SUDAN UNIVERSITY OF SCIENCE AND TECHNOLOGY

COLLEGE OF GRADUATE STUDIES

An Approach to Reduce Traffic Delay in Intersections Using VANET

آلية لتقليل زمن تأخير المرور في التقاطعات بإستخدام شبكة (فانت)

A Thesis Submitted in Partial Fulfillment of the Requirements of M.Sc. in Computer Science

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﴿ وَقَضَى رَبُّكَ أَلَّا تَعْبُدُوا إِلَّا إِيَّاهُ وَبِالْوَالِدَيْنِ إِحْسَاناً إِمَّا يَبْلُغَنَّ عِنْدَكَ الْكِبَرَ أَحَدُهُمَا أَوْ كِلَاهُمَا فَلَا تَقُلْ لَهُمَا أُفٍّ وَلَا تَنْهَرْهُمَا وَقُلْ لَهُمَا قَوْلاً كَرِيماً * وَاخْفِضْ لَهُمَا جَنَاحَ الذُّلِّ مِنَ الرَّحْمَةِ وَقُلْ رَبِّ ارْحَمْهُمَا كَمَا رَبَّيَانِي صَغِيراً ﴾

[سورة الإسراء الآية: 23-24]

I

Dedication

To my dear beloved mother, Hajja Al-Sharani Abdullah,

To my dear father, Al-Jayli Al-Haj Mohammed,

To my dear fellow brothers and sisters,

To all my friends and all those who have conferred their favors upon me and paved my way to success, all words and expressions of gratitude and thankfulness will be a drop in your sincere wide… wide sea of help and support.

Almighty Allah bless you all.

Acknowledgement

First and last thanks to Allah, peace and prayers be on human teacher Prophet Mohammed and his family and companions and who had followed them in a good way to the last day. Best regards and respect to the light in the dark roads I travelled Ustaza Entisar Alhaj, her guidance has helped me during the research and writing of this thesis. Also, all thanks to Ustaza Marwa Eltayib who has helped me in the implementation.

Abstract

Traffic congestion is considered one of the major problems around the world facing drivers; it results in wasting time and fuel. So many researches were proposed to solve this problem using a vehicular ad hoc network (VANET). This research aims to solve the problem of vehicle breakdown at intersection. In research two scenarios are designed, the first scenario simulates a normal state where the traffic signal light is not adaptive which mean it is assigned a fixed duration for each phase. The second scenario represents adaptive traffic signal light. In this scenario, when the vehicle brakes down, it sends a warning message to the Road Side Unit (RSU). This message contains information about the broken vehicle and the road where the vehicle has broken down. According to this message, the traffic light will change its phase by switching lights from green to red at the broken vehicle road. Three simulators are used to apply the mentioned scenarios. The first one is Vehicle in Network Simulation (veins); the second is Simulation of Urban Mobility (sumo) and the third is OMNET++. The simulation results show the enhancement in the vehicles total time when applying the adaptive scenario compared to the normal scenario. The proposed system also reduces fuel consumption and CO_2 emission.

المستخلص

يعتبر الإزدحام المروري أحد أكبر المشاكل التي تواجه السائقين في جميع أنحاء العالم، مما يؤدي إلى إضاعة الوقت والتكلفة (الوقود). وقد أُقترحت العديد من الأبحاث لحل هذه المشكلة باستخدام شبكة لاسلكية خاصة بالمركبات (vehicular ad hoc network). يهدف هذا البحث لحل مشكلة تعطل المركبات عند التقاطع. في هذا البحث تمت محاكاة حركة المركبات في تقاطع بأكثر من سيناريو. السيناريو الاولى يحاكي الوضع الطبيعي، حيث أن إشارة المرور تتغير بزمن محدد مسبقاً. يمثل السيناريو الثاني إشارة المرور التكيفية، بحيث يتم إرسال رسالة تحذيرية إلى وحدة جانب الطريق(Road Side Unit) في حالة تعطل إحدى المركبات في التقاطع، تحتوي هذه الرسالة على معلومات عن المركبة المتعطلة و الطريق الموجودة به. بناءً على هذه الرسالة فإن إشارة المرور تغير مرحلتها من الإشارة الخضراء إلى الإشارة الحمراء في الطريق الذي يحتوي على المركبة المتعطلة. لتطبيق التجارب ألمذكورة أعلاه تم إستخدام ال Vehicle in Network Simulation (veins), Simulation of Urban Mobility (sumo) and OMNET++. وتُظهر نتائج المحاكاة التحسن في زمن الوصول للمركبات عند تطبيق السيناريو الثاني مقارنة بالسيناريو الأول. ويقلل النظام المقترح أيضا من استهلاك الوقود وانبعاثات ثاني أكسيد الكربون.

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Abbreviations	Terms
AU	Application Unit
DSRC	Dedicated Short Range Communication
I-to-I	Infrastructure to infrastructure
MANET	Mobile Ad hoc network
OBU	On Board Unit
RSU	Road Side Unit
SUMO	Simulation of Urban MObility
VANET	Vehicular Ad hoc network
VEINS	Vehicle In Network Simulation
V-to-I	Vehicle to Infrastructure
V-to-V	Vehicle to Vehicle

Chapter one

Introduction

1.1 Background

Traffic congestion is currently considered one of the major problems around the world facing drivers and traffic police; because it results in wasting time and fuel. Moreover, the study of drivers is jeopardize due to accidents caused by congestion[1].

A vehicular ad hoc network (VANET) is an ad hoc wireless communication system, which allows multiple vehicles to communicate together (vehicle-to-vehicle or V2V) or communicate between with the road side unit infrastructure (V2I). To gain benefit of VANET, many applications have been proposed for different purposes such as safety, infotainment, finance, navigational aid, etc.[1].

The vehicle gets the information about the road state from neighbor vehicles found in its coverage area and shares it with other vehicles also found in its coverage area and so on alternatively, it can or shares it with some roadside unit and transmit this information to other road side units to broadcast it to other vehicles.

The researchers use simulation in the field of VANETs to evaluate systems and show results. Using simulation is cheaper and easier than applying the tests in real world because they need longer time and a large number of resources to obtain significant results. Simulating VANET is considered a challenge on the contrary of other systems because it needs to simulate more than one model together at the same time, by simulating the network and vehicles on that network. So, in most VANET applications, more than one simulator are used together to simulate the network and vehicles traffic on that network. For example, OMNET++ simulator is use to simulate the network and its functions, another simulator is simulation of urban mobility (SUMO) which is used to simulate the vehicles and their mobility [2].

1.2   Problem Statement

Traffic lights at intersections usually allocate a fixed time for each direction. Any vehicle that wants to cross the intersection must wait until the traffic signal light becomes green. Sometimes a vehicle may find the light green, but due to a faulty vehicle at the front of the lane, this car is stopped in the shared area of the cross section. These phenomena may lead to block the other vehicles in the intersecting direction of the road and create a traffic jam.

1.3   Hypothesis

The ability of a driver to know the traffic conditions on the road ahead will enable him/her to seek alternate routes saving time and fuel. In addition, Communication between vehicles and infrastructure will reduce traffic light bottleneck.

1.4   Research Objectives

The objectives of this research are design and implement system to:

- Generate and send warning messages when a vehicle brakes down using VANET techniques.

- Adapt the time of traffic signal according to actual traffic state.

- Send help request messages for removing broken vehicle from the road.

1.5   Research Significance

This research contributes to solve congestion problems by getting benefit of the advancements in the area of Vehicle-to-Infrastructure communication. This is achieved by sharing information about traffic conditions in advance, resulting in the avoidance congestions and reducing the time and cost (gallons of fuel) that is wasted while waiting in intersections.

1.6 Research Scope

This work is based on wireless communication between vehicles and Road Side Unit (RSU) in an intersection having two crossed roads, with only one-entry and exit points at each of them. And one traffic light located in the intersection.

1.7 Thesis Layout

Chapter one gives an introduction about the research, defines the problem, objectives and scope. Chapter two contains two parts. Part one represents a general background about VANETs. Part two is the related studies and techniques used in VANETs. Chapter three also contains two parts, the first part contains the project methodology, and the second part explains the tools and techniques that used in this project. Chapter four illustrates the results. Chapter five includes conclusions and recommendations.

Chapter Two

Literature Review

2.1 Introduction

This chapter is divided into two sections, the first section gives background about vehicular ad hoc networks. The second section is related works.

2.2 Adaptive Traffic Systems

Adaptive systems are used to provide traffic signals that respond to the state of the road, which differ from response systems that specify a preset time for the traffic signal. The adaptive systems use detectors to gather information about the state of the road, which is in turn entered into algorithms to adjust the traffic signal time [3].

Adaptive traffic systems are used for:

- Increasing the traffic flow on the road.
- Rapid response to traffic congestion.
- Road user's satisfaction.

Adaptive systems use cameras to monitor the road while using the loop detector to detect the presence of vehicles. The cameras and the loop detector provide information about the state of the road to the traffic signal controller, which in turn schedules road traffic by setting the green signal light to an appropriate duration of time [3].

2.3 Mobile Ad Hoc Network (MANET)

MANET is a type of ad hoc network. This can operate without the need of any central control, unlike the wired networks that need centralized control. A MANET is a self-forming network, each node in an ad hoc network acts as both a data terminal and a router. The nodes in the network use the wireless medium to communicate with other nodes in their radio range [4].

2.4 Vehicular ad hoc Network (VANET)

VANET is considered a subclass of Mobile Ad hoc Network (MANET). Vehicles are used as the wireless node and can be connected in the wireless range between 100 and 300m. Vehicles are connected together to make a mobile wireless network [4]. The IEEE 802.11p (Wireless Access in Vehicular Environments WAVE) is a standard on which the IEEE is working on, in order to provide Dedicated Short-Range Communication (DSRC) for future Vehicle-to-Vehicle (V2V) communication.

VANET has unique and special features different from MANET including [5]:

1. High mobility

High mobility is the most important feature of Vehicular Ad hoc Networks, which makes the mobility model one of the most important parameters. It should be carefully selected when evaluating any protocol [6].

2. Rapidly changing network topology

The high speed of the vehicles and the presence of many available roads leads to the rapid change in network topology [7].

2.5 VANET Type of communications

Vehicular ad hoc Network has three types of communications, which are:

- Vehicle-to-Vehicle Communication.
- Vehicle-to-Infrastructure Communication.
- Infrastructure-to-Infrastructure Communication.

2.5.1 Vehicle-to-Vehicle Communication

Vehicle-to-Vehicle Communications is the dynamic wireless exchange of data between neighboring vehicles that offers information about a vehicle such as position and speed. V2V communication enables active safety systems that assist drivers in preventing

76 percent of the crashes on the roadway, thereby reducing the total of fatalities and injuries that occur each year [8].

2.5.2 Vehicle-to-Infrastructure Communication

Vehicle-to-Infrastructure communications is the dynamic wireless exchange of data between vehicles and highway infrastructure. In V2I, The infrastructure gathers information about the environment state and exchanges this information with a vehicle moving on the road [8].

2.5.3 Infrastructure-to-Infrastructure Communication

Infrastructure-to-Infrastructure communication is the wireless exchange of data between the two base stations. The base station collects data from vehicles and processing will be done [8].
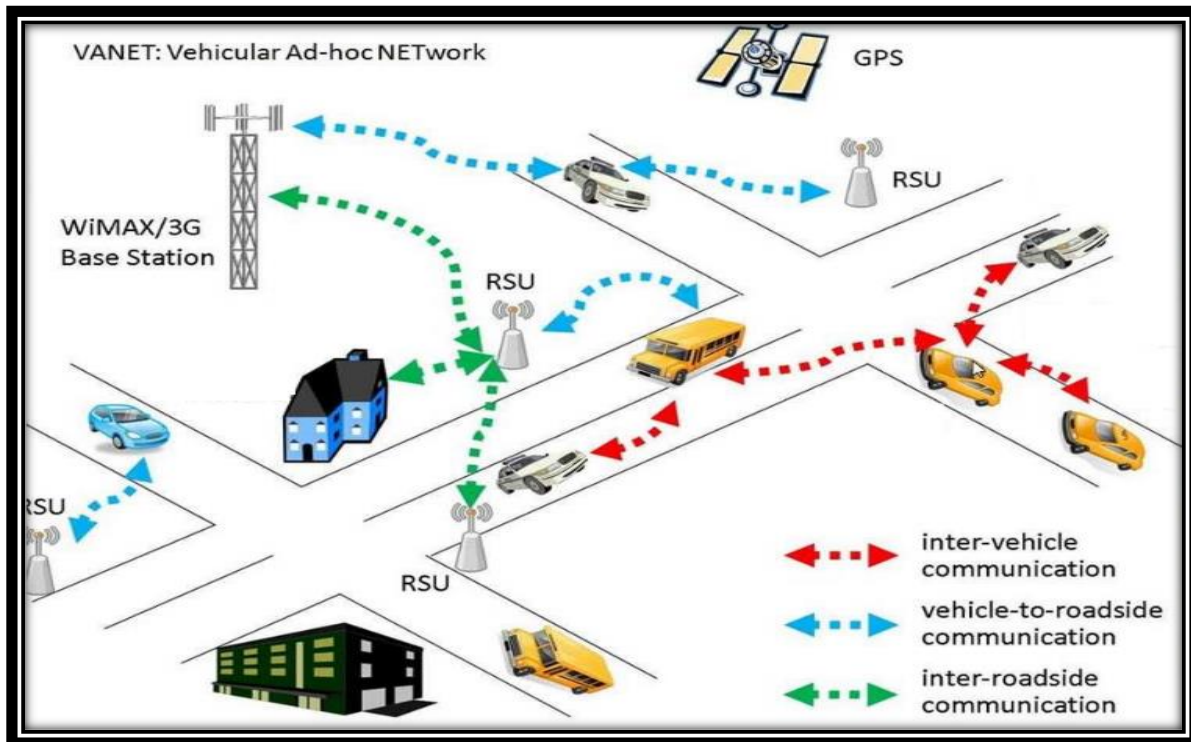

Figure 2.1 Different Types of Communication

2.6 Components of VANET

There are mainly three components of VANET [9]:

1. On-Board Unit.
2. Road Side Unit.
3. Application Unit.

2.6.1 On-Board Unit (OBU)

An On-Board Unit (OBU) implements the communication protocol stack and provides V2X communication services to application units(AU). OBUs are equipped with at least one network device for short-range wireless communication based on IEEE 802.11p, and may be equipped with more network devices from different technologies. Its main functions and procedures include wireless radio access, geographical ad-hoc routing, network congestion control, IP mobility support, and others. As shown in Fig.2.2, On-Board Unit is a physical device located in a vehicle and responsible for V2V and V2I communication.

2.6.2 Application Unit (AU)

Application unit is a dedicated entity that runs applications and uses the OBUs communication capabilities. An AU can be embedded in the vehicle and be permanently connected to an OBU, or can be dynamically plugged into the in-vehicle network by drivers or passengers. It can also be a portable device such as laptop or PDA; multiple AUs are allowed to be connected to a single OBU. AU and OBU communicate internally through Ethernet.

Examples of AUs are [9]:

- A dedicated device for safety applications like hazard- warning
- A navigation system with communication capabilities.
- A hand-held device such as a PDA that runs Internet applications.

2.6.3 Road Side Unit (RSU)

Road-Side Units (RSUs) are fixed nodes placed along roads or highways, or at dedicated locations such as traffic signs, parking places or gas stations. RSU has the same communication capabilities of OBUs. It is equipped with at least one device for short-range wireless communications based on IEEE 802.11p, and may be equipped with other network technologies in order to allow communications with an infrastructure network. RSUs may extend the communication range of the Ad-hoc domain, may provide Internet connectivity or may cooperate with other RSUs in forwarding information [9].

Figure2.2 bellow shows components of a vehicular ad hoc network, which include Road Side Unit (RSU), An Application Unit (AU) and On-Board Unit (OBU).
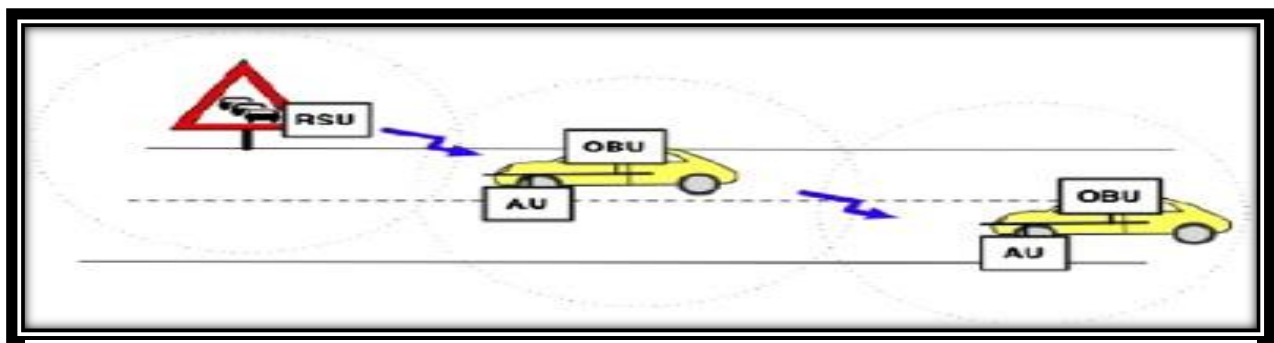
Figure 2.2 Components of VANET

2.7 Related Works

This section shows related works and previous studies about VANET technology.

Another survey of traffic congestion detection [1] summarizes research on traffic information systems based on VANET. Two classes of such systems are studied: infrastructure less solutions based on inter-vehicle communication and infrastructure-based solutions. The study includes the infrastructure less class systems. They analyze the systems strengths and weaknesses.

Adaptive Traffic Management [3] proposed a method to minimize the signal control problem to be a problem of scheduling jobs on a processor. The benefit of using this method is to increase the throughput, data rate and reduce the load compared to the with platoon algorithm.

In a survey of traffic congestion detection [9], A Greedy Forwarding Algorithm is used to increase delivery rate and throughput. This algorithm reduces the traffic load. Moreover, it uses event driven safety messages to reduce traffic congestion.

The work in [10] proposed a method for traffic congestion control based on event occurrence by sending broadcast messages from the affected vehicle to other vehicles.

Smart city [11] proposed a system for congestion detection by developing a smart city framework where intelligent traffic lights (ITLs) set in the crossroads of a city is involved. ITLs are used to collect information from passing vehicles and resend it after updating traffic statistics of the city. To avoid further congestion, a warning message is sent by ITLs when an accident occurs. Simulation results show that the use of ITLs in smart cities cannot only improve road safety but also the driver's quality of life.

Adaptive traffic lights [12] displays the possibility of deploying the signal control system at intersections, The traffic light controller listens to all information that cars are exchanging, thus knows how crowded the intersection is. To reduce the intersection delays, the method chooses the shortest cycle length as much as possible in order to produce less red time and shorter queues. This approach greatly improves traffic fluency at intersections and has clear advantages over other structures with respect to both cost and performance.

Street Smart [13] proposes a novel system for congestion detection in VANET; Street Smart uses clustering as a data aggregation technique to combine related recordings of unusually slow speed. Street Smart uses clustering algorithms that work over a distributed network where each node analyzes the collected statistics eliminating the need for a central entity. Clustering is the process of combining data points that are similar to each other by some measure.

The e-NOTIFY [14] system is designed for automatic accident detection, which sends messages to emergency centers and assistants of road accidents using the capabilities offered by vehicular communication technologies. e-NOTIFY focuses on improving post collision care with fast and efficient management of the available emergency resources, which increases the chances of recovery and survival for those injured in traffic accidents.

Table 2.1 Summary of related works

Paper name	Objective	Type of communication	Simulation tools
Adaptive Traffic Management Greedy Forwarding Algorithm	proposed a method to minimize the signal control problem to be a problem of scheduling jobs on a processor	V to I	NS-2
Traffic Congestion Control	present a strategy to control traffic congestion with the help of vehicle-to-vehicle (V2V) and vehicle to infrastructure (V2I) communication	V to I	Net Beans IDE
Smart city for VANETs	development warning system composed of Intelligent Traffic Lights (ITLs) that provides information to drivers about traffic density and weather conditions in the streets of a city	V to V	Net Beans IDE
A Survey of Traffic Congestion Detection and Management Technique using VANET	present a strategy to control traffic congestion with the help of Vehicle-to-Vehicle (V2V) and Vehicle to infrastructure (V2I) communication	V to I	NCTUns 6.0
e-NOTIFY	design system for automatic accident detection, which sends messages to emergency centers and assistants of road accidents using the capabilities offered by vehicular communication technologies	V to V & V to I	-
Adaptive Traffic Lights Using Car-to-Car Communication	displays the possibility of deploying the signal control system at intersections	V to I	-

Street Smart	proposed a novel system for congestion detection in VANET	V to V & V to I	-
Survey of Traffic Congestion Detection using VANET	Present a survey summarizes research on traffic information systems based on VANET	-	-

Chapter Three

Research Methodology

3.1 Introduction

This chapter is divided into two sections: the first section describes the system methodology and the second section describes the environment of the system that is being developed, which includes the simulations that were used in building it.

3.2 Research Methodology

After Studying related works and previous studies done in this area (VANET technology) and analyzing their outcomes, it became clear how to build a system for managing traffic and reducing congestion. The adaptive traffic light system we built is based on wireless communication between vehicles and the Road Side Unit (RSU) in intersections.

VANET has three types of communications as mentioned in chapter two: Vehicle-to-Vehicle, Vehicle-to-Infrastructure and Infrastructure-to-Infrastructure. We used Vehicle-to-Infrastructure, which is the dynamic wireless exchange of data between vehicles and highway infrastructure. This helps the Road Side Unit (RSU) get information about the state of traffic from vehicles moving around the RSU coverage area. According to this, our work is divided into two main tasks that run in parallel, one for vehicles and the other for the RSU.

3.3 Vehicle side processes

Vehicles moving on the road share information about themselves and the state of traffic with other vehicles and the Road Side Unit (RSU) that is found in the coverage area. This information is shared by broadcast messages from vehicles, which is sent every second, and contains information about vehicles like speed, position, and other information.

Vehicles should always be checked for problems, such as a tires puncture, machine malfunctions, and fuel leakage, which may cause the vehicle to stop working. Therefore, it is important to check the vehicle continuously to avoid any failures and to ensure that it is working properly. When the vehicle finds one of the faults has caused the vehicle to stop; it will send a warning message to inform the RSU that the vehicle has broken down.

3.4 Type of messages

There are three types of messages in our work that can be sent by the vehicle that is moving on the road:

3.4.1 Normal message

This message contains information about the vehicle such as speed and position.

3.4.2 Warning message

This is similar as a normal message, but we have modified it to distinguish it from the normal message by adding the word (**warning**) to the beginning of the message. The warning message is sent when the vehicle has broken down.

3.4.3 Notification message

This is similar to the normal message and the warning message, but we have added the word (**notify**) at beginning of the message. The notification message is sent when the broken vehicle is removed.

Figure 3.1 shows the vehicle side, which demonstrates the complete processes which vehicles go through in all cases either in normal case or in the breakdown case. Usually, the vehicle is in the case of monitoring and through this process, there are two possibilities: the first possibility is that there is no breakdown in the vehicle, and therefore the vehicle is continually in the process of monitoring breakdowns. The second possibility is the breakdown of the vehicle, in this case the vehicle sends a warning message to the

roadside unit containing the identification of the road on which the breakdown occurred and the identification of the lane on that road.
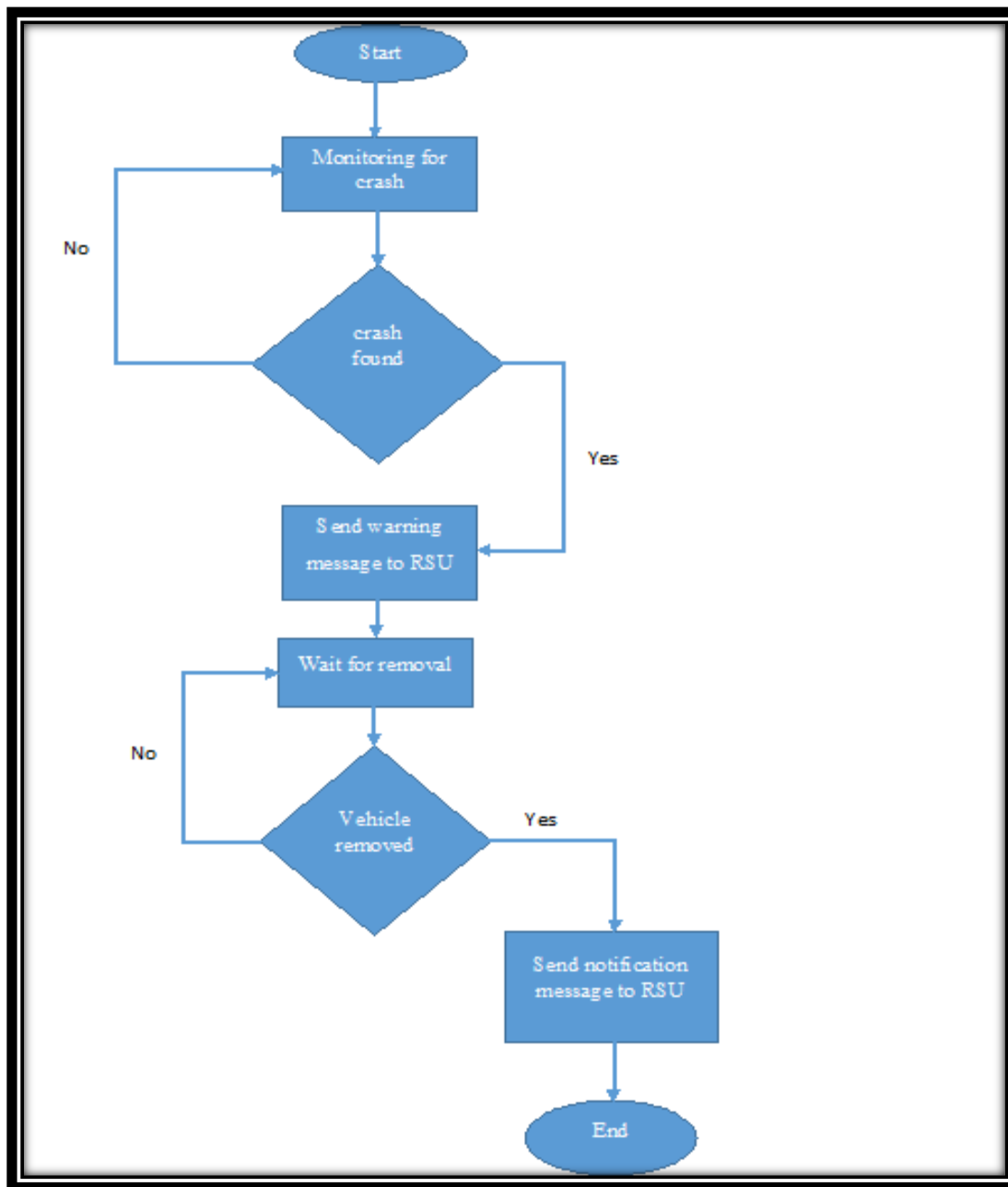

Figure 3.1 Vehicle side processes

After the warning message is sent to the road side unit, the vehicle waits until it is removed from the scene, and sends a notification message to the road side unit to tell it that the road is free of the broken vehicle.

3.5   Road Side Unit processes

The Road Side Unit (RSU) gets information of the state of traffic from vehicles through broadcast messages; these messages are sent every second, and contain information about vehicles like speed, position, and other information as mentioned before.

When a roadside unit has received a message from a vehicle passing through the road, the incoming message type is checked. This verification is done on the first part of the message. In the case of a warning message, the beginning of the message is (warning) and in the case of a notification message, the beginning of the message is (notify).

In the case of a vehicle brake down, the warning message is sent in a different form than a normal message. The RSU extracts important information from the message such as the identification of the road on which the vehicle broke down and the identification of the lane on that road. According to the extracted information, the RSU makes the decision on how to set the signal plans of traffic lights.

Figure 3.2 shows the Road Side Unit processes from the time the vehicle brakes down to the change in the traffic light. This helps it to adapt with the state of traffic and to remove the broken vehicle from the road.
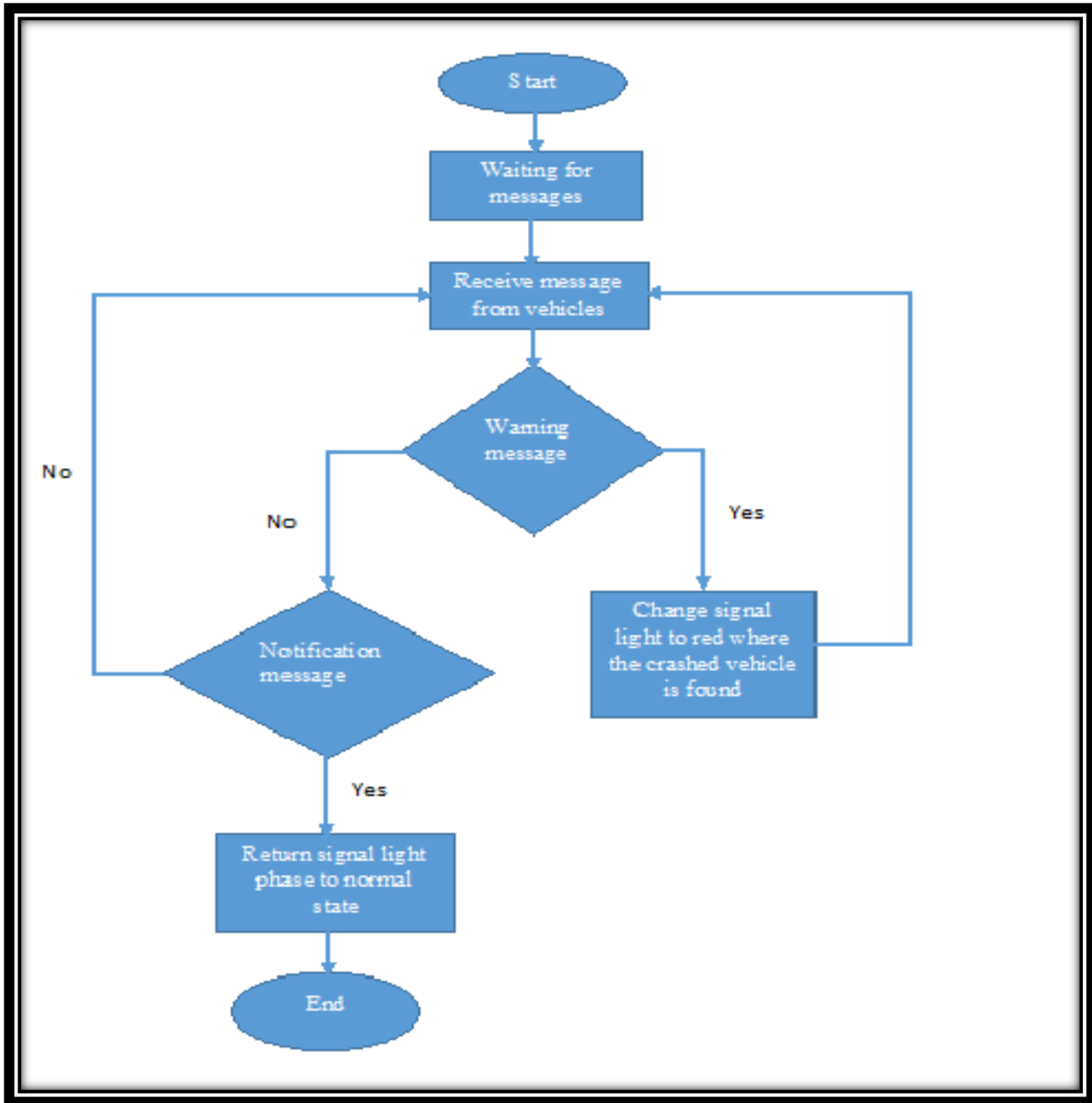
Figure 3.2 Road side unit processes

The decision is to switch off the traffic signal at the road containing the broken vehicle (we mean by switch off changing traffic light from green to red signal if it is green) and switching it on in the opposite road. As a benefit of this change in traffic lights, the efficiency of traffic flow is increased by letting vehicles in the opposite road have more

time of green light instead of waiting for the red phase to finish while the vehicles on the opposite road wait for the broken-down vehicle to be removed.

The other part of the process on the side road unit is when the vehicle is removed from the road. In this case, a message is sent from the vehicle. When the message arrives at the road unit, it is verified as a notification message, and then the RSU resets the traffic signal to the normal state.

The following diagram in figure 3.3 illustrates the method of the system in general. It shows the basic operations performed on both the vehicle and the RSU. The event of a vehicle breakdown is followed by sending a message (warning message) from the vehicle to the road side unit. Then the traffic signal adjusted until the broken vehicle is removed from the road.
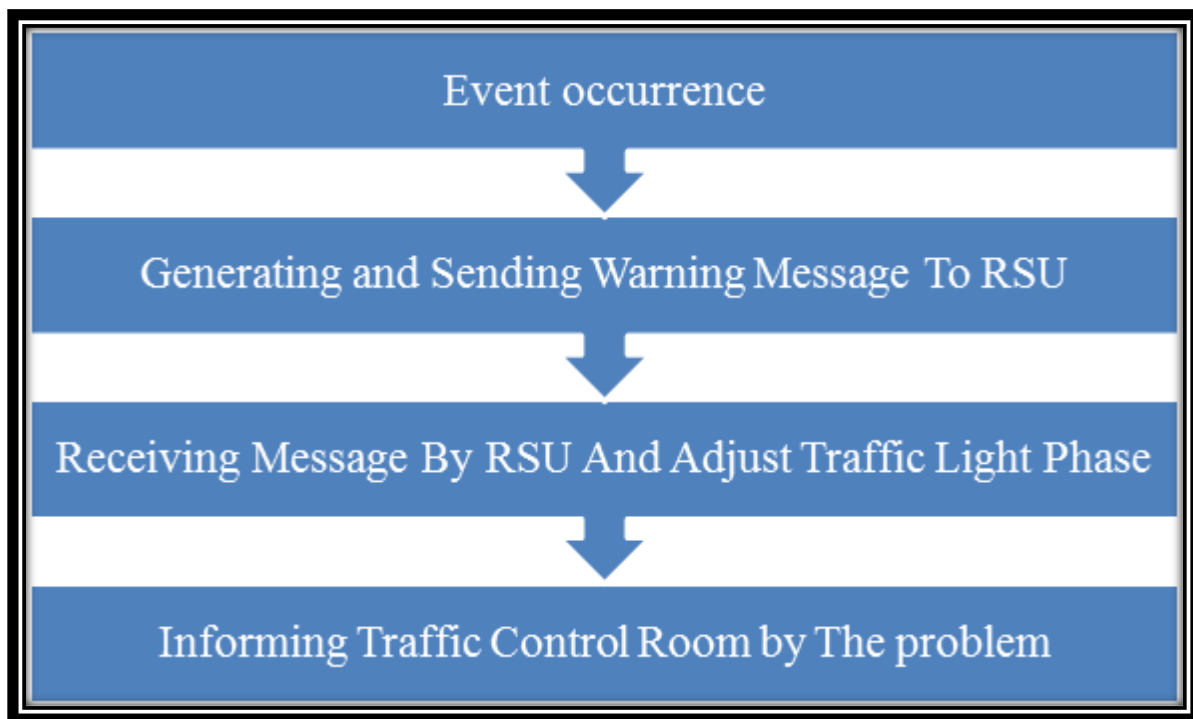

Figure 3.3 Research methodology in general

3.6 Work Environment

This section describes the environment of the simulation that was developed, as well as the simulations that were used to build the system.

Our system uses three-simulations that work together in parallel to simulate the system. The simulation of urban mobility (SUMO) is used to simulate the roads, vehicles and traffic signal lights. The second simulation is OMNET ++ is used to simulate the network functions. OMNET ++ is connected to SUMO by vehicle in network simulation (VEINS) as shown in figure 3.4 below.
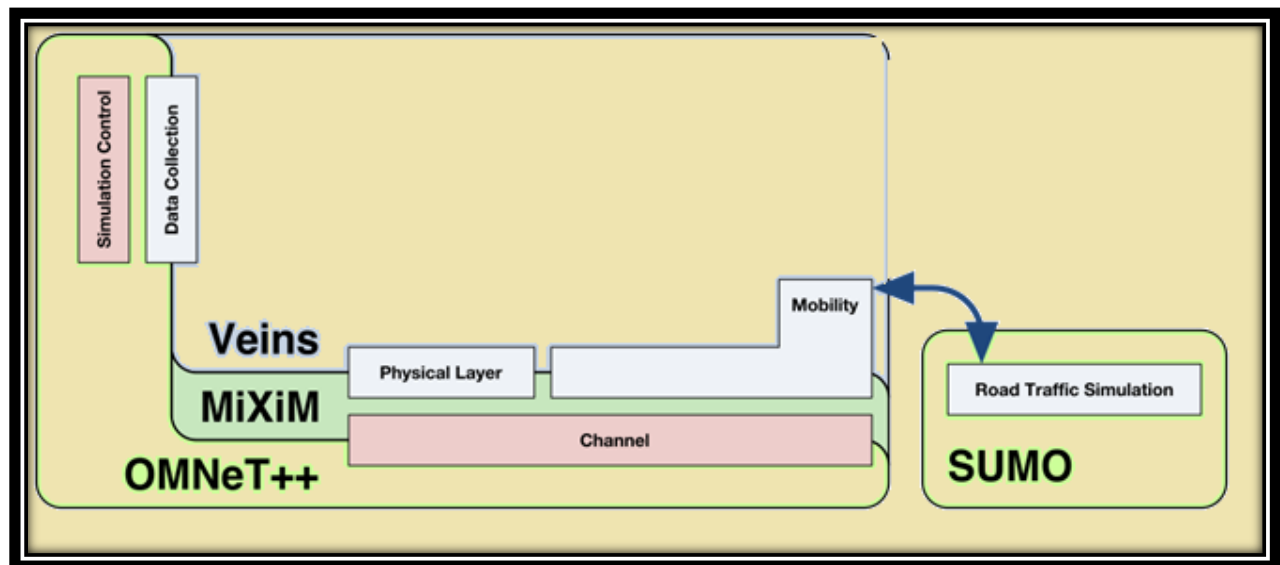

Figure 3.4 Veins Architecture [15]

3.7 Vehicle in Network Simulation (VEINS)

Veins is an open source Inter-Vehicular Communication (IVC) simulation framework composed of a network simulator and a road traffic micro simulation model used to integrate OMNET++ and SUMO.
Most important features are:
- Online re-configuration and re-routing of cars in reaction to the network simulator.

- Fully detailed models of IEEE 802.11p.

- IEEE 1609.4 DSRC/WAVE network layers.

- Supports the realistic map and realistic traffic.

Veins connects to OMNeT++ and SUMO simulators via a TCP socket to run in parallel. OMNeT++ provides a powerful networking simulation tool but has some limitations in modeling of wireless communication. Thus, MiXiM a framework for simulation of wireless channels has been used to provide detailed models of wireless channels, connectivity, mobility and MAC layer protocols for OMNeT++. Veins framework was develop based on MiXiM [15].

3.8   Simulation of Urban Mobility (SUMO)

SUMO is an open sourced and portable microscopic road traffic simulator developed by Institute of Transportation Systems at the German Aerospace Center using standard C++. It is licensed under the GPL (General Public Licenses). In sumo each vehicle has its own route and other characteristics such a deceleration, acceleration and length variation between vehicle types [16].

SUMO helps to study several research topics such as route choice and traffic light algorithm or simulating vehicular communication. Netgenerate (netgen) application that use sumo to generate roads can also generate them by importing a digital road map. The road network importer "netconvert" allows reading networks from other traffic simulators as VISUM, Vissim or MATsim. It also reads other common formats, as shape files or Open Street Map [17].

The following are the features provided by SUMO:
- Different vehicle types
- Multi-lane streets with lane changing
- Different right-of-way rules, traffic lights
- A fast openGL graphical user interface
- Manages networks with several 10.000 edges (streets)

- Fast execution speed (up to 100.000 vehicle updates/s on a 1GHz machine)

- Interoperability with other application at run-time

- Network-wide, edge-based, vehicle-based, and detector-based outputs

- Supports person-based inter-modal trips

- Imports VISUM, Vissim, Shapefiles, Open Street Map (OSM), RoboCup, MATsim, OpenDRIVE, and XML-Descriptions

- Missing values are determined via heuristics

- Microscopic routes - each vehicle has an own one

- Different Dynamic User Assignment algorithms

- Only standard C++ and portable libraries are used

- Packages for Windows and main Linux distributions exist

- High interoperability through usage of XML-data only

- Open source (GPL)

Figure 3.5 below shows Simulation of Urban Mobility (sumo) interface

Figure 3.5 Simulation of Urban Mobility interface

3.8.1 Components of Sumo

To work on sumo simulation there are some files that must be edited, these files are:

3.8.1.1 Nodes File

In this xml file, we set the location of nodes by (x- and y-coordinates, describing distance to the origin in meters) and an ID for future reference. The name of this file always begins with.nod.xml yourfile-name. The node file has the following format:

```
<nodes>
<node id="1" x="-250.0" y="0.0" />
<node id="2" x="+250.0" y="0.0" />
<node id="3" x="+251.0" y="0.0" />
</nodes>
```

3.8.1.2 Edges File

This file contains a description of how the nodes are connected with edges. Each edge has identification, source node ID and target node ID. Vehicles traveling on Edges are assigned a source and destination node.

```
<edges>
<edge from="1" id="1to2" to="2" />
<edge from="2" id="out" to="3" />
</edges>
```

After saving nodes and edges files we use NETCONVERT tool to build our network using the following command:

netconvert --node-files=. nod.xml --edge-files=. edg.xml --output-file=yourfile-name.net.xml

This will generate another xml file called yourfile-name.net.xml, which represents the network.

3.8.1.3 Routes File

Now we define a route for the vehicle, which consists of the edges and vehicle attributes as follows:

```
<routes>
<vType accel="1.0" decel="5.0" id="Car" length="2.0" maxSpeed="100.0" sigma="0.0" />
<route id="route0" edges="1to2 out"/>
<vehicle depart="1" id="veh0" route="route0" type="Car" />
</routes>
```

3.8.1.4 Configuration File

Now we glue everything together into a configuration file:

```
<configuration>
<input>
<net-file value=".net.xml"/>
<route-files value= ". rou.xml"/>
</input>
<time>
<begin value="0"/>
<end value="10000"/>
</time>
</configuration>
```

By saving this to yourfile-name.sumocfg we can start the simulation by either

sumo -c yourfile-name.sumocfg or by using the GUI by:

sumo-gui -c yourfile-name.sumocfg

When simulating with GUI it is useful to add a gui-settings file, so the settings do not have to be changed after starting the program as follows:

```
<Configuration>
<input>
```

```
<net-file value="yourfile-name.net.xml"/>
<route-files value="yourfile-name.rou.xml"/>
<gui-settings-file value="yourfile-name.settings.xml"/>
</input>
<time>
<begin value="0"/>
<end value="10000"/>
</time> </configuration>
```

After that a file with the view settings is created:
```
<viewsettings>
<viewport y="0" x="250" zoom="100"/>
<delay value="100"/> </viewsettings>
```
This is saved and included in the config file, in this example this would be .settings.xml [18].

3.9 OMNeT++ SIMULATION

OMNeT++ is a wireless network simulator, which is a component-based modular open-architecture discrete-event network simulator implemented in C++ for [16]:
• Wired and wireless communication networks
• Protocol modeling
• Multiprocessors and distributed hardware systems

OMNeT++ can be used under the Academic Public License that makes the software free for non-profit use. The motivation of developing OMNeT++ was to produce a powerful open-source discrete event simulation tool that can be used by academic, educational and research-oriented commercial institutions for the simulation of computer networks and distributed or parallel systems [16].

OMNeT++ uses Network Description (NED) language to describe simulation models. NED contains simple module declarations, compound module definitions and

network definitions to create simple modules. These simple modules are grouped together into compound modules. Simple and compound modules use message passing to communicate to each other through 'gates' over connections that span between modules and other compound modules[16, 19].

OMNeT++ is not a ready to use network simulator by itself so it needs to import another simulation models, such as MiXiM, INET/INETMANET or VEINS to simulate the network [15].

Figure 3.6 shows OMNeT++ IDE interface, which represents the work environment to edit source files.
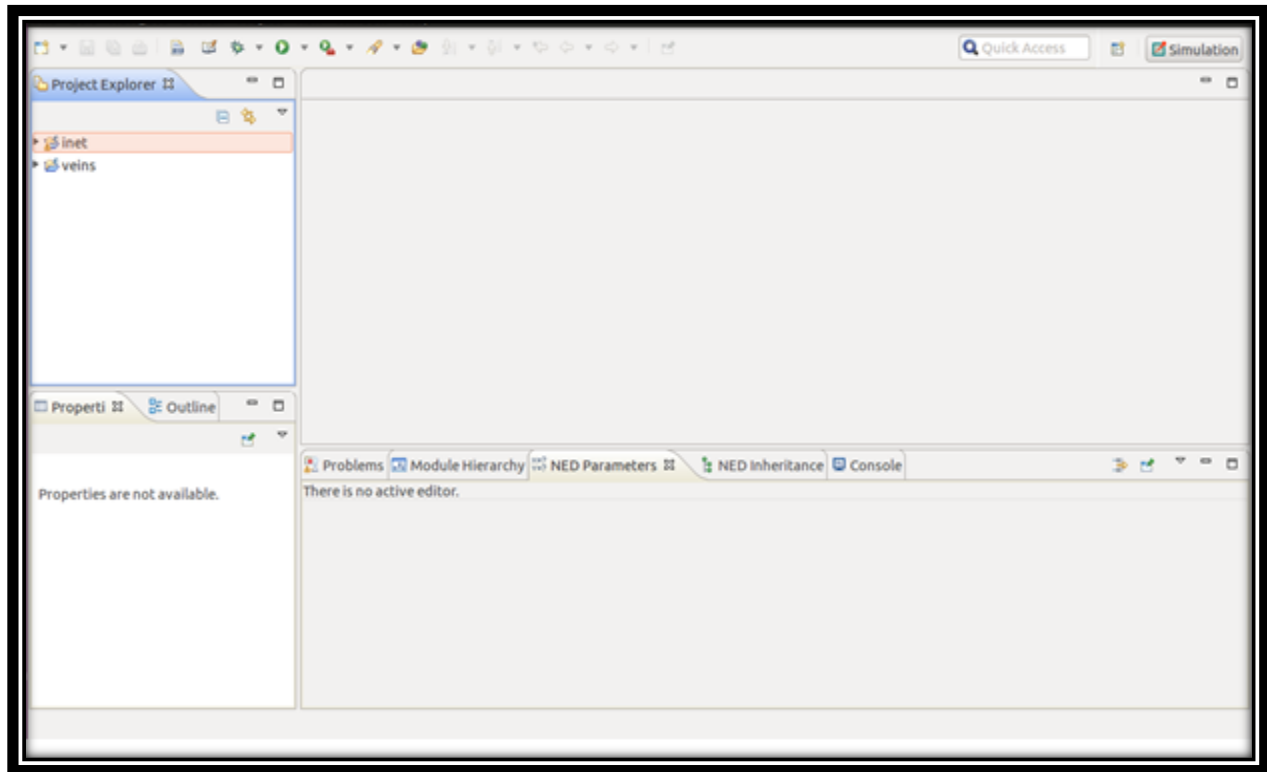

Figure 3.6 OMNET++ IDE interface

Chapter Four

Results

4.1 Introduction

In this chapter, we present the results showing significant improvement in traffic fluency in intersections and the advantages over other architectures in term of total time. The goal of the project is to reduce congestion in intersections by enabling a vehicular ad hoc network between traffic lights and vehicles.

To extract the results, we conducted two experiments. The first experiment simulated the normal situation where the traffic signal is not adaptive. The second experiment represents our work, so that we made the traffic signal adaptive so that it responds to messages sent by passing vehicles on the road through the road side unit.

To conduct these experiments and extract the results, we have assumed the following:

1. One cross roads; each road has two lanes one for vehicles to enters the road and the other for vehicles coming out of the same road.

2. Each lane of the road (road capacity) allows only one vehicle.

3. The maximum speed of vehicles on the road is 16.67 m / s.

4. One traffic sign at the intersection between the roads.

5. Road side unit (RSU) to provide the possibility of communication with vehicles

4.2 Total time

The time from when the vehicle entering in the simulation until it leaves it, including stop time at the traffic lights.

4.3 Total time in Normal Scenario

Figure 4.1 illustrates a problem of a broken vehicle (The red colored vehicle) at an intersection in normal scenario. After the phase of green light is finished for vehicles going from east to west and the green light phase starts for those vehicles going from north to south, the second vehicle in the same lane of the broken vehicle causes traffic congestion for other vehicles mainly for vehicles moving from north to south. For this scenario, we assumed that the vehicle's downtime is 100 seconds and the number of vehicles is 20.
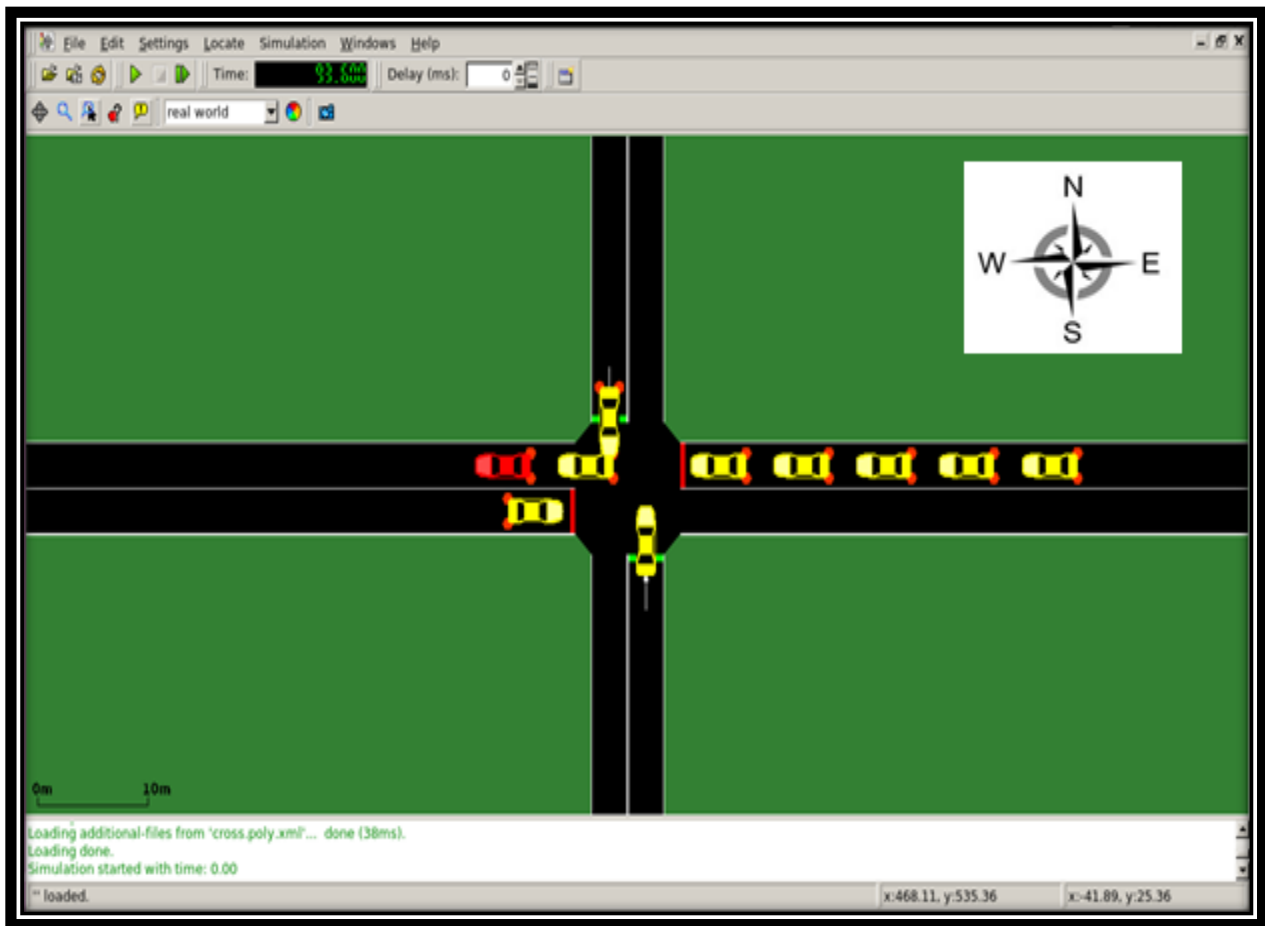

Figure 4.1 Simulation Result for Normal Scenario

Table 4.1 illustrates the total time for all vehicles in normal scenario where the traffic light is not adaptive.

Table 4.1 Total time for each vehicle in normal scenario

Vehicle number	Total time
Vehicle [0]	202.3
Vehicle [1]	143.4
Vehicle [2]	90.5
Vehicle [3]	139.3
Vehicle [4]	141.9
Vehicle [5]	90.4
Vehicle [6]	183
Vehicle [7]	177.1
Vehicle [8]	176.6
Vehicle [9]	174.2
Vehicle [10]	238.2
Vehicle [11]	174.3
Vehicle [12]	146.4
Vehicle [13]	142
Vehicle [14]	183.7
Vehicle [15]	124.2
Vehicle [16]	177.7
Vehicle [17]	175
Vehicle [18]	119
Vehicle [19]	90.2
Average	**154.47**

Figure 4.2 illustrates the total time for all vehicles in normal scenario where the traffic light is not adaptive.
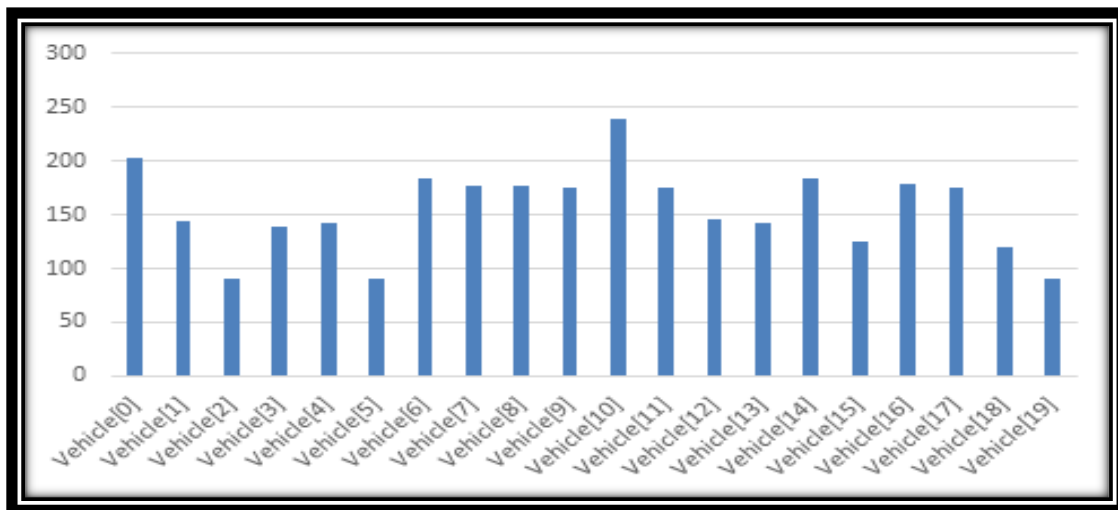

Figure 4.2 Total Time for Each Vehicle in Normal Scenario

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4.4 Total time in Adaptive Scenario

Figure 4.3 illustrates the second scenario with adaptive traffic lights to solve the problem of delay caused by the broken vehicle (the red colored vehicle) at the intersection. After the phase of green light is finished for vehicles going from east to west and the green light phase starts for those vehicles going from north to south. The broken vehicle sends a warning message to the traffic light. Once the warning message is received by the traffic light, the traffic light of the lane containing the broken vehicle will change from green to red before the phase is complete to avoid congestion caused by vehicles entering the same lane. For this scenario, we also assumed that the vehicle's downtime is 100 seconds and the number of vehicles is 20.
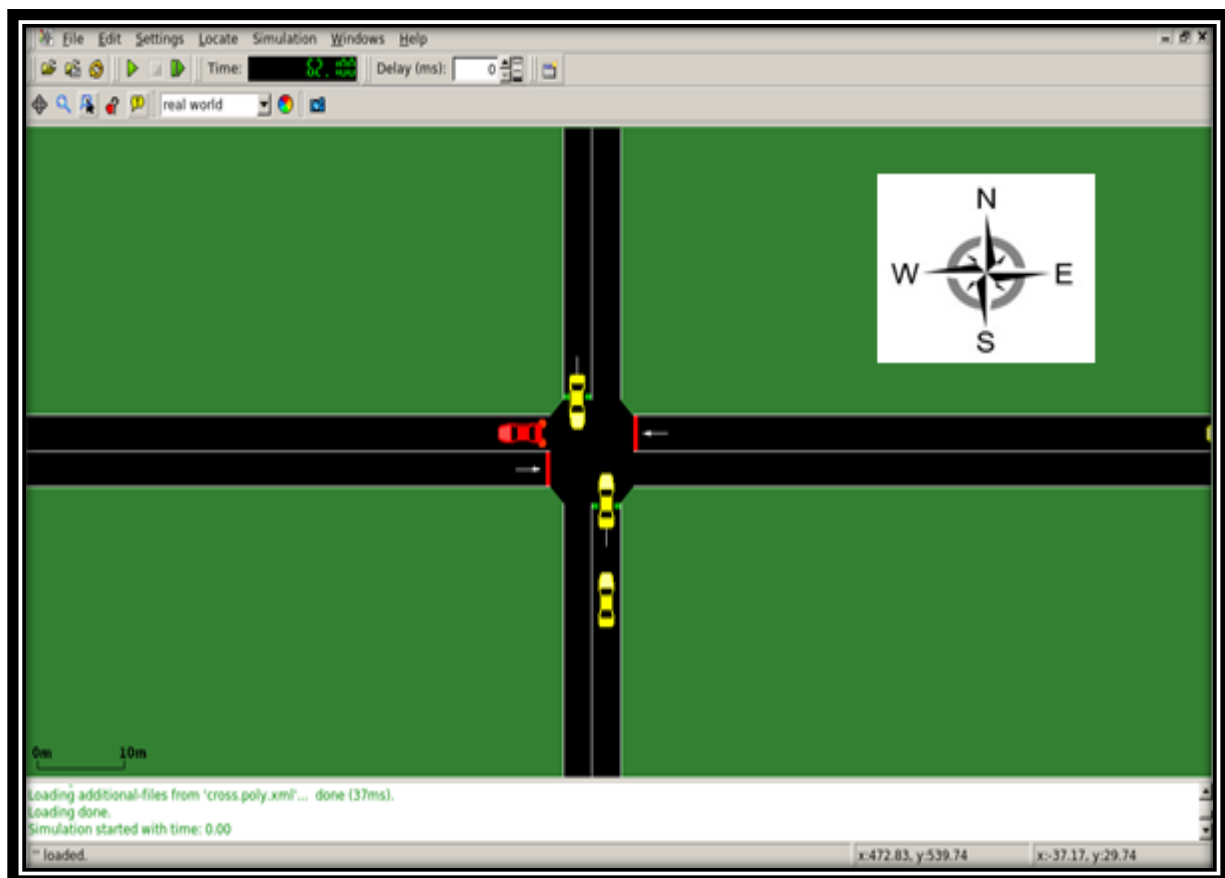

Figure 4.3 Simulation Result for Adaptive Scenario

Table 4.2 illustrates the total time for all vehicles in the second scenario where the traffic light is adaptive.

Table 4.2 total time for each vehicle in adaptive scenario

Vehicle number	Total time
Vehicle [0]	202.4
Vehicle [1]	111.9
Vehicle [2]	90.5
Vehicle [3]	108.3
Vehicle [4]	110.5
Vehicle [5]	90.4
Vehicle [6]	183
Vehicle [7]	177.1
Vehicle [8]	192.2
Vehicle [9]	188.8
Vehicle [10]	203.4
Vehicle [11]	187.8
Vehicle [12]	96.2
Vehicle [13]	96
Vehicle [14]	149.3
Vehicle [15]	136.5
Vehicle [16]	143.3
Vehicle [17]	140.4
Vehicle [18]	96
Vehicle [19]	112
Average	**140.8**

Figure 4.4 below, illustrates total time for all vehicles in the second scenario where the traffic light is adaptive.
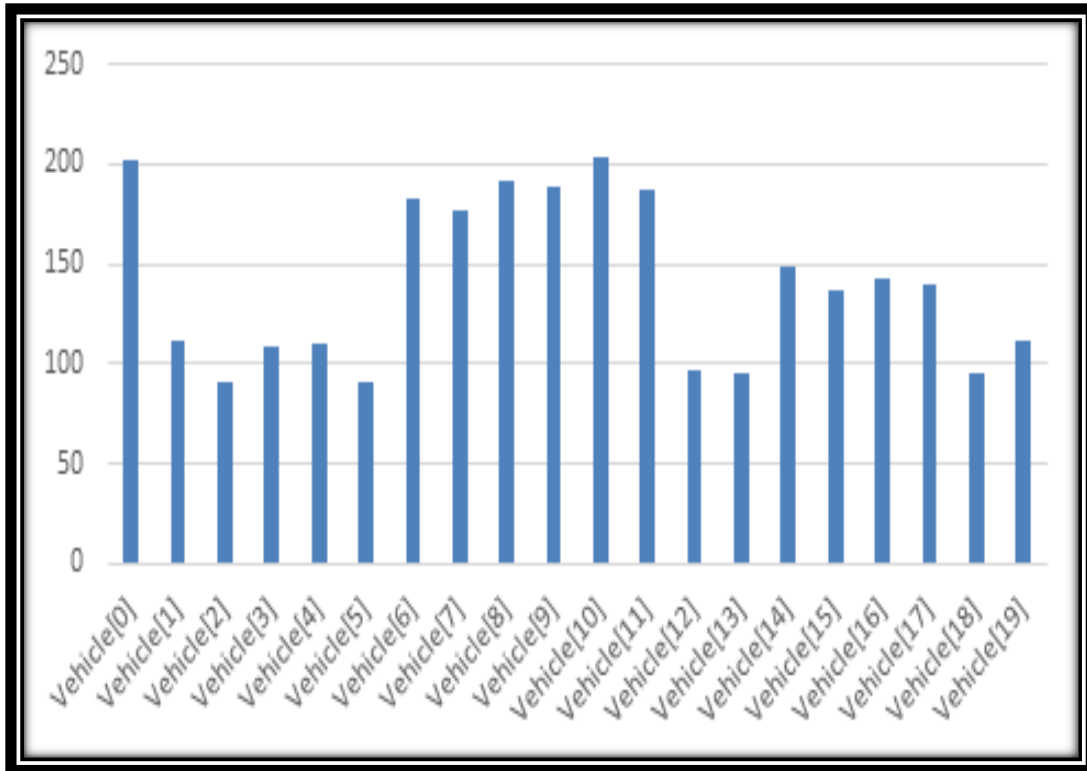
Figure 4.4 Total time for each vehicle in adaptive scenario

4.5 Comparison of the total time in the two scenarios

Figure 4.5 below, shows the comparison of the total time for each individual vehicle in two the scenarios, and shows variation in total time (As we note in the figure, the total time is improved for 50% of vehicles in the adaptive scenario). Also, from Figure 4.5, it is found that the average time of 25% of vehicles remained as it was in the normal scenario, so that it did not increase or decrease, and this percentage represents the number of vehicles that are located in the same road and lane where the broken vehicle is. It is also noted that the average time of 25% of vehicles has been affected so that it increased compared to the normal scenario. These are the vehicles that are in the same lane and direction of the broken vehicle. This is because the traffic signal was changed from the green light to the red light by the roadside unit, which responded to the warning message sent from the broken vehicle. This change was made before the traffic signal completed its normal duration.
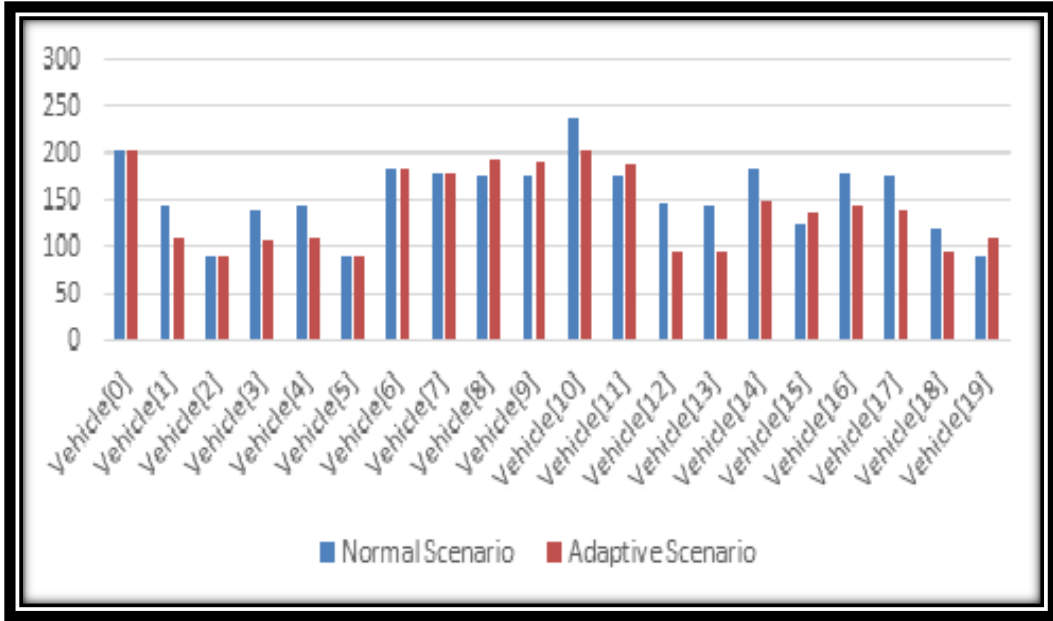
30

Figure 4.5 Variations in total time in the two scenarios

As shown in Figure 4.6, the intersection recovered sooner from congestion when using the proposed adaptive strategy, compared to the pre-timed system deployed in the intersection. The average total time decreased for vehicles in the adaptive scenario.
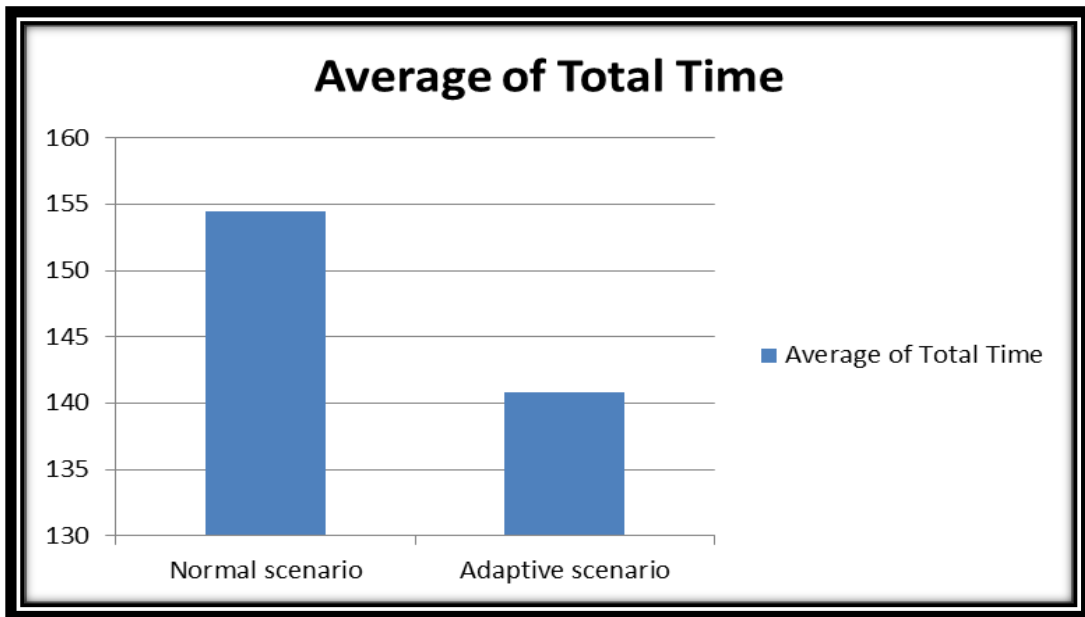

Figure 4.6 Comparison of the average total time in the two scenarios

We have re-conducted the previous tests more than once by increasing the number of vehicles and increasing the time of the broken vehicle at the intersection. The following table 4.3 shows the results of the experiments after the increase in the number of vehicles and the time of broken vehicle. We assumed that the vehicle was broken for five minutes.

Table 4.3 Results of the experiments when the increasing in the number of vehicles and the time of broken vehicle is five minutes

Number of vehicles	Average of total time		Enhancement%
	Normal scenario	Adaptive scenario	
60	445.77	364.19	18.30
84	477.93	410.09	14.19

4.6 Average CO2 emissions

We measured and compared the percentage of carbon dioxide emitted from the vehicles in the normal scenario and the adaptive scenario. Table 4.4 below shows the comparison of result in the two scenarios.

Table 4.4 Comparison of the average CO2 emissions in the two scenarios

Number of vehicles	Average of CO_2 emission in g		Enhancement%
	Normal scenario	Adaptive scenario	
84	623.08	551.19	11.53

Figure 4.7 below illustrates the comparison of the average CO2 emissions in the two scenarios. As we note in the figure that the amount of emissions is less in the adaptive scenario compared to the normal scenario.
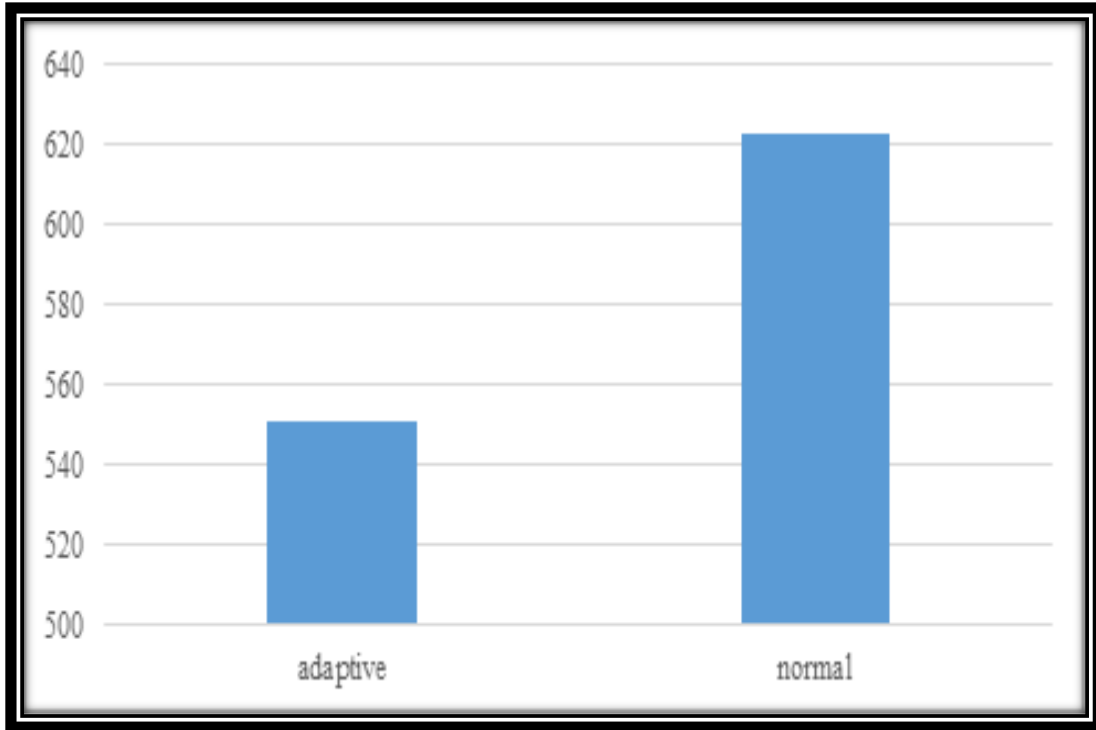

Figure 4.7 Comparison of the average CO_2 emissions in the two scenarios

4.7 Comparative study

This section demonstrates a comparison of our proposed strategy with [20] which proposed an approach to avoid traffic congestion using VANET: We compare several aspects such as total time, total distance (meters), fuel consumption, CO_2 emission (in g) and the method used to reduce the congestion. Table 4.5 shows this comparison.

Table 4.5 Comparative study

Name of study	Total time	Total distance in meters	Fuel consumption	CO_2 emission in g	Reduce congestion
Our approach	reduced	same	reduced	reduced	By using adaptive traffic signal
An approach to avoid traffic congestion using VANET	reduced	reduced	reduced	reduced	By selecting best path using Dijkstra's algorithm

As we can see in Table 4.5, the two studies have resulted in similar improvements in all aspects except the total distance. The total distance in our proposed strategy is the same because vehicles do not change their path, they cross the same intersection, but with an overall reduction in total time.

Chapter Five

Conclusions and Recommendations

5.1 Conclusions

This research presented an adaptive traffic light system based on vehicular ad hoc network between vehicles and the Road Side Unit (RSU) to solve the problem of delay caused by a broken vehicle at an intersection. When a vehicle brakes down, it sends a warning message to the Road Side Unit to change the traffic light according to the traffic state discovered by warning message.

The results show enhancement in total arrival time when applying the adaptive scenario compared with the normal scenario. The proposed system also reduces fuel consumption and CO_2 emission.

5.2 Recommendations

Our work is based on a vehicular ad hoc network between vehicles and Road Side Unit (RSU) in an intersection, with only one entry and exit point at each road, so we recommend to:

1. Increase the number of lanes in the road.
2. Make the traffic signal more adaptive by allowing it to signal a green light for one specific lane instead of the whole road (i.e. go straight or turn left).
3. Connect more than one traffic light together to expand the area of detection of broken vehicles.

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