limited information to the driver about the upcoming traffic in the form of warnings. Introduction of the video based system can extend the amount of driver information, thus increasing the reliability of the assistance. However, when two platoons of vehicles are meeting each other, the quality of the video information can undergo significant degradation since a common multiple-access communication channel is used. Our proposal gives the guarantee of low latency and acceptable visual quality by making use of the additional information obtained from the beaconing [6]. ”

3.3 Autonomous Vehicles for Overtaking Maneuver

Jose E. Naranjo, Carlos Gonzalez, Member, IEEE, Ricardo Garcia, and Teresa de Pedro they provide a paper in IEEE TRANSACTIONS ON INTELLIGENT TRANSPORTATION SYSTEM (2008) titled by “Lane-Change Fuzzy Control in Autonomous Vehicles for the Overtaking Maneuver”. They built an automation system of an overtaking maneuver by using automated vehicles with fuzzy controller. Their scenario consists of two vehicles, the first one is the overtaking vehicle and the second one is the overtaken, which moves in the same direction. They built and automated vehicle that can perform overtaking maneuver by first perform lane change to the right, passing the overtaken vehicle and change lane to left. The only drawback of their design that they aren’t taking in their consideration the approaching vehicle from reverse direction.

“After the steering wheel of a vehicle has been automated, it can do more complex maneuvers that may require high-level planning and information-sharing cooperation among vehicles that are circulating along the same stretch of the road. Automatic parking [15], obstacle avoidance, intersection automatic management, and overtaking, which is the maneuver studied in this paper, are some examples of this kind of cooperative autonomous driving. There is a lot of literature, as well as research projects, related to the lane-change issue, which has mainly been generated by the California PATH Program. In [6], a lane change is used to get an autonomous vehicle to automatically leave or join a platoon of unmanned vehicles circulating in a different lane. This paper describes a control system for lane keeping and lane change.

From the point of view of complexity, there is a clear difference between a simple lane-change maneuver and an overtaking maneuver. An overtaking maneuver is a sequence of a lane-change maneuver, a path tracking along the new lane, and a return to the original lane; it requires a much greater degree of planning. First, there is the decision whether to initiate an overtaking maneuver. Then, after deciding that the maneuver is possible and necessary, the sequence of partial maneuvers is to be coordinated, so the vehicle returns to the original lane as soon and as safely as possible.

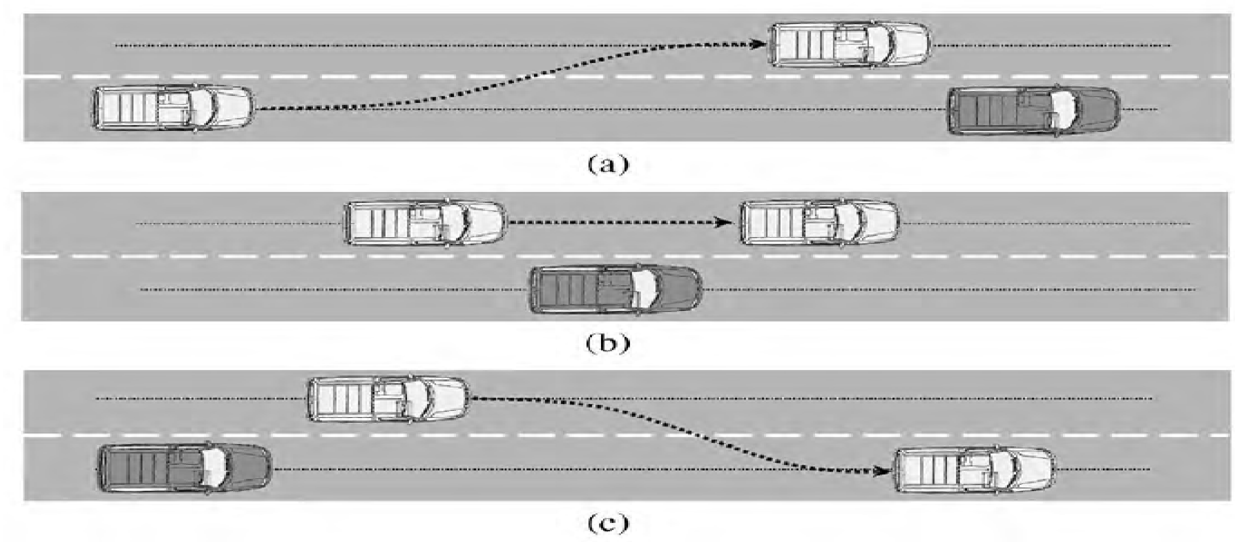

Figure 3.4: Overtaking maneuver phases, (a) First lane change to the contiguous left lane, (b) Circulation in the left lane, (c) Second lane change to the right lane

An exhaustive analysis for calculating the lane-change trajectory is conducted in [21]. It also defines the four situations in which a lane change is safe or unsafe when circulating on freeways. Consider that the overtaking vehicle is vehicle 1, and vehicle 2 is circulating in the contiguous lane.

Case 1) Vehicle 1 is moving at a lower speed than the other vehicle; vehicle 1 performs a lane change without modifying its speed and pulls in behind vehicle 2.

Case 2) Vehicle 1 is driving slower than vehicle 2 and makes a lane change, constantly accelerating to pull into the lane in front of vehicle 2.

Case 3) Vehicle 1 is driving faster than vehicle 2 and makes a lane change at a constant speed to pull into the lane in front of vehicle 2.

Case 4) Vehicle 1 is moving at a higher speed than vehicle 2 and makes a lane change, constantly decelerating to pull in behind vehicle 2 [7].”

3.4 Overtaking Margin Assessment

Andree Hohm and Hermann Winner provide a paper in IEEE Intelligent Vehicles Symposium (2010) titled by “Assessment of Adequate Overtaking Margin (AOM) for an Overtaking Assistance System”. In this paper they try to assess the adequate overtaking margin (AOM) overtaking assistance system in the real word. Overtaking margin (OM) is the time needed by the overtaking vehicle to change its lane, passing the overtaken vehicle and back to the original lane before reaching the vehicle coming from reverse direction. They define a threshold that if the OM is lower than it the overtaking maneuver is prohibit and if the OM is bigger the overtaking is permitted.

"a driver assistance system has been proposed which can detect cars in the surrounding of the EGO car (the car equipped with the system) to the effect that the system is capable of a valid prediction whether an overtaking maneuver started by the driver is dangerous or not [5]. As Figure 1 shows, if a hazardous situation is predicted, then the driver is informed via visual, audible and haptic perception channels so the driver can terminate the maneuver easily - at a time when the maneuver has barely started and hence the danger level is still very low.

To accomplish the intended composition of a prototype system according to the description above, a test-car has been equipped with radar and video sensors for environment perception as well as an electronically engageable braking system and appropriate computer hardware for the evaluation of algorithms. The realization of the overtaking prediction algorithm was done using an approach assuming constantpower- acceleration of the overtaker; this led to good results in the verification process. The system was successfully demonstrated to the public October 6th 2009.

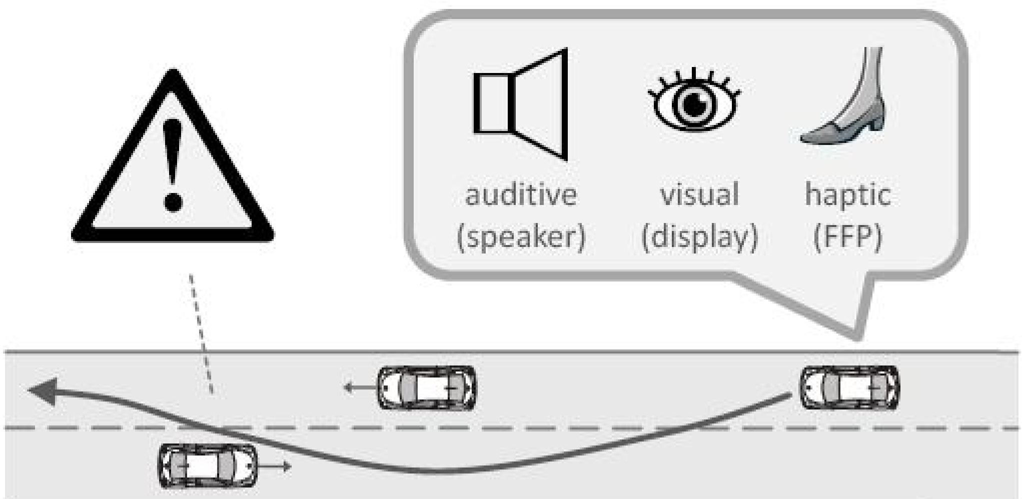

Figure 3.5: If the prototype overtaking assistance system predicts that the driver is about to begin an overtaking maneuver, which will lead to a dangerous outcome, it informs the driver through multiple receptive channels, audible, visual and haptic, with usage of a Force-Feedback-Pedal (FFP).

At the end of any overtaking maneuver (in this work this is indicated by the re-entering of all the wheels of the car into the original lane-area) there is a certain time gap between the overtaking car and the oncoming car, which is the duration till the front of the cars pass. Within this research, this value is called Overtaking Margin (OM) and can be considered as a safety parameter. Obviously, when this value is predicted to be negative, a collision is very likely to happen. However a driver should not accept all values OM > 0 as safe, i. e. when the value is very small, drivers will presumably assess the maneuver as dangerous. From this it follows that the OM has to be above an appropriate threshold. On the other hand, when the OM is chosen too large, drivers will not accept a warning when they assess the situation themselves as clearly safe for overtaking. This implies that the OM has to be below another threshold to be defined. The tests carried out within this research were designed to define of an optimal value for the OM – called Adequate Overtaking Margin (AOM) – to gain maximum acceptance by drivers. Taken into account that this value is most probably driver dependent, its determination requires extensive research involving subject persons [8].”

3.5 Overtaking Vehicle Detection

Fernando Garcia, Pietro Cerri, *Member, IEEE,* Alberto Broggi, *Senior Member, IEEE,* Arturo de la Escalera and José María Armingol provide a paper in Intelligent Vehicles Symposium (2012) titled by “Data Fusion for Overtaking Vehicle Detection based on Radar and Optical Flow”. They write this paper as a contribution in vehicle safety application. Their application use two radar sensors and camera for detecting overtaking vehicle. They mentioned that the system can be used for detecting blind-spot vehicle if anther camera installed.

“Raw radar detections are the detections obtained from the radar device without ECU. As it was mentioned before, these detections cover a wider field of view. These detections proved to be a not very trustable information source since the amount of misdetections was relatively high. Moreover, other inconvenient had to be solved. These problems were lack of information since the radar did not differentiate among vehicle and lateral obstacles such as lamppost, milestones, etc. Also multiple detections can be given for each vehicle as shown in figure 6. The classification among vehicles and lateral road obstacles was performed by the fusion procedure that will be presented below. Problems related by non continuous detections were solved by performing tracking that keeps the tracks even when there were no radar detections.

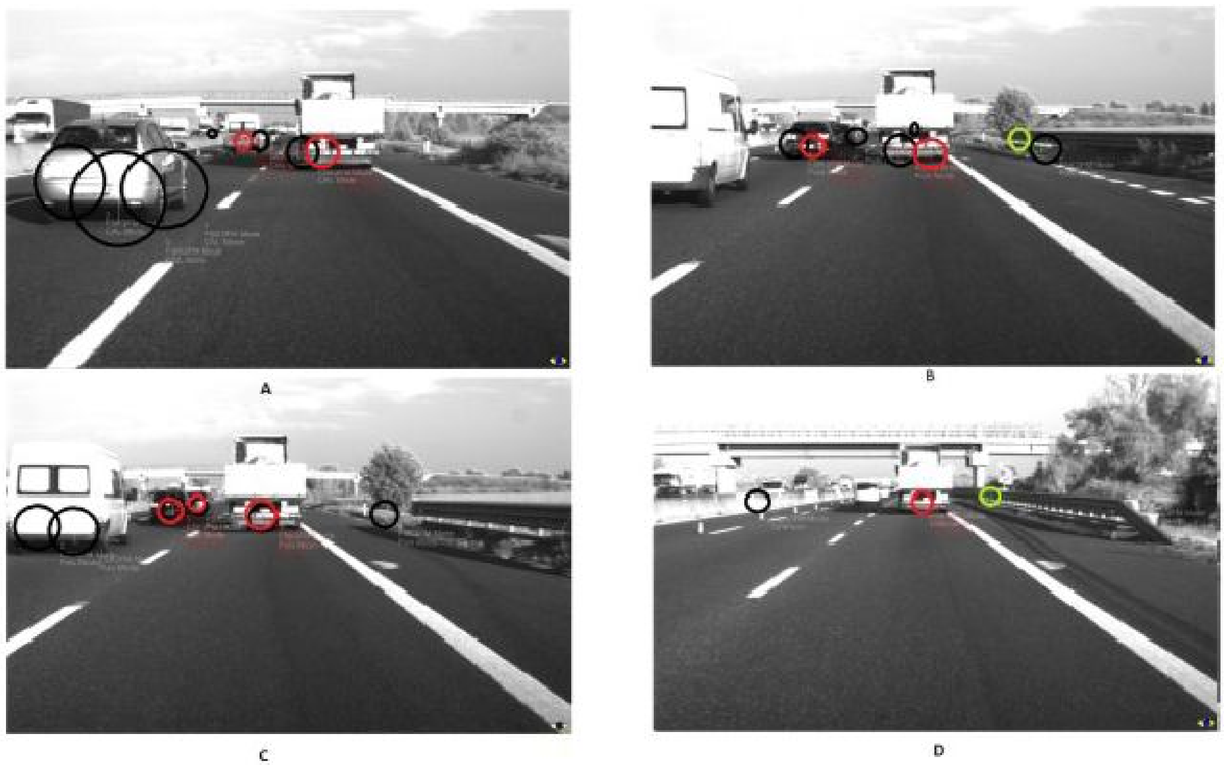

Figure3.6: Raw radar data detections on black, vehicles detection given by the ECU on red, and not moving detections on green. A Multiple detections for a single vehicle. B Misdetection of an overtaking car. C and D not vehicles detections at laterals.

A simple metric is used to associate old tracks with new detections from the radar, using euclidean distance. After this association three sets of candidates are available, these three sets are going to be checked using optical flow: updated old tracks, non updated old tracks and no-matching radar detections.

Figure 3.7: Radar detection of a vehicle outside the field of view of the camera and optical flow positive detection.

To check the three available sets with optical flow information search windows were created centered in the radar detections projections in the image. Thus only the valid features found in the optical flow detection process that are inside these windows were taken into account. For each window if the number of features is higher than a certain threshold, a new matching is reported. Figure 4 shows a case in which a sufficient number of significant features are detected inside the search window of a given radar detection [9]."

CHAPTER FOUR

METHODOLOGY

4.1 Introduction

This chapter discusses the methodology that use in this research and how the solution will achieved by using deferent mathematical equations.

4.2 concepts of overtaking maneuvers

Overtaking maneuver is one of the most dangerous maneuvers in the road especially in two-lane high way road. A total of 13 939 fatal crashes occurred during overtaking maneuvers in the United States from 1994 to 2005. As a direct consequence of these accidents, 24 565 people died [10]. And these accidents may happened to driver misestimating the speed of the vehicle approaching in the reverse direction or when driver try to overtaking other vehicle in a carve while the driver of the overtaking vehicle haven't visual cover of the road especially the vehicle in the reverse direction. Often, inaccurate assessment of the traffic situation is identified as the major cause [11].so, to avoid these kinds of accidents and overcome its sequences' an overtaking assistance application will be developed using VANET protocol.

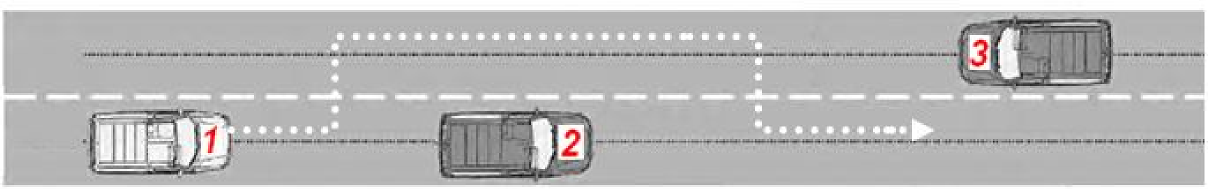

Figure 4.1: Overtaking maneuver

First of all let's see how the overtaking happened and its procedures. The steps to overtaking maneuver as shown in figure 4.2:

a) There is vehicle 1 which is the overtaking vehicle, in front of it vehicle 2 which is the overtaken vehicle and vehicle 3 which is the vehicle came from reverse direction. We should know that vehicle 1 is moving with speed higher than vehicle 2 so that can overtake it, otherwise vehicle 1 will not be capable to overtake vehicle 2.
b) The first step that vehicle 1 change its lane to the neighbor lane in the left which its direction is opposite vehicle 1 direction.
c) The second step that vehicle 1 move in the reverse direction lane until passing vehicle 2.
d) The third and the last step, vehicle 1 change its lane to the right and back to its original lane.

The overtaking problem can be solved by developing safety application that can assist the deriver in overtaking maneuver by inform him whether to overtake or not, and this decision will be taken in accordance to mathematical calculation. The safety application will use VANET protocol

IEEE 802.11p wave (wireless access in vehicular environment) WSMP messages protocol which vehicle use it periodically broadcast messages contain information about it, such information is its velocity, acceleration and direction. From that information contain in messages received by each vehicle the application will use it to do some calculation to decide whether to take this overtaking maneuver or not. The next section will briefly discus these mathematical equations.

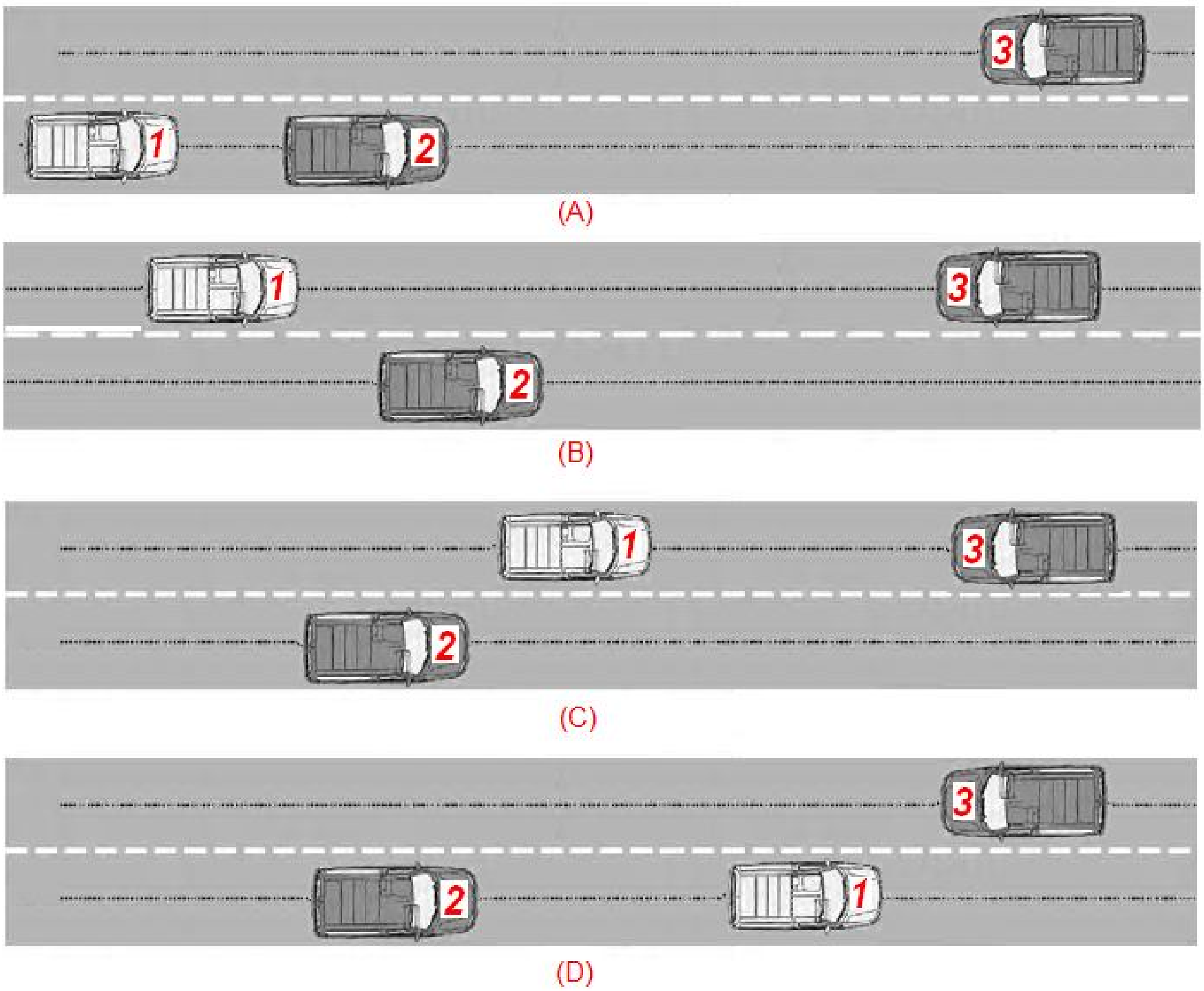

Figure 4.2: Steps of Overtaking maneuver.

4.3 mathematical equations

This section will discuss mathematical equation used in overtaking assistant application to determine that the overtaking maneuver is safety or not. At the first the safety application will gather the information that it gets from VANET message that broadcast periodically by VANET-enabled vehicle. All vehicles participate in the overtaking maneuver, the overtaking vehicle, the overtaken vehicle and the vehicle approaching from reverse direction, should be VANET-enabled vehicle (can send and receive messages using VANET).

The application will calculate the time needed for all overtaking maneuver steps and find out if this time is safety enough for the overtaking vehicle to overtake the front vehicle and back to its lane before it collides with the other vehicle. With the knowledge of each vehicle velocity, acceleration, position and direction it will calculate distance between each vehicle and time needed reach the other ones.

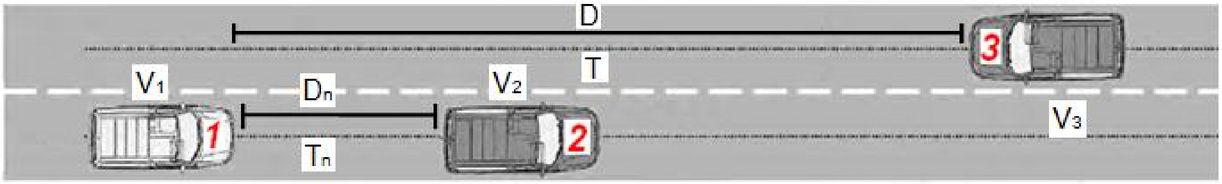

Figure 4.4: Distance between vehicles participating in overtaking maneuver.

4.3.1 First equation

First of all, the safety application will find the distance between vehicle 1 (the overtaking vehicle) and vehicle 2 (the over taken vehicle) and the distance between vehicle 1 and vehicle 3 (vehicle in reverse direction). After that with the knowledge of vehicle 1 velocity and 2 velocity and distance between them, the application will calculate the time needed for vehicle 1 to reach vehicle 2 and be in the same position as shown in figure 4.5.

$$T_n V_1 - T_n V_2 = D_n$$

$$T_n (V_1 - V_2) = D_n$$

$$T_n = D_n / (V_1 - V_2) \longrightarrow (1)$$

Where:

T_n: Time needed for vehicle 1 to reach vehicle 2.

V_1: Vehicle 1 velocity.

V_2: Vehicle 2 velocity.

D_n: Distance between vehicle 1 and 2.

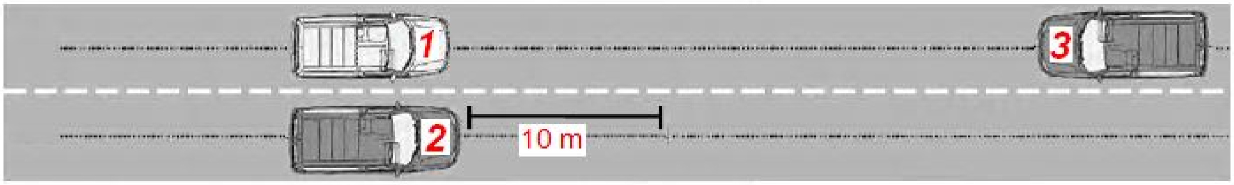

Figure 4.5: vehicle 1 and vehicle 2 at same position.

4.3.2 Second equation

After calculating the time needed to reach vehicle 2, we should calculate the needed time by vehicle 1 to pass vehicle 2 by 10 meter which is the safety distance that allow vehicle 1 to switch lane back to right lane without collide or disturbing vehicle 2.

$$T_p V_1 - T_p V_2 = 10$$

$$T_p (V1 - V_2) = 10$$

$$T_p = 10 / (V_1 - V_2) \longrightarrow (2)$$

Where:

T_p: Time needed by vehicle 1 to pass vehicle 2.

4.3.3 Third equation

After that the program will calculate the total time from the start of overtaking maneuver until passing vehicle 2.

$$T = T_n + T_p \longrightarrow (3)$$

Where:

T: Total time.

4.3.4 Fourth equation

When the vehicle 1 passing vehicle 2 in T seconds we should not forget vehicle 3 that it's moving too in reverse direction, so when vehicle 1 moving in its direction there is vehicle 3 moving in the reverse direction. The distance between vehicle 1 and vehicle 3 is shrinking by two value, vehicle 1 velocity and vehicle 3 velocity, so we need to calculate the left distance between vehicle 1 and vehicle 3.

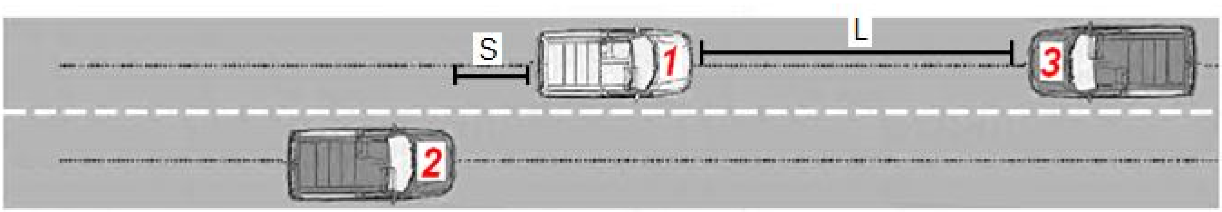

Figure 4.6: vehicle 1 pass vehicle 2 by 10m as safety distance.

$$L = D - T V_1 + T V_3$$

$$L = D - T(V_1 + V_3) \quad (4)$$

Where:

L: Left distance between vehicle 1 and vehicle 3 after vehicle 1 pass vehicle 2.

V_3: vehicle 3 velocity.

D: Distance between vehicle 1 and vehicle 3 before starting overtaking maneuver.

If the left distance is equal to zero or negative value the overtaking maneuver will not allowed; because the two vehicles (1 and 3) will collide before vehicle 1 even pass vehicle 2. Otherwise the further calculation will be made.

4.3.5 Fifth equation

At this moment vehicle 1 pass vehicle 2 but it still in the right lane, so we need to make sure that the left distance is enough for vehicle 1 to switch back to left lane with a safety manner and with no panic. The safety margin should be added in order to keep a safe distance to oncoming vehicles at the end of overtaking maneuvers. Three seconds is a commonly applied safety margin for, e.g., collision avoidance systems [2].

$$L / (V_1 + V_3) \geq 3 \text{ Sec} \quad (5)$$

If the equation equal true the overtaking maneuver will allowed otherwise will prohibited.

	A	B	C	D	E	F	G	H	I	J	K
1	V_1 (m/s)	V_2 (m/s)	V_3 (m/s)	D (m)	D_n (m)	T_n (Sec)	T_p (Sec)	T (Sec)	L (m)	T_L (Sec)	CAN OVERTAKE
2	28	22	28	300	20	3.333333333	1.666667	5	20	0.357142857	FALSE
3	28	25	42	300	20	6.666666667	3.333333	10	-400	-5.714285714	FALSE
4	28	27	28	300	20	20	10	30	-1380	-24.64285714	FALSE
5	28	10	28	300	20	1.111111111	0.555556	1.666666667	206.6666667	3.69047619	TRUE
6	11	5.5	28	300	20	3.636363636	1.818182	5.454545455	87.27272727	2.237762238	FALSE
7	28	20	42	300	20	2.5	1.25	3.75	37.5	0.535714286	FALSE
8	11	8	11	150	20	6.666666667	3.333333	10	-70	-3.181818182	FALSE
9	25	15	10	200	10	1	1	2	130	3.714285714	TRUE
10	30	20	20	190	15	1.5	1	2.5	65	1.3	FALSE
11	30	10	10	201	15	0.75	0.5	1.25	151	3.775	TRUE

Table 4.1: VANET equations test with random values.

As it seem, in the above equations we assume that the vehicles moving in fixed velocity and do not accelerate and the acceleration is equal to zero, but here we will take in our consideration the acceleration and deceleration; because if the vehicles are accelerate or decelerate there will be change in values that may cause miss estimation to the time which leads to wrong decisions and serious consequences. Safety application will calculate the value with same equations but this time it will use an algorithm to calculate the acceleration. Safety application will use this algorithm to calculate that where the vehicles will be after certain time and at what velocity.

In case that the vehicle accelerate, the application should increment the velocity each second by the value of its acceleration (until reach its max velocity) or decrement it if its deceleration.

```
Inputs: Acceleration, current speed, max speed.

Output: the time needed to reach the front vehicle.

I=0, C1=V1;

While(true){

        If(maxV1 – V1 ≥ A1){

                // if the vehicle don't reach it maximum
                speed

                C1 += V1 + A1 * I ;

                V1 += A1;

        }

        Else {

                V1 = maxV1 ;

                C1+= V1 ;

        }

        I++;

        // and do the same to vehicle 2

        If(C1 – C2 == Dn ){

                // from equation (1)

                Tn = I ;
```

```
                    // return the time
                    Return T_n;
          }
}
```

Figure 4.7: Acceleration Algorithm.

Where:

C1: The total distance vehicle 1 moved in I second.

C2: The total distance vehicle 2 moved in I second.

A_1: vehicle 1 current acceleration.

A_2: vehicle 2 current acceleration.

$maxV_1$: The max velocity that vehicle 1 can reach.

$maxV_2$: The max velocity that vehicle 2 can reach.

```
Inputs: Acceleration, current speed, max speed, distance.
Output: Boolean indicate whether to overtake or not.
I=0, C3=V3;
While(true){
          If(maxV3 – V3 ≥ A3){
                    // if the vehicle don't reach it maximum speed
                    C3 += V3 + A3 * I ;
                    V3 += A3;
          }
          Else {
```

```
            V3 = maxV3 ;
            C3+= V3 ;
        }
        // and do the same to vehicle 1
        I++;
        L=D – (C1 + C3)


        If(L > 0 && I >= 3 ){
            //overtaking is safe
            Return True;
        }
        Else if (L < 0){
            //overtaking is not safe
            Return false;
        }
}
```

Figure 4.8: Acceleration Algorithm for overtaking.

And these algorithms will be used in the rest of equations to solve them in appearance of acceleration.

CHAPTER FIVE

SIMULATION AND RESULT

5.1 VANET Simulators

In this chapter VANET application will be developed and tested using one of the VANET simulators and chose NCTUns simulator. At the beginning of this chapter will provide a brief introduction about NCTUns simulator.

5.1.1 NCTUns VANET Simulator

NCTUns stands for National Chiao Tung University Network Simulator [12], a network simulator and emulator. It is open-source software running on Linux, Fedora 11, with an integrated GUI environment. NCTUns provide several advantages in front of other network simulators [13]:

- Realistic network traffic can be generated by realistic life applications to generate more realistic simulation results.
- The performance of any real-life application can be easily evaluated on NCTUns under various simulated network conditions.
- Any network application program developed for NCTUns device can be directly run up on a real-life Linux device without any modification.
- In its 6.0 release, the simulator provides a complete implementation of the emergent IEEE 802.11(p) and 1069 standards for wireless vehicular networks.
- It also exists a commercial version of NCTUns, named EstiNet Network Simulator and Emulator, defined as "a software tool for network planning, testing, education, protocol development, and applications performance prediction. It is both a network simulator and emulator with worldwide customers and global impact." [14].

Figure 5.1: NCTUNS 6.0 start screen.

NCTUns has supported the simulation and emulation of ITS vehicular networks in its 4.0 release (released on July, 25, 2007). In this release, NCTUns supports:

1. Basic driver behavior models;
2. Basic road network construction; and
3. Simulation/ emulation of road side unit (RSU) and on-board unit (OBU) devices those are equipped with a radio, such as an IEEE 802.11(b) infrastructure mode, IEEE 802.11(b) adhoc mode, GPRS, and DVB-RCST radio.

As compared with other ITS network simulators, such as SUMO, NCTUns 4.0 provides users with a tightly-integrated simulation environment for ITS vehicular network research. The advantages of this tightly-integrated architecture are presented in [15]. In its 5.0 release (to be released on July, 2008), NCTUns greatly enhances its support to ITS network simulation. Such new functions include:

1. Node mobility control for large-scale vehicular networks;

2. Road network construction from the well-known SHAPE-format map file; and, most importantly,
3. Simulation and emulation of the leading edge IEEE 802.11(p)/1609 wireless vehicular network (WVN).

5.1.2 Running NCTUns

As mentioned before, NCTUns recommended to run in Linux fedora 11 virtual machine with 256 MB RAM, 1.6 GHz processor and 200 MB free desk space as minimum requirements. To install NCTUns you need to run one command:

- ./install

After installation finished you need to reboot your virtual machine, to let the changes take apart, by this command:

- reboot

After rebooting you should select the kernel start with NCTUns from GRUB menu as shown in figure 5.2.

Figure 5.2: selecting NCTUns kernel.

To login you should use the following credentials:

- Username: nctuns
- Password: nctuns

To run NCTUns you need to run three commands using root privilege:

- dispatcher $
- coordinator $
- coordinator $

Now NCTUns is started and ready to use. In NCTUns you can write your own application program that will control vehicle behavior, this program is written in C++ and control each vehicle running this application. There are different predefined application came with NCTUns, CarAgent which simulate ordinary vehicle behavior, Lane-Switch which enable vehicle to change its lane and WSM which simulate IEEE 802.11(b) WAVE message protocol.

I write my own application program to control vehicle behavior to perform overtaking maneuver using previously mentioned equations to allow or prohibit overtaking.

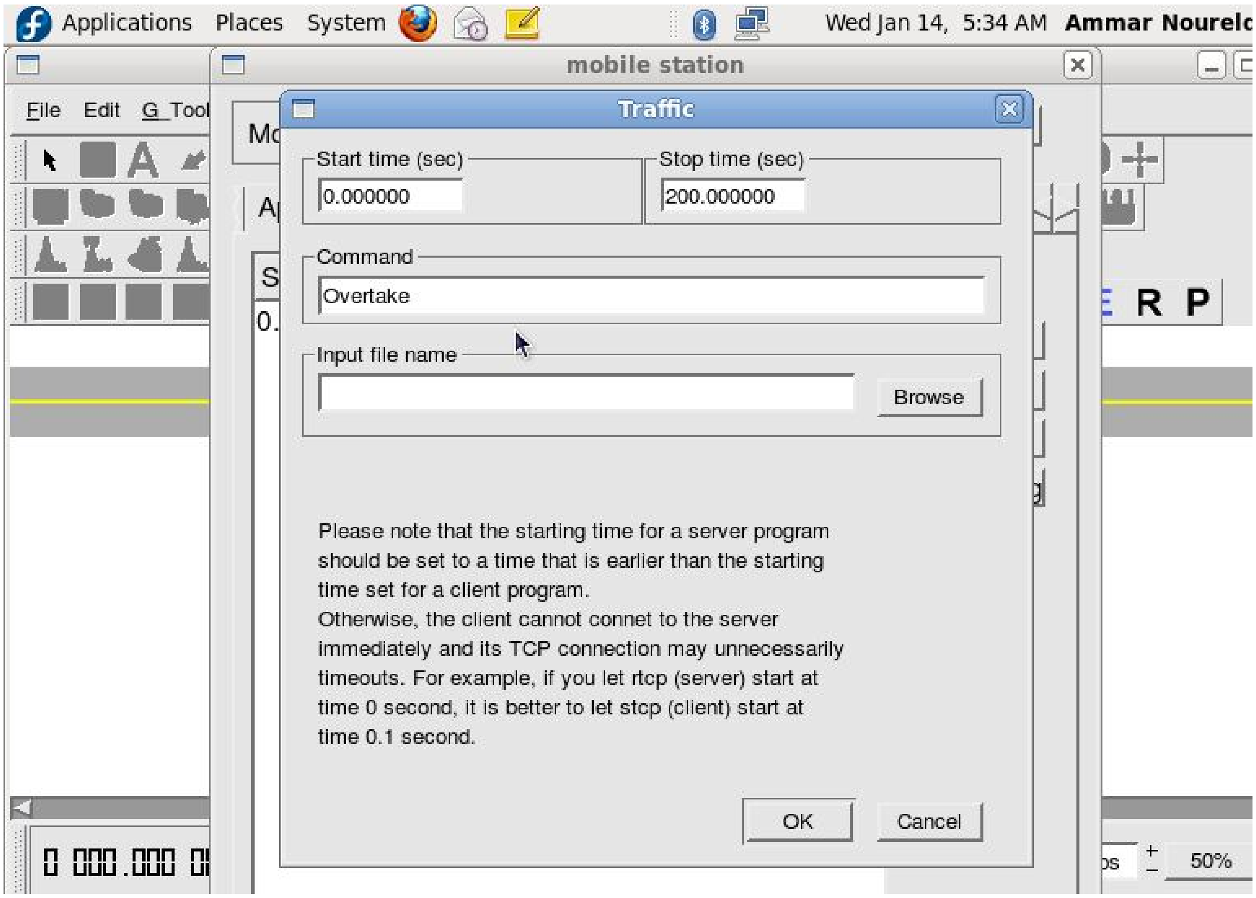

Figure 5.3: adding overtaking application to control vehicle.

5.2 Results

In this section will test safety-overtaking application program in NCTUns simulator by using deferent scenarios.

5.2.1 First scenario

In the first scenario there will be three vehicles with free enough space to perform overtaking maneuver. Scenario will run in these steps:

1) Overtaking vehicle moving behind other vehicle (overtaking vehicle) in a velocity higher than it and other vehicle approaching in reverse direction.
2) The overtaking vehicle start calculating the distance and time needed and determine whether to overtake or not.
3) The overtaking vehicle find out that it’s safety to perform overtaking maneuver and overtake the in front vehicle.

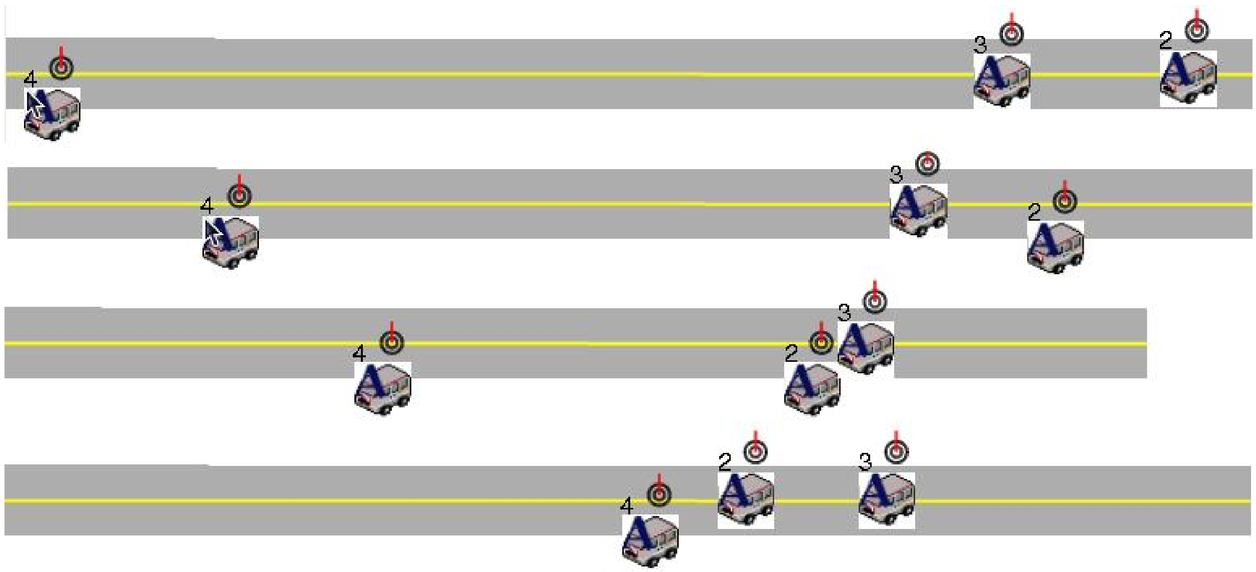

Figure 5.4: First scenario snapshots.

5.2.2 Second scenario

The second scenario is same as first scenario except that the distance will not be enough to overtake. The steps of this scenario will be:

1) The overtaking car will not allowed to perform the overtaking.
2) Overtaking vehicle will perform car following and wait until the vehicle approaching in reverse direction pass it.
3) Then the vehicle perform overtaking maneuver.

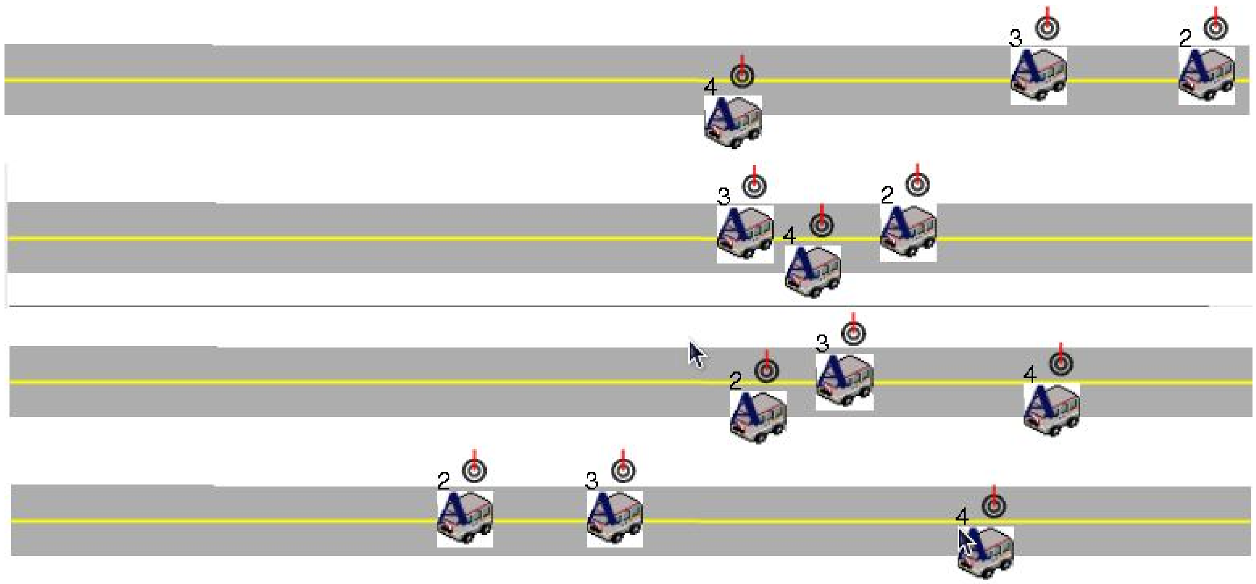

Figure 5.5: Second scenario snapshots.

5.2.3 Third scenario

The third scenario will be combination between the first and the second scenario, there will be two vehicles approaching in the reverse direction. The scenario will run in these steps:

1) The overtaking vehicle finds out that the distance between it and first approaching vehicle is not enough to overtake.
2) The overtaking vehicle will perform car following and wait until the first vehicle passes it.
3) After that the overtaking vehicle to calculate the distance but this time between it and the second vehicle and finds out it's safety to overtake.

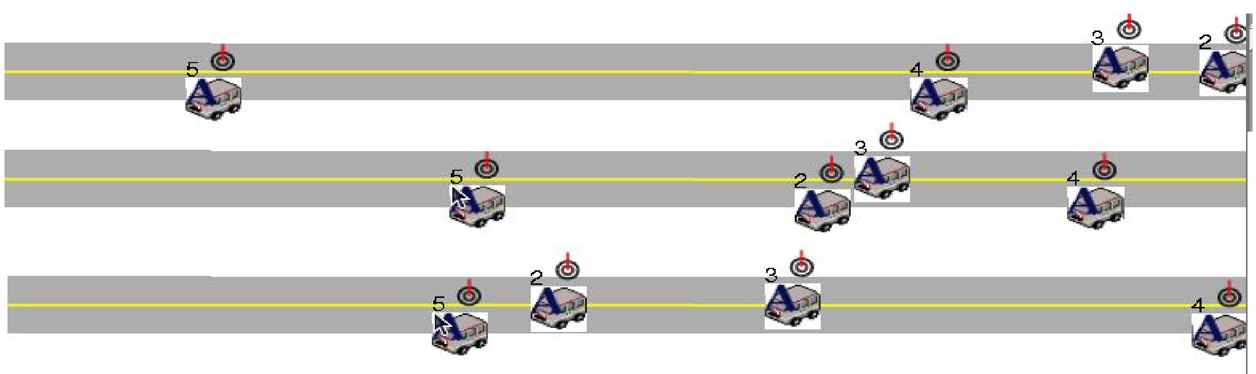

Figure 5.6: Third scenario snapshots.

5.3 Conclusion

Three deferent scenarios used to test safety-overtaking application program by simulating deferent situation and all three scenarios are succeed and the application work as expected and the vehicle is perform the overtaking maneuver in a reasonable and safety manner without collide with other vehicles.

CHAPTER SIX

CONCLUTION AND FEATURE WORKS

6.1 Conclusion

The continuously growth of the traffic accident and vehicle collision specially in high ways due to overtaking maneuver and the work done in this thesis to find a solution to this serious problem. The work done in three stages:

6.1.1 First section

This section started by analysis the problem and how the overtaking maneuver happened and its steps, from the overtaking vehicle start to change its lane to the left lane and passing the overtaken vehicle and get back to its original lane in the right, and how each step happened. After that, start work in defining some equations that can be used by the overtaking application program to calculate the distance between each vehicle, participate in the overtaking maneuver, and another and predicting each vehicle position in cretin time and finding out if it's safety to overtake or not.

6.1.2 Second section

This section used to search for VANET simulator that satisfies the application need, that it must be open source simulator with powerful documentation and easily add my own application program to simulator to control vehicle behavior. At the beginning, GrooveNet VANET simulator was used but some problems were founded:

1. All vehicles should use one of predefined mobility model that already came with the simulator.
2. Had very small and poor documentation.
3. Its C++ codes are very hard to understand and not will documented.
4. It's very hard to add your program because you should inherit all other model classes.
5. It's difficult and almost impossible to construct the road that you need, you should work with map that came with the simulator.

So I change to NCTUns simulator which satisfies all my application program needs:

1. Each vehicle can run its own application program, that deferent from other vehicles, to control its behavior.
2. Very will and rich documentation.
3. Its C++ codes are understandable and well documented.
4. It's easy to add your application program to the simulator and easy to communicate with other parts of the simulator.
5. Easy to construct the road and easy to deploy vehicles on the road.
6. You can easily edit other parts of the simulator to satisfy your application.
7. It's came with built in IEEE 802.11p / 1609 Wave Short Message Protocol (WSMP).

6.1.3 Third section

This section started by developing safety-overtaking application program containing the equations and adds it to the simulator. This is the most difficult part of the work; because the application was faced by allot of problems. But at the end the application program is work and has been added to the simulator. When the application program was used to control a vehicle it functioned as expected.

After those three sections was finished. The testing phase started by testing the application with different scenarios to make sure that it will function appropriately in deferent situations.

1. The first scenario the distance is enough to overtake.
2. The second scenario the distance is not enough to overtake.
3. The third scenario is combination between the first and the second scenario, that there are two vehicles approaching from reverse direction the distance between the overtaking car and the first approaching car is not enough and the distance between the second approaching vehicle is enough. So the overtaking vehicle waits until the first vehicle passes it and overtakes before second approaching vehicle reach it.

At the end that all scenarios work correctly with zero collision and the overtaking application program work correctly as it should with no errors.

6.2 future works

I. Take in the consideration the length of each vehicle in overtaking specially the trucks with single or double trail.

II. Take in the consideration the situation that the overtaking vehicle needs to overtake more than one vehicle.

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