Republic of Iraq
Ministry of Higher Education and Scientific Research
University of Anbar
College of Computer Science and Information Technology
Department of Computer Science

Adapting Simple Approach for Traffic Light Intersection

A Thesis

Submitted to the Department of Computer Science - College of Computer Science and Information Technology, University of Anbar as a Partial Fulfillment of the Requirements for Master Degree of Science in Computer Science

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1443 A.H. *2021 A.D.*

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Abstract

Traffic congestion is one of the major problems facing drivers some over the world, especially in the urban road network, where lost time and fuel consumption are major concern. Economic, social and environmental problems arise due to ineffective intersection control. Therefore, Intelligent Transportation Systems (ITS) are important in reducing congestion and accidents, increasing traffic safety and reducing air pollution. With the tremendous advances in mobility and networking technology, **V**ehicular **A**d hoc **NET**works (VANETs) have attracted researchers from academia and industry. Traffic Signal Control (TSC) can be self-regulating and adaptive to changes in traffic conditions using VANET technology and intelligent control algorithm as VANET technology provides comprehensive information on vehicles approaching intersections. Communication between vehicles allows the exchange of information to improve traffic safety. One of the types of VANET communication is V2X as it can send, receive and rebroadcast safety messages, so TSC communication with V2X is a very effective solution to the problem of traffic congestion.

In this thesis, an intersection in the city of Ramadi was studied and analyzed by collecting real-time traffic information in the road network surrounding the intersection. Then, a dynamic scheduling algorithm was proposed based on the VANET scenario, which schedules competing flows in traffic. The proposed algorithm aims to increase traffic flow and performance of the intersection by taking advantage of excess green time in order to reduce the waiting time and delay of mobile vehicles depending on vehicles information (speed, location, and number of vehicles) under different coverage area. Instead of using the fixed maximum green time currently used at the intersection, and depending on the coverage area and vehicles arrival, an adaptive green time method has been proposed and investigated. The coverage area and developed algorithm are simulated in SUMO simulator with MATLAB through TRACI tool to obtain the results. The results showed a significant improvement in traffic throughput and reduced delay time by different percentages (the lowest was 7.322% and the highest was 16.902%) according to the difference in the coverage area compared to the traditional (i.e. fixed) cycle time currently used in our case study.

Keywords: Scheduling algorithm, Traffic light, VANET, Adaptive green time, Coverage area, Isolated intersection, Non-isolated intersection.

Acknowledgments

All praises to Allah Almighty, who enabled me to complete this work successfully.

At first, there are no appropriate words to express my deep gratitude, thanks and appreciation to my supervisor and teacher since the undergraduate stage, ***Dr. Muntaser Abdulwahed Salman***. For the support, guidance and advice he provided me during my research this. Where he was my first reference in every problem I faced. What I found from him was clear guidance and a correct way to accomplish my work this.

I would also like to extend my thanks and gratitude to ***all my teachers*** in the College of Computer Science and Information Technology for everything.

Special thanks to ***my wife*** and ***all my family members*** for their tolerance and support and encouragement throughout the period of my studies.

Finally, I would like to thank ***all my friends*** for their support.

My thanks for all…

Dedicate

- ✓ To my father (may God have mercy on him), who wished to see me in the advanced stages of my scientific career.
- ✓ To my dear mother.
- ✓ To my supervisor and my teachers.
- ✓ To my wife and children.
- ✓ To my brothers and sisters.
- ✓ To my relatives and friends.
- ✓ To my city (Ramadi) and my dear country.

Belal Rasheed Alwan

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Abbreviations

AU	**A**pplication **U**nit
DSRC	**D**edicated **S**hort-**R**ange **C**ommunications
E-W direction	**E**ast to **W**est **direction**
GLOSA	**G**reen **L**ight **O**ptimal **S**peed **A**dvisory
GPS	**G**lobal **P**ositioning **S**ystem
IoT	**I**nternet **o**f **T**hings
ITS	**I**ntelligent **T**ransportation **S**ystems
OBU	**O**n-**B**oard **U**nit
RFID	**R**adio-**F**requency **ID**entification
RSU	**R**oad **S**ide **U**nit
SUMO	**S**imulation of **U**rban **MO**bility
TraCI	**Tra**ffic **C**ontrol **I**nterface
TSC	**T**raffic **S**ignal **C**ontrol
V2I	**V**ehicle-to-**I**nfrastructure
V2V	**V**ehicle-to-**V**ehicle
V2X	**V**ehicle-to-everything
VANET	**V**ehicular **A**d hoc **NET**works
W-E direction	**W**est to **E**ast **direction**
WLAN	**W**ireless **L**ocal **A**rea **N**etwork
WSN	**W**ireless **S**ensor **N**etwork
XML	E**x**tensible **M**arkup **L**anguage

1

Chapter One
General Introduction

Chapter One

General Introduction

1.1 Introduction

Traffic congestion and traffic delays are among the main problems that drivers around the world are facing nowadays, especially in urban cities. In our city, Ramadi, drivers at the intersection always compete for who can cross first and with weak law enforcement against violators crossing an intersection become dangerous. With the increase in vehicle ownership and the absence of intersections operating with a traffic light system as shown in Figure 1.1, traffic congestion has increased. This is because it takes a long delay time for vehicles and double effort for drivers as well as traffic has become restricted.

Figure 1.1 Cinema intersection before installing the traffic light

Delay or waiting time of vehicle is the most important issue to overcome. This is because it is related to the drivers' time while crossing the intersection. Where, improving the transportation system in the city does not only require expanding and improving roads beside new roads and services, but also improving levels of traffic light systems. Intersection points in the city need traffic signal devices. Therefore, a traffic light that works in traditional system installed at a major intersection in the city (only available one to the time of writing this thesis, called Cinema intersection).

However, the traffic congestion problem has not been resolved and investigated, as road users still need to spend a lot of time waiting for their turn at the intersection as shown in Figure 1.2.

Figure 1.2 Intersection congestion after installation up a traffic light

In general, the traffic light device is one of the infrastructure assets of transportation systems that are used to control the traffic of vehicles to reduce the conflict of road users. Traffic light device is able to make the traffic flow smoothly at the intersection to reduce traffic congestion and improve navigation along the roads. Then it is also able to reduce the waiting time and travel time for road users at the intersection point [1]. Therefore, such traffic light system must be improved using modern technologies instead of the traditional system that is currently used at the intersection. One of these techniques is the use of a traffic light control system in a VANET environment based on real-time data, where a comprehensive vision of the intersection with speed, location, and direction about each vehicle must be available.

In this thesis, proposition of VANET based traffic light system using scheduling algorithm has been investigated and developed to find a solution to the congestion issue.

Traffic lights have been used to schedule and control competing traffic flows at every intersection using light cycle schedules. They provide secure scheduling that allows all traffic flows to share a road intersection.

Researchers and transportation engineers worked jointly to create appropriate traffic light systems. Systems that can achieve the goals of ITS, where the traffic light control system needs to respond faster to traffic variables in real time. Traffic lights are managed using different methods and techniques including:

- **Artificial Intelligence Algorithms:** One of the areas of computer science that has become very widely used in real life activities. It can rely on smart algorithms (such as reinforcement learning, genetic algorithm, fuzzy logic, and evolutionary algorithm) to solve traffic congestion problems. For instance, accurate reinforcement learning technique was used in [2] where the authors built an adaptive traffic light control model and proposed a Deep Q-Network algorithm that accurately represents the problem-related elements (factors and environments) using real-time traffic condition to reduce the average waiting time. Authors in [3] applied a function approximation reinforcement learning technique to train an adaptive traffic signal controller and used asynchronous Q-Learning with an artificial neural network to learn how to make decisions and reduce the overall average delay in random prime time. Fuzzy logic has also been used to manage traffic lights based on several parameters (number of vehicles, queue length, road width) to optimize time settings based on required real-time conditions and predict the right time to reduce congestion [4]. Woroud Al-Othman [5] also provided a comprehensive survey of ITS and showed that the use of fuzzy logic provides better performance for controlling isolated intersections. A new traffic light system designed in Hong Kong [6] that uses machine learning with object detection and analysis by an evolutionary algorithm. It aims to make a real-time strategic signal switch arrangement for traffic lights at an intersection. This is done in order to reduce vehicles waiting time.
- **Image processing**: This technique usually applied to find out the number of vehicles, length of the queue, and place where the image was taken, by installing cameras next to the traffic light, and images are taken sequentially. Based on this input, the algorithm is expected to know the flow, density, priority, and duration of the traffic light cycle. The researchers in [7-10] discussed traffic light management based on surveillance cameras and the use of image processing.
- **RFID and Internet of Things (IoT) technologies:** This technologies have been used to develop intelligent traffic control systems to collect and monitor traffic information. This is done in real-time to make the timing of the traffic signal dynamic by sensing traffic density. For example, in [11], an Internet-connected adaptive traffic system has been proposed to for continuous

monitoring of different lanes to estimate traffic congestion. In [12], a solution has also been proposed to the traffic congestion problem by using IoT traffic control systems with priority for emergency vehicles. Authors in [13] and [14] presented a method to detect traffic congestion and blockage at the intersection using RFID technology to make traffic light timing work dynamically.

- A **Wireless Sensor Networks (WSN)**: these networks have also been used a lot to detect the presence of vehicles and communicate with traffic control units. For instance, the author in [15] proposed a WSN architecture using healing algorithm to collect traffic data and enable traffic lights to make appropriate decisions in real-time. The proposed a traffic light dynamic control system that integrates a real-time traffic monitoring WSN with several fuzzy logic controllers that run in parallel, one for each phase. Each fuzzy controller tackles vehicle turning actions and manages the phase and green time of traffic lights in a dynamic manner to shorten vehicle waiting times in lineups, particularly in congested areas [16]. The deployment of sensors is one of the factors that limit the effectiveness of the wireless sensor network. Therefore, the centrality measurement of the graph is used as a base to determine the best locations to install sensors in the traffic network [17].
- **Other methods and techniques**, for instance, in [18] and [19] a new tool called Uppaal Stratego was used as an online intersection controller. This tool works with machine learning techniques to synthesize near-perfect traffic light controllers. The goal of using this tool is to reduce the waiting time for vehicles and the length of queues. In [20], Green Light Optimal Speed Advisory (GLOSA) systems aim to give a driver the ideal target speed recommendation when approaching a traffic light. These systems are used to predict traffic lights and signal changes 15 seconds into the future. These systems also calculate the distance required to pass through the intersection without stopping during the remaining green signal time. In [21], the required distance is displayed on the surface of the outer road as a green rectangle through a head-up display. With another technique called Cooperative Adaptive Cruise Control used in [22], Vehicles have the ability to broadcast speed and location information in real-time. The information of these vehicles was used in a collaborative algorithm to control traffic lights and predict

future traffic conditions and thus set signal priority for approaching an intersection. Also, one of the methods used to intelligently control traffic lights is to use a theoretical game framework relies on decision-making processes done in [23]. Each incoming link is considered to be an individual player and the status of the light signal (green or red) is considered as decisions made by those players. Thus, the best vehicle path is selected by combining all decisions and cost evaluation.

1.2 **Related Work**

This section presents related work and previous studies on VANET technology and scheduling algorithm.

A traffic light is used to schedule competing flows of vehicles crossing an intersection and to control them using a light cycle schedule. The main control key of the traffic light is to adjust its timing appropriately according to the flow of traffic. It allows all competing flows to share the intersection, reduce waiting time and increase traffic efficiency in the surrounding road network. Therefore, many researchers have designed intelligent scheduling algorithms in which traffic light phases based on VANET information are adjusted according to the real-time traffic of the flows surrounding an intersection.

M. K. Avzekar in 2014 applied an adaptive traffic light control algorithm to reduce the delay time of vehicles at an intersection [24], using VANET for collecting information about the location and speed of the vehicles. Author worked on developing the algorithm by suggesting priority-based signaling (giving priority to emergency vehicles).

J. Li, Y. Zhang, in 2016 proposed a self-adaptive traffic light control system based on the vehicle's speed in real-time. They used vehicle to infrastructure (V2I) communication to achieve data transfer between vehicles and traffic lights [25]. The vehicles send quick messages to the traffic lights at the intersection, then the traffic lights analyze the messages and adjust the timing of the signal in real-time by applying a control algorithm to one intersection. Their proposal reduced traffic congestion but assumed that each vehicle only goes straight (SN or EW) and not turn left or right.

D. Shao, in 2016 proposed a new type of intersection scheduling model through V2I communication to convey the speed and direction of the vehicle crossing the intersection [26]. This information is used in a scheduling algorithm and returns the time required for the vehicle to reach the intersection. The vehicle adjusts its speed according to the amount of time of arrival. The results of the proposed algorithm showed saving time and energy and improving road use, but their proposal did not take into account the different traffic conditions on the road.

M. B. Younes in 2016 designed a self-scheduling algorithm for context-aware traffic lights [27]. Periodic announcement messages are used for mobile vehicles, and the green phase can be interrupted for any traffic flow to enable emergency vehicles to cross quickly.

R. F. O. Adebiyi in 2017 develop the adaptive dynamic scheduling algorithm based on artificial bee colony and a mathematical model for vehicle traffic control [28]. The developed model relied on scheduling the green light timing based on the traffic situation at the intersection to reduce the average waiting time. The results showed a reduction in average waiting time, but the intersection area distance was not taken into consideration.

Z. Cai, Z. Deng, and M. Liang in 2019 introduced an intersection signal control mechanism using data collection on distant vehicles through VANET [29], to calculate the cumulative waiting time of each traffic flow at a future moment of signal decision making. They also designed two schemes: the first scheme, fixed-phase and time-period improvement based on the waiting time for each traffic flow. The second scheme is dynamic phase and period control based on the sum of the waiting time for vehicles passing the intersection during green time.

Choudhury. Abantika, in 2019 improve a scheduling algorithm using V2I connectivity to collect and share vehicle movement information, relying on the density of vehicles located within a fixed ready zone and controlling the timing of the green light. The results showed a decrease in the average vehicle waiting time and an increase in the performance of the intersection, but the work was limited to a fixed area distance [30].

K. S. Kasodekar, in 2019 used an algorithm for scheduling traffic lights using a multiple linear regression model [31]. His algorithm relied on the number of vehicles stopped at the red light in each direction and predicting the green time for each signal. His study aims to reduce the number of vehicles parked at the red light and thus reduce traffic congestion. Its results showed a reduction in the number of vehicles stopped at the red light by about 11%, but it did not show the percentage of the delay time for vehicles at the intersection.

J. Rezgui in 2019 proposed three different algorithms for intelligent traffic signal scheduling [32]. The first algorithm depends on the density of traffic and priority is given to the flows with the highest density. While the second algorithm depends on the density of traffic in addition to the waiting time for each vehicle, priority is given to vehicles whose waiting time exceeds a certain amount (it is set and can be modified). As for the third algorithm, it has worked like the previous two algorithms, but it gives priority to emergency vehicles when they appear at the intersection, so the higher density and longer waiting time are ignored.

A. Yousef in 2019 proposed a new, adaptive, date-based traffic management scheduling algorithm that relies on historical traffic information recorded [33]. This is done to calculate green and red times throughout the year to predict traffic flow at busy intersections. Three conditions of the methods were used through a simple linear model of the weighted combination. The results showed the superiority of the algorithm over the traditional systems, as the average waiting time and the average length of the queue were reduced.

M. Razavi in 2019 proposed a traffic light scheduling algorithm based on the density and number of vehicles passing through the main roads leading to intersections [34]. It presented a smart solution to control traffic lights using a combination of image and video processing technologies. This method works by analyzing the route and the number of vehicles waiting at the intersection to help make decisions, and their suggestion gave priority to emergency vehicles. Results showed the success of proposal and reduction of traffic congestion regardless of vehicles speed and distance of intersection area.

The timing of the traffic lights is an important consideration to carefully consider. To improve traffic light timing, traffic engineers use data on traffic volume and vehicle speed. The green light duration and cycle length are dynamically changed according to traffic fluctuations. Other researchers have worked to fine-tune and improve the green-light time of traffic lights.

A. Ranjan in 2015 propose an adaptive traffic light control system using VANET communications and green light allocation algorithm [35]. This is done to estimate the intensity of vehicular traffic on the roads surrounding the intersection. Data collected is evaluated and analyzed by the traffic light control unit to adjust the cycles, so that the waiting time for vehicles can be reduced. The evaluation results showed that the proposed system is better than the traditional system. Vehicles speed, their location, and distance of intersection area were not taken into consideration.

P. Guo in 2018 proposed a new timing strategy that includes optimizing the green time and calculating the set of lanes according to the traffic flow in real-time [36]. Green time for lanes with fewer vehicles is reduced and green time for lanes with more vehicles is increased. Appropriate group of lanes is also calculated through the concept of the main and compatible lanes, so that more than one direction is processed at the same time. Results showed an increase in the efficiency of traffic at the intersection compared to traditional fixed time, but its work was limited to a fixed maximum for the green time.

Z. Yao, L. Shen and R. Liu, in 2020 proposed a dynamic framework for predictive traffic control for isolated intersections in a cross-sectional [37]. This is done with infrastructure integration environment, which has the ability to predict the arrival of vehicles and use their speed data to improve traffic signals. A dynamic programming algorithm is applied to update the timing plan in real time based on the expected short-term traffic flow. The algorithm also uses a complete enumeration method to search for the optimal timing plan within the minimum and maximum green time constraints in order to reduce the delay.

It is necessary to update and conFigure the maximum and minimum green time coefficient to adapt to real-time traffic conditions. Therefore, many researchers worked on the possibility of determining the minimum and maximum green time.

M. J. Shirvani Shiri in 2016 applied a fuzzy control unit to an isolated intersection to determine the minimum and maximum limits, allowing the green time to be set automatically for different times of the day [38]. This is done by measuring the length of the vehicles queue at a red light (service queues) and vehicle queues at green light (while in service) and calculating the detected arrival flow rate corresponding to the service phase. After that, appropriate green time for each stage is determined according to density of the compounds. In this study, organic functions were calibrated by trial and error.

H.C. Hu in 2020 updated the green time scheduled traffic maximum controller with many parameters in its model and some of them need to be conFigure d according to the traffic situation [39]. Author presented a method for determining the maximum green time by proposing a two-stage hierarchical structure that combines online planning and reinforcement learning. Online planning is used to calculate the schedule for short-term traffic signal management, and reinforcement learning is applied to fine-tune model parameters over a longer time scale.

Also, types of traffic light are categorized based on several criteria's, e.g. traffic density, load and effect of adjacent intersections. The term "isolated" intersection is referred to an intersection far enough from their neighboring intersections that do not adversely affect it.

Andronov R in 2019 presented a study on the effectiveness of adaptive control at a traffic light intersection on the performance of an isolated multi-lane intersection [40]. As it is assumed that the uniformity in the distribution of the time period differs for the intersections, so explain the difference between the effect of adaptive control at isolated and non-isolated intersections using the Monte Carlo experiment on traffic modeling. ***The same researcher in 2020 has also presented*** a study and analysis of the nature of isolated intersections and examining the incoming traffic flow [41]. This is done to ensure that it conforms to the basic statistical laws of the time period distribution between vehicles. According to Pearson criterion as a basis for knowing the general nature of the distribution of the intervals that will change significantly at the intersections controlled by the traffic light and how close they are to other intersections.

As a summary, Table 1.1 shows related works that have been surveyed in this research.

Table 1.1 Summary of related works

Ref. no.	Title	year	Goal	Technique used	simulation tool
[24]	Adaptive Traffic Signal Control with VANET	2014	Reducing vehicle delays at the intersection and giving priority to emergency vehicles	VANET (V2V) (V2I)	Windows NT and VMS
[25]	A Self Adaptive Traffic Light Control System Based on Speed of Vehicles	2016	Reduce congestion at intersections depending on the speed of vehicles	VANET (V2I)	Simulink Matlab
[26]	V2I Based Intersection Scheduling Algorithm	2016	Take an appropriate decision by scheduling traffic light stages to reduce time based on speed and direction information	VANET (V2I)	NCTUNS
[27]	Context-Aware Traffic Light Self-Scheduling Algorithm for Intelligent Transportation Systems	2016	Reduce emergency vehicle waiting time with context-aware scheduling algorithm	VANET	SUMO and NS-2
[28]	Management of Vehicular Traffic System using Artificial Bee Colony Algorithm	2017	Reducing the average waiting time at the intersection by scheduling the green light timing based on the artificial bee colony	VANET (V2V and V2I)	Simulink Matlab

[29]	An Intersection Signal Control Mechanism Assisted by Vehicular Ad Hoc Networks	2019	Reducing the average waiting time and the percentage of long-waiting vehicles	VANET (V2V and V2I)	Veins (SUMO and OMNeT ++)
[30]	Dynamic Scheduling of Traffic Signal Management in Urban Area Network	2019	Reduce congestion and delay time by scheduling traffic light stages	VANET (V2I)	SUMO and OMNET ++
[31]	Intelligent Traffic Light Scheduling Using Linear Regression	2019	Reduce traffic congestion based on the number of vehicles parked at the red light	VANET (V2I)	Simulink Python
[32]	Smart Traffic Light Scheduling Algorithms	2019	Improve traffic flow and reduce delay time for road users	VANET	Simulink Java
[33]	Intelligent Traffic Light Scheduling Technique Using Calendar-Based History Information	2019	Predict traffic flow at intersections and thus improve traffic flow	History Information	SUMO and Matlab
[34]	Smart Traffic Light Scheduling in Smart City Using Image and Video Processing	2019	Preventing traffic jams at the intersection of roads and direction at the same time depending on the density of vehicles	Image and Video Processing	Raspberry-Pi ++ OpenCV

[35]	VANET Based Four Way Road Intersection Traffic Light Control Model	2015	Reducing the waiting time at the intersection by estimating the density of vehicles and allocating the necessary green time for them	VANET (V2V and V2I)	Simulink Matlab
[36]	An Indefinite Cycle Traffic Light Timing Strategy	2018	Reducing traffic congestion by improving the green time and calculating the set of lanes	VANET	Simulink Matlab
[37]	A Dynamic Predictive Traffic Signal Control Framework in a Cross- Sectional Vehicle Infrastructure Integration Environment	2020	Reduce delay and queue length	VANET (VII) vehicle Infrastructure Integration	VISSIM
[38]	Maximum Green Time Settings for Traffic-Actuated Signal Control at Isolated Intersections Using Fuzzy Logic	2017	Controlling the maximum green time at isolated intersections through fuzzy control	VANET and IoT	AIMSUN
[39]	Learning Model Parameters for Decentralized Schedule-Driven Traffic Control	2020	Reduce the cumulative waiting time for vehicles approaching the intersection by dynamically adjusting the green time	Reinforcement and IoT	VISSIM

As a summary, over mentioned algorithms address traffic congestion problem with different solutions. Therefore, investigating our case study intersection is possible taken into consideration its environment parameters such as intersection area and characteristics (i.e. isolated or not).

1.3 Problem Statement

Many vehicles travel during different times of the day through the road network surrounding an intersection increase delay time. This issue increased rapidly if the intersection is located on a road that is considered a major transport artery in the city. The case study intersection operates with a traditional traffic light control system. In other words, there is a waiting time for each vehicle to cross the intersection until traffic light turns green. Sometimes, one of road direction is given the green light, but there are no vehicles crossing the intersection in this direction. Another case, when vehicles may cross early during green stage while others waiting green time period to be reached. This will increase their delay time during the red light in the opposite direction. These problem occurs due to the lack of effective control of the traffic light management at the intersection.

By using VANET technology, which collects and shares information on vehicles in real time with the area surrounding the intersection, traffic can be improved and traffic safety increased. In an urban environment there is a need to monitor and evaluate the performance of the intersection during the flow of vehicles.

1.4 Research Objectives

The main objectives of this thesis are:

1. Simulation of an intersection in the city of Ramadi that works with a traditional traffic light system.
2. Propose an adaptive VANET traffic light system with a dynamic scheduling algorithm instead of the traditional system to reduce traffic congestion at the intersection.
3. Take advantage of the excess green time at the intersection and study the effect of the VANET coverage area on the intersection.

1.5 Research Contribution

Before adopting any control technique, it is required to first observe traffic conditions. For the success of implementation of any smart transportation system requires the participation of many responsible authorities such as the municipality, traffic officials, IT developers, drivers and citizens.

As part of improving the city's transportation system, this thesis introduces a dynamic scheduling algorithm to simulate the reality of intersection, by uses vehicles information (speed, location, and number of vehicles) to investigate and analyze its results. It is considered a contribution for finding a solution to the problem of traffic congestion and reducing the delay time. This is done through the use of modern technologies in the field of wireless communications, such as VANET technology.

The research done in this thesis deals with the sharing of real-time traffic information in the road network surrounding the intersection using V2X communications in a VANET environment. This information is used in the proposed algorithm to calculate the best green time for each stream within a different coverage area.

1.6 Thesis Structure

Thesis is organized as follows:

- ✓ ***chapter one*** present general introduction about the main problem, the importance of the research and its objectives. Also it present the most important works related to the research problem.
- ✓ ***Chapter two*** provides a background on traditional and adaptive control systems, VANET and types of VANET communications. It also includes a general description of the intersection scenario.
- ✓ ***Chapter three*** provides a description of the simulation programs used in the work environment. It reviews the proposed scheduling algorithm and its steps, determine the coverage area, and how to calculate the best green time.
- ✓ ***Chapter four*** presents the simulation results obtained through experiments, evaluate those results and discuss them.
- ✓ ***Finally, chapter Five*** gives the main conclusions of this thesis with some future works.

2

Chapter Two
Theoretical Background

Chapter Two
Theoretical Background

2.1 Introduction

After studying relevant works and previous studies conducted in the field of VANET technology. In this chapter, traditional and adaptive traffic light control systems, VANET technology, and types of communications used in VANET are be explain. Intersection scenario also studies, in order to investigate the ability to change time of the signal with traffic conditions changing, based on VANET commensurate with the nature of the intersection that controls traffic light and makes it adaptive instead of traditional control**.**

2.2 Traditional Control Systems

Traffic lights are mainly used to control the movement of vehicles. It controls the correct directions at intersections. This is done to ensure that vehicles do not conflict when they use the roads at the same time by distributing the green light in all directions. Thus, vehicle traffic flows smoothly at the intersection in order to reduce congestion and improve mobility.

Traffic light components include display unit that displays timing and crossing signal, and control unit on which the efficiency of traffic light depends. Control unit is the most important part in processing and making a decision either to provide a long or short green period for a particular road. Traffic light controller has to calculate cycle length and the corresponding effective green time for each phase traffic light. The console can also perform functions such as scheduling newly arrived vehicles. Traffic controller serves as the focal point for managing the urban transportation system. It integrates data from a variety of different data sources to identify potential traffic problems, then develops strategies to address the problems and provides a way for operators to manage traffic and inform the public from a central point. While most of the controllers are working according to same rules, but different region and countries adopt different standards. The general idea is still the same using logic to control direction and timing [42, 43].

Traditional traffic light system operates at fixed and predetermined time intervals for traffic lights. It is considered easy to implement, cost-effective, and widely used. Sometimes an improved version of traditional traffic light system is used, where there can be different settings during the day in order to reduce traffic congestion, and others used at night. However, traditional system does not provide effective traffic routing when traffic load approaching the intersection changes during day and cannot handle constantly flowing vehicular traffic with time, accidents, and passage of emergency vehicles. For example, during peak hours, a traditional traffic light cannot direct and control the traffic due to the high density of vehicles that leads to traffic jams [11].

The World Health Organization in [44] has states that there are 1.6 million deaths worldwide due to traffic accidents. From which 62% are due to technologies not available for efficient traffic management. Increasing population, increasing number of vehicles and poor traffic management systems are also attributed to severe traffic jams in cities.

Traffic lights use radar, cameras, and others to detect traffic conditions. Their high cost and constant need for maintenance and complex treatment make these techniques useless. Traditional traffic control strategies have gone through phases including: Fixed time phase and the actuated phase. Fixed time traffic control uses historical traffic data to determine the timing of the signal. However, in reality, the demand for traffic is unpredictable and fluctuates over time. Fixed timing parameter settings cannot meet the requirements of rapidly changing traffic conditions. The actuated traffic control (typically applied to an isolated intersection) collects real-time traffic data through infrastructure-based sensors, for example, loop detectors, video, infrared, or radar detectors. However, triggered traffic controllers change these timings based on a set of pre-set fixed parameters [45].

The current technological progress in wireless communications, especially VANET, has become possible to use in traffic light systems. It makes them adaptive instead of traditional depending on vehicle data. Therefore, one of practical solutions to problems of traffic congestion and to increase the traffic flow is the use of traffic lights that operate with an adaptive control system based on the collection of vehicle information in real-time. This information is transmitted to the traffic light control unit, which in turn schedules the traffic phases at the intersection.

2.3 Adaptive Traffic Light Systems

Considered one of the strategies for traffic management in which the timing of the traffic light changes to modify the traffic timing parameters (green and red). This is done in real time according to the changes and fluctuations in the actual traffic flows. Such adaptation may lead to improve the efficiency of traffic operation on urban road networks and reducing traffic jam. This can be achieved by using an adaptive traffic control system consisting of both advanced hardware, information technologies [44], algorithms [46], software, and others.

2.3.1 Benefits of Adaptive Traffic Light Systems

Ease and speed of traffic with fewer stops and delays can be achieved by consistently distributing the green light time for all movements fairly. Also, improving performance can be achieved by adapting and re-adjusting the timing to suit traffic variables in real time (such as waiting longer vehicles, dealing with accidents, and emergency vehicles) and thus reducing traffic congestion and travel time. Adaptive traffic light control systems are environment friendly technologies [47]. In addition to reducing travel time, the number of rear-end collisions, congestion costs (such as fuel) and vehicle emissions can be reduced beside increasing customer satisfaction. Therefore, adaptive traffic lights may be worth the cost because of those benefits that they produce better than traditional systems [48].

More than 20 self-adaptive traffic control systems have been developed by transportation research institutes and companies around the world [49]. They have gone through several generations, but less than half of the systems have been used. For example, Sydney coordinated adaptive traffic system (SCATS), Optimization Policies for Adaptive Control (OPAC), and Split Cycle and Offset Optimization Technique (SCOOT) [45], [46] and [47].

2.4 Vehicular Ad-hoc Network (VANET)

VANET is a technology that uses moving vehicles as nodes to create a mobile wireless network. It turns each participating vehicle into a wireless router or node, allowing the vehicles to communicate with each other and create a broadband network. This done through several ad hoc network technologies such as Wi-Fi IEEE 802.11p (A special wireless communication system in the vehicles environment supporting ITS applications that uses a bandwidth of 10MHz in the 5.9GHz band (5.850 - 5.925GHz)) and WiMAX IEEE 802.16 (High-quality broadband wireless technology that adopts Wireless MAN). With vehicles out of signal range and get out from the network, other vehicles can join and connect vehicles to each other. VANET improves traffic safety, reduces accidents, updates vehicle information (such as location, speed, direction, etc.), intersection collision warning and weather information.

2.4.1 Characteristics of VANET

VANET is considered a distinct field of research, as VANET has unique and important characteristics that affect the design of transportation systems, especially in providing safety and ease of movement. Here are some of the characteristics of VANET [50]- [53]:

- **Highly Dynamic Topology**: Speed and path selection determine the dynamic topology of VANET. it has a very dynamic environment due to the random movement and high speed of vehicles, the architecture changes frequently because the links between nodes are online or offline, and the time remaining to exchange data packets is small.
- **Communication environment**: The mobility model varies greatly from highway (low density) to urban city environment (high density). In a high-density network, there are many things like buildings, trees, and other things that act as obstacles that reduce signal bandwidth and data transmission speed between vehicles and RSUs. In a low-density network, all these obstacles are less vulnerable and do not affect the communication between vehicles.

- **Large number of nodes**: In general, VANETs is a technical basis in relation to the envisaged ITS. Thus, most of the vehicles were expected to be equipped with communications capabilities such as Global Positioning System (GPS) for vehicle communications as well as fixed roadside infrastructure units.
- **Restricted and Predictable Mobility Patterns**: The above features of connectivity need to know node positions and movements which are extremely difficult to predict given the nature and pattern of movement of each vehicle. However, VANET's mobility model is maintaining connectivity through restrictive rules such as road maps, speed, traffic flow, etc. It is of paramount importance to effective network design, making it predictable as a minimum in the short term.
- **Unlimited storage and computational power**: Smart vehicles consist of electronic chips with sufficient storage capacity and power, so they can store routing information, confirm the identity of drivers and vehicles and other information. The vehicles themselves provide continuous power for communication and computing services.
- **Interact with on-board sensors**: Vehicles can use on-board sensors such as a GPS device to provide information such as its location, direction, nodes movement speed, and other vehicle-related information that is used for effective communication and routing purposes.
- **Network Size and Connectivity**: Potentially unrestricted network size: VANET can include vehicles in one city, several cities, or even a country. Thus, it is necessary to make any VANET protocols scalable in order to be practical. The degree of network connectivity can also be measured, which depends largely on two important factors: the range of wireless links as well as the fraction of nodes. Thus, only a few nodes on road may be equipped with wireless interfaces.
- **Difficult Delay Limitations**: In some VANET safety applications, high priority emergency messages may be submitted and must be delivered to relevant nodes (e.g. disasters, accidents) on time. These applications have high requirements with reliability as well as in real time. Therefore, end-to-end delay associated with one second may have a negative impact on

relevance with respect to stale emergency information. Thus VANET does not compromise with any hard data delays in this regard.

- **Anonymous addressee**: Most applications in VANET require the identification of vehicles in a specific area, rather than specific vehicles. This may help protect node privacy in VANETs.

2.4.2 Components of VANET

There are mainly three components of VANET [52], [54] and [55]:

1. On-Board Units (OBU): It is sensors embedded in vehicles that are mobile nodes for the signal processing (data sharing) to and from RSUs, Also an (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. Each vehicle has its structure in device called (OBU) that facilitates them communicating with the other vehicles and RSUs and also enabling short-range wireless ad hoc networks which receives security messages such as unexpected break warning from other vehicles, essential emergency alerts etc., and non-security message such as comforts and amusement related information.

In general, OBUs helps the vehicle to be warned with critical situations such as accidents, traffic jams, and predicting the movements of the nearby vehicles through the dissemination of traffic associated messages with certain information regarding its current time, speed, deceleration/acceleration, direction, as well as position.

2. Application Unit (AU): It 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:

- 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.

3. 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 might be utilized to increase overall coverage that is related to vehicular ad-hoc network, may provide Internet connectivity or may cooperate with other RSUs in forwarding information. In addition, RSUs ware equipped with excellent equipment, and at a lower cost compared to the units used in vehicles, they improve network performance and improve the spread of messages. Figure 2.1 bellow shows components of a vehicular ad hoc network, which include Road Side Unit (RSU), An Application Unit (AU) and On-Board Unit (OBU).

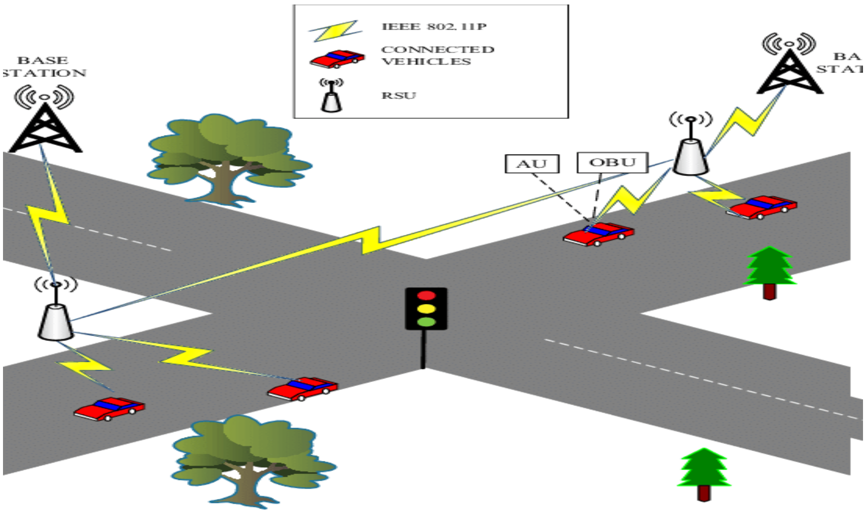


Figure 2.1 Components of VANET [56]

2.4.3 VANET Uses and Applications

Over the years, there has been a lot of research on application development and usage models for the VANET communication type. As more people spend time on the road, more requirements for an internet connection to communicate with each other, to receive real-time news and traffic movement knowledge in real-time, to cooperate in messaging, road hazard control notification, traffic alert, remote vehicle personalization, digital map downloading, real-time video relay and online entertainment via V2V, V2I or V2X communication type. VANET applications are categorized as safety and convenience applications[53],[55] and [57].

A . Safety applications: These applications aim to save human lives on the road by delivering safety-related information to the desired future in time to avoid any accident, VANET can assist drivers in obtaining advance information and warnings from a nearby environment by exchanging messages. These messages can be described as follows [51] and [53]:

1) Information Messages (IM): Consist of work zone messages while driving on the highway, toll collection points, and speed limit messages, etc.
2) Assistance Messages(AM): This is the kind of information that will assist the driver during the journey. AM includes messages related to lane switching, cooperative collision avoidance (CCA), and navigation. CCA message is considered to be the most critical in terms of helping the driver by warning him or her to reduce the speed for avoiding any uncertain condition.
3) Warning Messages (WM): Include information like traffic signal a head, toll point, or any bad road condition warnings.

Table 2.1 shows some of VANET applications related to safety.

Table 2.1. VANET Safety Applications

Name	**Description**
Traffic signal violation	Send alert to vehicles associated to dangerous situation.
Intersection collision warning	Send information about the road intersection points.

Turn assistance	Assist the driver in turning of vehicle.
Blind spot warning	Alert the presence of another vehicle in the blind spot.
Pedestrian crossing information	Send information of pedestrian crossing in the path.
Lane change warning	Ensue that the intended lane is clear for entry.
Forward collision warning	Alert the driver of a slower car in front.
Do not pass warning	Alert the driver about overtaking safety.
Post-crash	Alert of a crash that has happen.
Emergency service	Provide clear path for emergency vehicle like vehicle ambulance.
Curve speed	Warns vehicle about road curves ahead.
Wrong way	Alerts a vehicle of the wrong way movement.

B. **Convenience applications**: These applications aim to provide passenger/driver comfort and traffic efficiency, and are value-added services. These applications include automatic toll collection and location-based services such as the location of shopping malls, restaurants, and internet connection facilities.

Drivers using VANET may also have the opportunity to participate in other tasks. [51] and [54].

2.4.4 Types of Communications in VANET

In this section, we focus on types of vehicle communications. Vehicle communications are expected to contribute to safer and more efficient roads by providing timely information to drivers, as well as making travel more convenient. Generally speaking, there are three types of communication in VANET. They are:

1. **Vehicle-to-Vehicle Communication (V2V)**: A wireless communication that exchanges vehicle information between all vehicles about what you are doing. V2V communications are based on Dedicated Short-Range Communications (DSRC). V2V communication enables vehicles to access

information of other V2V-enabled vehicles around them using a wireless communication protocol similar to Wi-Fi. This information may include speed, location, direction, braking, and loss of stability. V2V connectivity has the power to make driving a safer and more predictable activity for everyone on the road. The simple form of V2V communication technology will not offer many benefits to users of traffic light control systems, other than the ability to communicate with nearby drivers. Figure 2.2 shows V2V communication.

Figure 2.2 V2V communication

2. **Vehicle-to-Infrastructure (V2I) communication**: A wireless communication from a vehicle to infrastructure or vice versa. Data from infrastructure components can be delivered to the vehicle over a dedicated network (the general data such as traffic and weather alerts, also user-specific data such as email and surfing the Internet). Vehicles are allowed to capture information from components that support ITS.These components may include readers, overhead RFID cameras, traffic lights, lane markings, street lights, signs, and parking meters. V2I uses DSRC frequencies for data transmission as well. V2I is part of the ITS program that is designed to facilitate the adoption of technology in real-world transportation. The future of V2I could improve driver assistance systems such as smart parking and self-driving vehicles, which could enhance future city planning of traffic lanes, parking lots, and more. Figure 2.3 shows V2I communication.

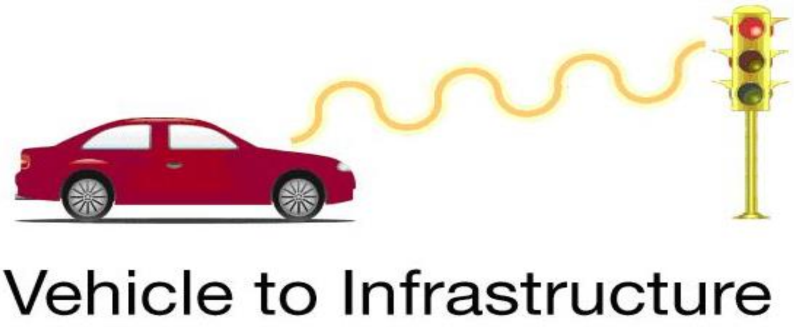


Figure 2.3 V2I communication

Due to the major limitations of V2V and V2I, seamless vehicles connectivity management is a new challenge for VANET networks.

3. **Vehicle to everything (V2X) communication**: A wireless connection from the vehicle to everything. It may include any device that has the ability to connect wirelessly to vehicles such as mobile phones, tablets, sensors...etc. The hybrid connection method may also refer to V2V and V2I interconnection. Coexistence of these two different methods can ensure good connectivity in VANET scenarios, which is fundamental to ensuring safety especially in remote or sparsely developed neighborhoods where V2V connections are not always available [58]. Figure 2.4 shows V2X communication.

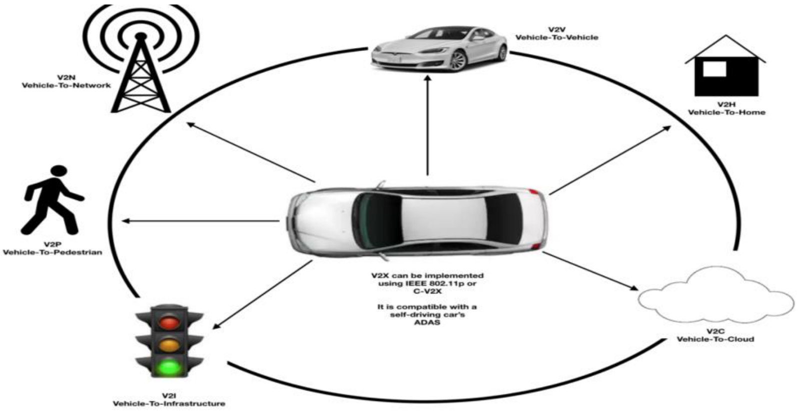


Figure 2.4 V2X communication [59]

IEEE 802.11p is the original V2X standard, and it uses WLAN technology which is particularly suitable for V2X connections, due to its low latency. Connects (V2V) and (V2I) when two V2X senders come within range of each other. The 802.11p standard does not require any communication hardware or infrastructure to function, and this capability makes it ideal in less developed areas. In addition, the standard conveys messages known as Cooperative Awareness Messages (CAM) or Basic Safety Message (BSM), and Decentralized Environmental Notice Messages (DENM). Other roadside infrastructure related messages are signal phase and timing message (SPAT), vehicle information message (IVI), and service request message (SRM). [60]

Key benefits of V2X systems include increased road safety, fuel economy, traffic efficiency, and better road management. When V2X systems are integrated into conventional vehicles, information from vehicle sensors and other sources travels through high-bandwidth, high-reliability links, allowing them to communicate with other vehicles and infrastructure such as parking spaces, traffic lights, and smartphone-tossed pedestrians, by sharing information (such as speed, location, direction, etc.) with other entities around the vehicle. This technology improves driver awareness of potential hazards and helps reduce the severity of injuries and deaths from road accidents and collisions with other vehicles. [58] and [60]

V2X can also notify drivers of important information about dangerous weather patterns and conditions, accidents and traffic congestion nearby, warning of road work, an approaching emergency vehicle, activities of other drivers on the same road, and other dangerous behaviors that occur within walking distance. The technology also enhances traffic efficiency by warning drivers of oncoming traffic, suggesting alternative routes to avoid traffic, and identifying available parking spaces, thus allowing autonomous vehicles to scan the surrounding environment and make instant decisions based on the information received, reducing response time The action it takes for the driver to respond.

Although the V2X market is still in its infancy, most manufacturers are starting to integrate the technology, and cars are becoming increasingly connected to other vehicles and the infrastructure around them. Vehicles are also becoming smart and equipped with systems that require less human involvement. As a result, users benefit from safer, more environmentally friendly journeys with lower carbon emissions, thanks to adaptive cruise control and sensors. However, the full benefits of V2X systems will take time to be realized because, for a vehicle to communicate with an entity, that entity must be V2X enabled. Most entities such as parking spaces, traffic lights, and conventional vehicles do not have V2X systems, which means they cannot communicate with vehicles that are already using the system.

2.4.5 VANET Issues and Challenges

There are many interesting issues and challenges that can be looked at and discussed in the VANET environment. We mention some of them as follows[51],[53] and [61]:

a) **Network congestion and node speed:** Due to the high portability, the network structure and channel state change rapidly. It is difficult to manage the network and control congestion collision in the network. The main goal of congestion control is to make better use of available network resources while preventing the continuous overloading of network nodes and links. Appropriate congestion control mechanisms are essential to provide efficient network operation. Ensuring congestion control within vehicular networks faces special challenges, given the peculiarities of this environment such as high node mobility, high rate of topology changes, high variability in node density and neighborhood configuration, nature of broadcast/geocast connections, etc. Prospective node speed is one of the most important components of VANET portability. In this case, the nodes are either roadside units (RSU's) or vehicles. The node speed can be from zero relative to a passive RSU or when vehicles are stuck on highways in traffic jams to more than 200 km per hour. These two extremes present an exceptional challenge to the communication system. In cases of node speed inflation, the shared wireless window has a relatively smaller range of several hundreds of meters.

b) **Mobility management:** VANET is defined by a large number of mobile nodes (eg about vehicle speed). This high mobility can be relatively necessary for the nature of roads (highways and RSUs). Vehicles do not move in random ways, in fact, they are likely to move in two directions on predetermined routes. It is usually irregular changes in the direction of the vehicle. In a vehicle alert system, different types of information must be collected to enable drivers to make appropriate decisions. Direct communication of emergency messages between vehicles should be supported, as well as access to digital map updates and weather information via roadside WLAN or cellular network, etc. The main challenge of mobility management is to seamlessly integrate several classes of wireless network technologies that differ among others in terms of bandwidth, cellular coverage, quality of service (QoS), low latency, support for multi-hop connections, and scalability in terms of overhead.

c) **Data Dissemination:** When propagating data to locations outside the transmission range, two delivery strategies must be considered: relay and flood. The flood approach usually results in high contact traffic. Thus, the main challenge of this method is to avoid the transmission storm problem. This is very difficult due to the high mobility nature of inter-vehicle communication networks which results in frequent network disconnects and fragmentation into disconnected clusters. A successful VANETs data deployment model needs to address issues such as scattered network density, interference environment, long path length, latency, etc. To avoid the burden of flooding, data aggregation techniques are required, which reduce the number of packets sent drastically by merging several messages related to the same event into a single aggregate message. It is widely agreed that VANETs must rely heavily on node-to-node communication, allowing for malicious traffic. At the same time, easy access to information provided by VANETs is likely to achieve the difficult security goal of data validation.

d) **Routing**: Routing in VANETs poses challenging to the dynamic nature of the network. The time varying vehicle density results in a rapid change in topology, which makes preserving or route a difficult task Moreover, dynamically changing topology and high speed mobility of vehicles pore interference and large delay in the routing. In order to timely and properly sending data packets from one node to another node an efficient routing algorithm is required. In VANET, an efficient routing algorithm means a routing scheme with minimum delay, maximum system capacity, and less computational complexity.

e) **Security and privacy:** VANET has an association between the user and the vehicle. Concerns about privacy should not reveal the driver's location. The security issue is prominent in VANETs because the networks are publicly available in any ways and at any time, hijackers easily hijack the session after the connection is established. Most of the critical messages are broadcast-oriented security messages that must have deep penetration and must be delivered in a timely manner. In addition, such messages must be secure and must not leak personally identifiable or linkable information to authorized parties. The driver is the same as the vehicle owner, so obtaining the owner's ID may jeopardize privacy. Safety is the most important issue at VANET. The secure processing and exchange of messages can lead to security services. Security capabilities provide security, scalability, trustworthiness, transparency, disavowal, privacy and confidentiality, data management, access protection, traceability, and reversible error detection.

2.5 Work Scenario

Mobile vehicles aim to cross the intersection safely and with minimal delay. The intersection is controlled by a traffic light that controls all competing traffic flows at the intersection. In a traditional intersection, the timing of the traffic light is fixed, including cycle length, phases, intervals, and displacement parameters that are set according to real-time traffic characteristics. Table 2.2 summarizes the definitions of timing variables, at any intersection.

Table 2.2 Definitions of timing variables.

Variable	The definition
Cycle Length	The amount of time it takes to complete a complete series of signal intervals (phases)
Phase	Any single combination of one or more traffic movements concurrently gaining the right-of-way at one or more intervals during a signal cycle.
Interval	The signal indications (pedestrian or vehicle) remain unchanged for a specific portion of the signal period.
Split	The percentage of a signal cycle's duration allotted to each of the different phases.
Offset	The difference between a given point in the synchronized green light and a device reference point determines the time relationship, which is expressed in seconds or as a percentage of cycle duration.

Our simulation study is based on an isolated intersection of the city of Ramadi, which is of medium density (not one of the major cities). Due to the nature of the traffic surrounding the intersection under study, there are times when the congestion is very large (refered to peak traffic time). Such times did not taken into consideration to find a solution to that congestion. This is because of the lack of registered and approved data (such as the number of vehicles in each direction and density traffic, as well as the traffic difference during the day). Hence, traffic light control system at the intersection needs to monitor the conditions of the intersection movement in real time.

The intersection consists of 6 flows; two main flows with each one containing two lanes, and two secondary flows containing one lane. In addition to sub-flows very close to the intersection that do not fall within the traffic light intersection (their impact on the performance of the intersection will be discussed later). A traditional traffic light control system at this intersection is already deployed and implemented with fixed time setting. The main axes have a higher priority than the secondary axes, and no more than one flow is allowed to be treated at the same time. Vehicles arrive at different estimated times, and large vehicles are not allowed to pass at this intersection. Also it does not include a pedestrian traffic light system. In fact, the secondary flows are currently closed for city security reasons (as the traffic departments and the municipality responsible for managing the intersection inform us) and the intersection has only two of the main flows to be considered. This scenario covers an area of 1000 m x 500 m, with a limited vehicle speed of 50 km/h. Based on the real-time traffic characteristics of the competing flows at the intersection, the green light time is set for 46 seconds, the yellow light for 5 seconds, and the red light as safety phase for all phases for 4 seconds, so the total time duration for each cycle is 110 seconds. Table 2.3 shows the work program of the intersection phases in sequence, states given for each phase, and the time duration of the phases.

Table 2.3 Program of Intersection

No.	**Name Phase**	**State**	**Duration**
1	EGREEN	'GGGggrrrgg'	46
2	EYELLOW	'yyyggrrrgg'	5
3	ERED	'rrrggrrrgg'	4
4	WGREEN	'rrrggGGGgg'	46
5	WYELLOW	'rrrggyyygg'	5
6	WRED	'rrrggrrrgg'	4

Appendix A shows the phases of the traffic light in reality and the light given for each direction in each phase.

2.6 Summary

This chapter summarizes the background of traffic light control systems. The aim was to clarify the traditional control systems, their mechanism of action, their components, and methods of use. In addition to knowing the adaptive traffic control systems, their benefits and superiority over the traditional systems in terms of reducing traffic congestion, especially by using the VANET technology. After that, the characteristics, uses, and applications of VANET were detailed and discussed, then the components and the classification of vehicle communications in the VANET environment were explained based on those characteristics and the parties involved in the traffic light control systems, and to identify the most prominent issues and challenges of VANET. Finally, the work scenario for the intersection in our study has been clarified, VANET scenario also assumes that vehicles equipped with V2X communication (i.e., V2V and V2I), Where V2X technology can continuously monitor the approach of an intersection and thus provide comprehensive information on approaching vehicles. With this scenario, an infrastructure unit called road side unit (RSU) is set in the center of the intersection. It collects comprehensive information about vehicles approaching the intersection. This information transmitted by vehicles (such as speed, location, direction, time, and others). Such information is used to conFigure traffic light settings. This configuration requires real-time information to be processed and executed by an algorithm. Therefore, the scheduling algorithm for adaptive traffic light will be described in the next chapter.

3

Chapter Three

Design and Implementation

Chapter Three

Design and Implementation

3.1 Introduction

This chapter describes the simulation programs used in this thesis and the steps for executing the simulation. Also reviews the proposed scheduling algorithm and the mechanism for implementing its steps by determining the coverage area (fixed and different) and the method of calculating the best green time. In addition to working to know the maximum green time.

3.2 Implementation Tools

The proposed system was implemented using the following hardware and software:

Hardware:

Processor: Intel(R) Core(TM) i5-3210M CPU @ 2.50GHz
Installed Memory (RAM): 8 GB.
Storage: SSD 500 GB.

Software:

Operating System: Windows7 Professional.
System type: 64-bit Operating System.
Simulation Environment: SUMO 1.6v.
Programming language: MATLAB R2020a..
Connectivity tool: TraCI4Matlab 3.1v.

3.3 Simulation Environment

This section Illustrates simulation environment that was developed as well as scenarios that were used to build the system. SUMO simulator [62] had been used to simulate road network, vehicles and traffic lights. MATLAB program to implement the proposed algorithm. SUMO was connected to MATLAB via the TraCI4Matlab [63] tool. Figure 3.1 shows the method of connection.

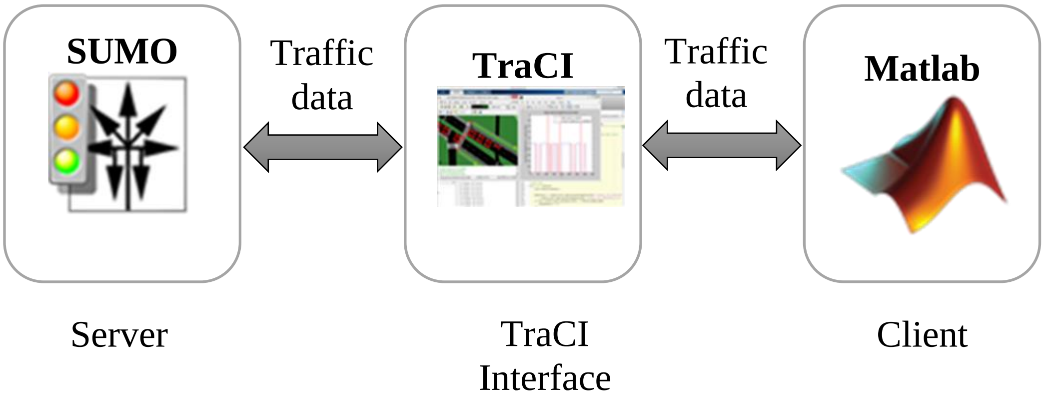


Figure 3.1 Connection method of Simulation tools

3.3.1 **TraCI4Matlab**

An Application Programming Interface (API) developed in Matlab which allows the communication between any application developed in this language and the Simulation of Urban Mobility (SUMO) microscopic road traffic simulator. The functions comprising TraCI4Matlab implement the Traffic Control Interface (TraCI) application level protocol which is built on top of the TCP/IP stack, so that the application developed in Matlab, which is the client, can access and modify the simulation environment provided by the server (SUMO). TraCI4Matlab allows controlling SUMO objects such as vehicles, traffic lights, junctions, etc, enabling applications like traffic lights predictive control, dynamic route assignment, and vehicular communications, among others [63].

3.3.2 **SUMO "Simulation of Urban MObility"**

An open source, highly portable, microscopic and continuous traffic simulation package designed to handle large networks. It allows for intermodal simulation including pedestrians and comes with a large set of tools for scenario creation [62]. In SUMO, each vehicle has its own trajectory and other characteristics such as deceleration, acceleration and length change between vehicle types. SUMO helps in studying many topics such as lane selection, traffic light algorithm or vehicle communication simulation [54].

The digital map of intersection and roads around were imported from OpenStreetMap [64] using Netconvert road network importer. Simulation network was built and its file was created through the following procedure steps:

1. Use the main file (osmNetconvert.typ.xml) and execute the following directive (**netconvert --osm-files map.osm -o test.net.xml -t osmNetconvert.typ.xml --xml-validation never**). To create a file (**test.net**) that contains including:
   Coordinates of map location, data of edges (addresses, shape, speed, and length), type of vehicles allowed to pass, traffic light information, junctions between roads, method of connection between junctions depending on the direction of each road, and all information of contents of network.
2. Use the main file (typemap.xml) which contains the polygons code and execute the directive (**polyconvert --net-file test.net.xml --osm-files map.osm --type-file typemap.xml -o map.poly. xml --xml-validation never**). To create (**map.poly**) file including polygons and shapes of the map , and to create (**map.rou**) file which contains the automatic routing path for vehicles in the road network.
3. Use the main file (randomTripy.py) and execute the directive (**python randomTrips.py -n test.net.xml -r map.rou.xml -e 1000 -l --validate**). To creates a file(**trips.trips**) that contains the trip identifiers for each vehicle (the address of edge where vehicle begins to appear in simulation and address of edge from which vehicle departs.
4. Finally, emulator file (name.sumo.cfg) was created to start and run the simulation. Which contains:
   - <net-file value="test.net.xml"/>
   - <route-files value="trips.trips.xml"/>
   - <additional-files value="map.poly.xml"/>

Appendix B shows the steps for creating simulation files and their contents.

3.4 Suggested Scheduling Algorithm

In this section, details of the proposed traffic lights scheduling algorithm are provided. In any traffic light scheduling algorithm, schedule must be set to allow all competing traffic flows to cross a lighted intersection fairly and safely. The sequence of phases is periodically scheduled as successive cycles of traffic lights. The phases of each cycle are dynamically adjusted to allow vehicles to pass through the signaled intersection safely and efficiently. The scheduled time of the component phases can be set and set differently during each cycle. In a typical road intersection, any vehicle in a specific section of the road can cross the intersection in three different ways: straight, right turn, and left turn. Given the scenario of intersection of road under our study, it does not allow the presence of simultaneous flows in different directions from other directions, and for security reasons, the directions of each flow were restricted. Therefore 6 different flows were conFigure d and each traffic flow competing for the intersection was assigned a certain number as shown in Figure 3.2.

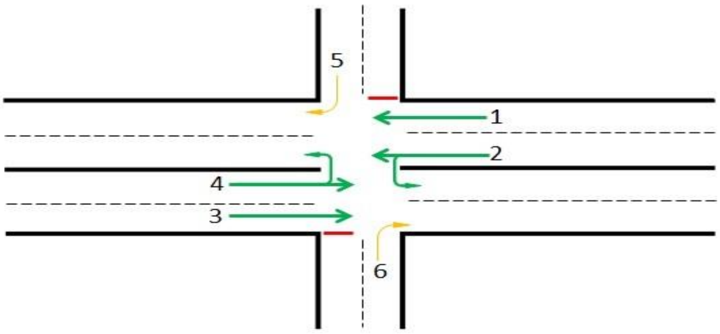


Figure 3.2 TLCinama intersection

The nature of the intersection work is as follows:

1. Two flows (1,3) are compulsorily straight as they are not allowed to turn right.
2. Two flows (2,4) have two directions, either straight or turning left.

3. Two flows (5,6) were considered secondary and had a lower priority, so their light is always green, as vehicles can only turn right without obstructing other traffic flows (i.e. they are not placed in the scheduling algorithm).

Hence, only the two main roadways that consists of the two flows (1,2) and (3,4) can only be scheduled in the algorithm.

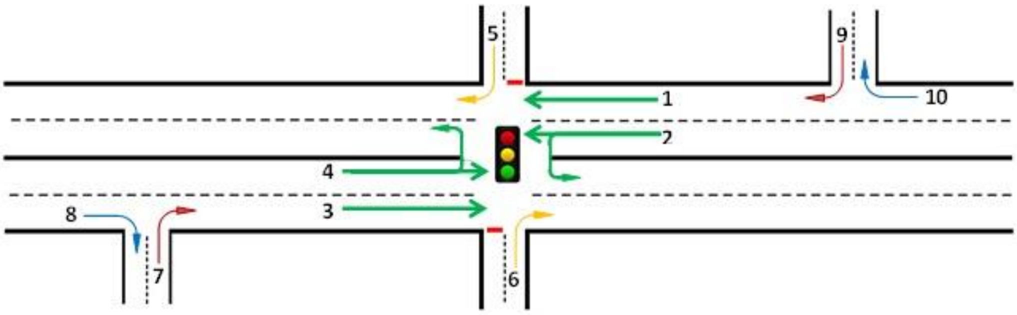


Figure 3.3 TLCinama intersection with sub-flows

4. As shown in Figure 3.3, there are sub-flows that affect the performance of the intersection, as several vehicles of the flows (7 and 9) enter during the time of the green light without reading their data.

5. On the other hand, there are vehicles whose data is read, but they go out to the sub-flows (8 and 10) before they reach the intersection.

Thus, the impact of these flows is clear on the performance of the intersection (as will be explained in the results section).

In each cycle of traffic lights, a certain period of time is assigned to each conFigure d stage. This scheduled time varies between zero seconds for empty streams and a maximum green time (***MaxGreenTime***) of seconds for high-density streams. The ***MaxGreenTime*** value represents the maximum amount of green time that can be allocated to any phase to ensure the equitable sharing of the intersection between all competing traffic flows. The ***BestGreenTime*** is determined for each stage based on the traffic distribution over the traffic flows of specified stage, so the value of ***BestGreenTime*** will be between 0 and ***MaxGreenTime***.

3.4.1 Determine the Coverage Area

In first stage of our work, as shown in Figure 3.4, coverage area was considered fixed (i.e. 100m) according to main roads of the intersection.

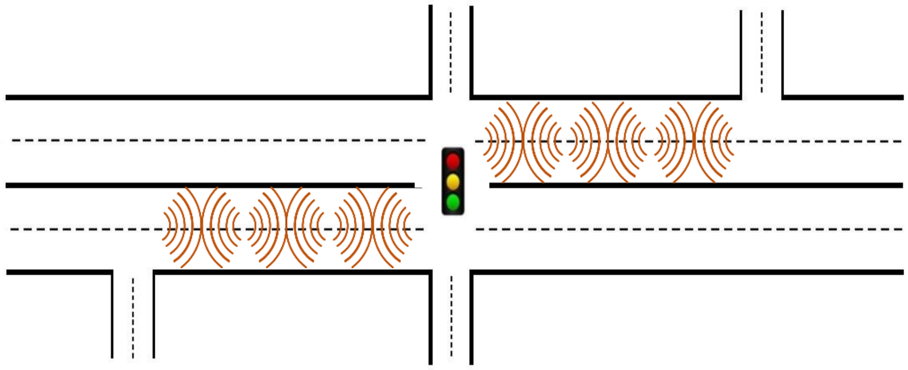


Figure 3.4 Fixed coverage area

VANET allows vehicles that are used as nodes to communicate with each other within a wireless range of 100 to 300 m. [54][65].

Therefore, in second stage working on determining a different distance was done for coverage area between vehicles according to the nature of the area surrounding the intersection (i.e. 100m, 150m, 200m, 250m, and 300m). If vehicles enter this area, their data (speed and location) is collected and used in the algorithm to calculate ***BestGreenTime***. Figure 3.5 shows different coverage area ranges with our intersection case study.

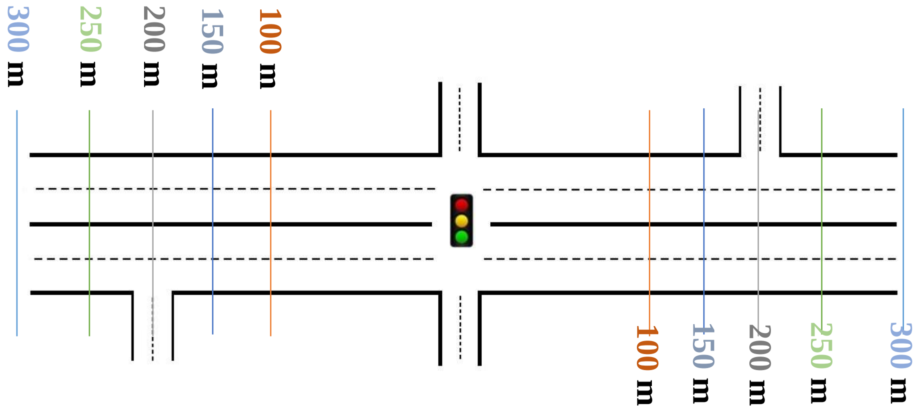


Figure 3.5 Different coverage area

3.4.2 BestGreenTime Calculation

For a medium-density traffic flow, the intersection sometimes remains without vehicles because it manages to cross early before the end of the ***MaxGreenTime*** duration and enables next phase to begin. Thus there is a waste of green time remaining to reach the value of ***MaxGreenTime***. This is illustrated in Figure 3.6 (a). On the other hand, for a high-density traffic flow, vehicles continue to cross the intersection during the entire ***MaxGreenTime*** period. This is shown in Figure 3.6 (b). Finally, traffic flow is low density, vehicles under coverage area are almost non-existent and therefore time is lost to reach the ***MaxGreenTime*** value. This is illustrated in Figure 3.6 (c).

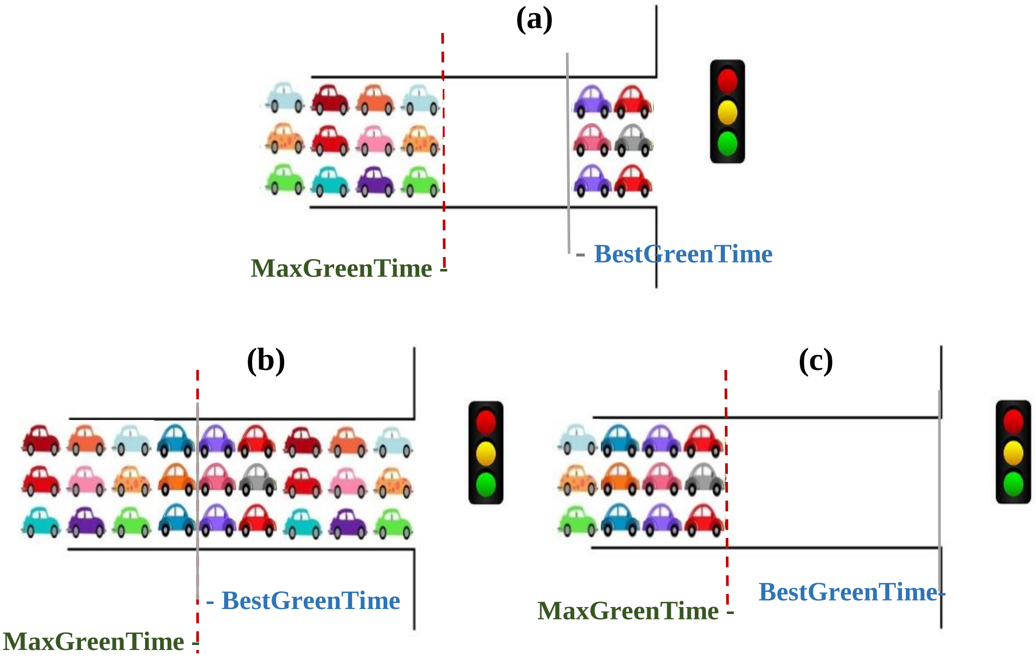


Figure 3.6 Relationship between green time and: (a). medium vehicles density (b). high vehicles density. (c). low vehicles density

The main point in our work is to calculate the best green time to reduce wasted time. ***BestGreenTime*** is checked for each direction separately based on its traffic flow. Depending on the traffic flow at each edge, the vehicles that can cross the intersection during ***MaxGreenTime*** can be determined using the average traffic speed. Depending on the average vehicle speed within the area and the location of the last vehicle within this area, ***BestGreenTime*** is calculated for each direction according to Equation 3.1.

$$\textit{BestGreenTime} = \textit{LastVehicleLocation} / \textit{AverageTrafficSpeed} \quad \text{Eq. 3.1}$$

where (***LastVehicleLocation***) is the location of the last vehicle within the coverage area away from the intersection. ***AverageTrafficSpeed*** is the average speed of vehicular traffic within the coverage area.

3.5 Stages of Implementation of the Algorithm

3.5.1 Distance Coverage Area(Fixed or Different)

Determining the value of ***MaxGreenTime*** is the first step in our algorithm, and based on the fixed signal timing in fact it is set for 46 seconds. After that, the distance of the coverage area is calculated (or determined). Read the data of all vehicles for each direction, including the location of each vehicle. If the vehicle is within the coverage area, the average vehicle speed is calculated and the location of the last vehicle is calculated according to the nature of the flows surrounding the intersection and the total distance to it. ***BestGreenTime*** is calculated based on the average vehicle speed and the location of the last vehicle to determine the stages of each cycle. The steps of the first stage of the algorithm are set as follows:

```
Set MaxGreenTime value.
Calculate or Determine DistanceCoverageArea for each flow.
Read all vehicles and calculate their location in each flow.
If vehicle located in DistanceCoverageArea
   Calculate AverageTrafficSpeed for each flow.
   Calculate LastVehicleLocation in each flow.
   Calculate BestGreenTime
         if   BestGreenTime < MaxGreenTime
           Schedule current phase time by BestGreenTime
         else
           Schedule current phase time by MaxGreenTime
         End
End
```

3.5.2 Maximum Green Time Calculation

In first stage, ***MaxGreenTime*** value was set fixed in the algorithm for 46 seconds. At this stage, the ***MaxGreenTime*** value variable was made based on the density of compounds within the different coverage area distance. Where the value of ***MaxGreenTime*** is calculated by Equation (3.1). By executing the remaining steps of the algorithm, determining a variable distance for the coverage area, then calculating the average speed of the vehicles in each stream that are located within the coverage area only, and calculating the location of the last vehicle within the coverage area. The phases of each cycle are then defined and a ***MaxGreenTime*** is calculated for each phase. The steps of this stage of the algorithm are set as follows:

```
Determine DistanceCoverageArea for each flow.
Read all vehicles and calculate their location in each flow.
If vehicle located in DistanceCoverageArea
    Calculate AverageTrafficSpeed for each flow.
    Calculate LastVehicleLocation in each flow.
    Calculate MaxGreenTime
    Schedule current phase time by MaxGreenTime
End
```

3.6 Summary

To implement the simulation, the simulation environment, programs, and tools used in this thesis were presented and studied. In this chapter, we explained the steps of the practical implementation of simulation programs from the first step, how they work, and the preliminary results for each step, so that these files can be used in implementing the proposed scheduling algorithm. Then the main idea of the proposed algorithm was clarified, which is how to take advantage of the excess time of the green light depending on the speed of the vehicles and the location of the last vehicle within a different coverage area.

4

Chapter Four
Results and Discussions

Chapter Four

Results and Discussions

4.1 Introduction

In this chapter, performance of the proposed algorithm is evaluated. Simulation program SUMO is used to create the scenario of intersection and network of roads and vehicles. Then, algorithm steps are written and implemented in Matlab through TraCI tool. Part of simulation results are extracted via the XML outputs file. According to the nature of the intersection, in fact, the following study distance was determined:

The traffic light is located in the center, from which a distance of 500 m was taken towards the east, 500 m towards the west, 250 m towards the north, and 250 m towards the south, and only for the roads surrounding the intersection where vehicles are located. Table 4.1 shows the variables that were identified in the scenario.

Table 4.1: Simulation Parameters

Simulator	SUMO 1.6v
Duration time	1200 seconds
Number of traffic light	1
Number of vehicles	0-1000
Maximum speed	50 km/h

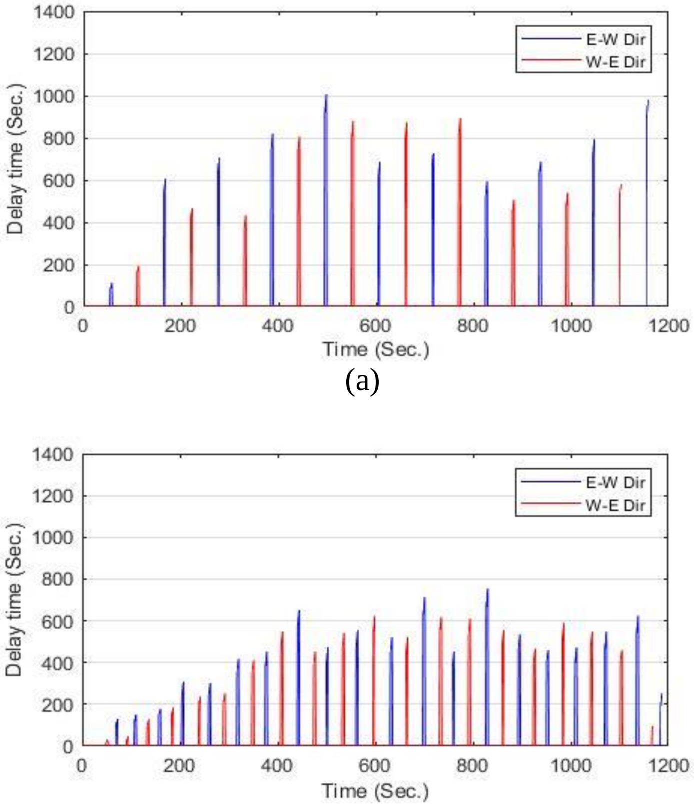
4.2 Fixed Distance Coverage Area

In our first experiment, total delay time for all vehicles in traditional fixed algorithm (currently implemented in the intersection) is compared with the proposed scheduling algorithm. This is done by using a fixed distance for coverage area (as described in paragraph 3.4.1) and the location of the last vehicle within an area aswell as average speed vehicles in each flow. The results show a significant improvement in the delay time when the proposed algorithm is implemented. Table 4.2 shows the total delay time.

Table 4.2: Total vehicles delay time during the implementation period in Fixed Distance for Coverage Area

Delay (second)	
Traditional algorithm	44425
Proposed algorithm	40099
Percentage (%) of reduction in delay	9.7377

At the same time, comparison between delay time of vehicles in traditional and proposed algorithm shows effective behavior behind our suggestion. This suggestion is simulated for each direction in each time step of the red light stage (the safety stage) in which the maximum delay for all stopped vehicles during the implementation period is considered. The total delay time of the vehicles during each cycle was calculated to find out the maximum time the vehicles wait while stopping at the intersection. This is clearly shown in Figure 4.1, where in the traditional system (a) we find that the maximum total waiting time for vehicles at the intersection is 1000 seconds. As for the proposed algorithm (b), we find that the maximum total waiting time for vehicles is 800 seconds. Therefore, the proposed algorithm outperformed the traditional system.

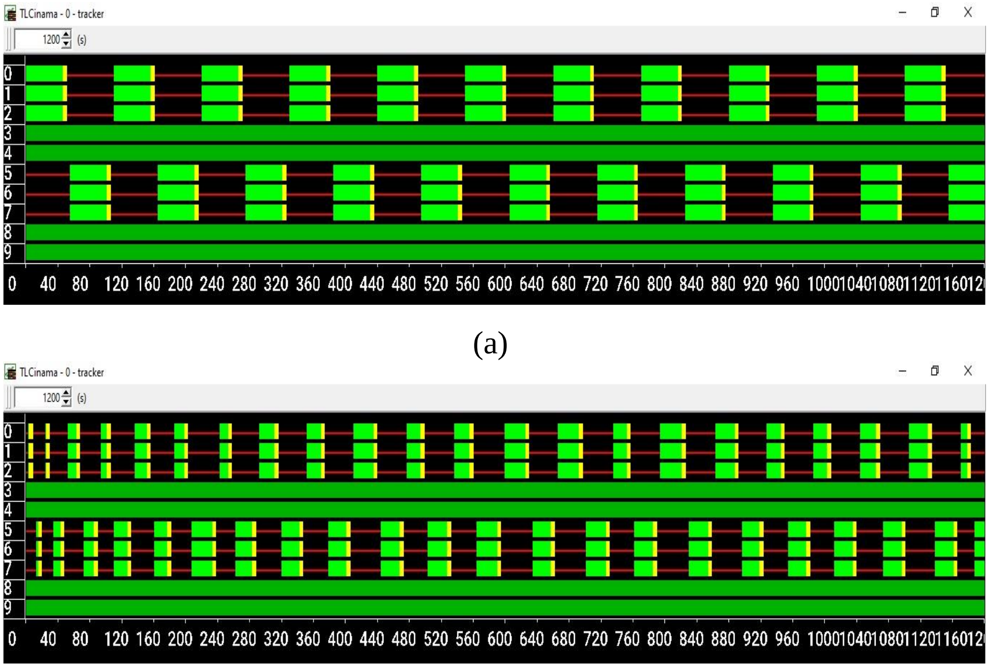


(a)

(b)

Figure 4.1 Sum Delay time with two directions in each time Cycle:
(a) Traditional algorithm (b) Proposed algorithm.

As for the simulation period, we worked on comparing the performance of the intersection by examining track phases to see the number of cycles during implementation. The results showed an increase in the number of intersection cycles to double when implementing the proposed algorithm compared to the traditional system, while the traditional system in which the performance of the intersection is fixed regardless of the density of vehicles at the intersection, as it works according to fixed times. Figure 4.2 shows the time-setting mechanism of the traditional algorithm and the proposed algorithm with respect to the simulation period.



(a)

(b)

Figure 4.2 Traffic light setting during simulation period for (a) traditional and (b) proposed algorithm

4.3 Different Distance Coverage Area

At this stage, total delay time of all vehicles in traditional algorithm is compared with proposed scheduling algorithm. It is important to study the assumption of an intersection under consideration be isolated. This is done by implementing different distances for coverage area (as in paragraph 3.4.1). Table 4.3 shows the effect of distance for coverage area on the intersection, depending on the average speed of vehicles inside coverage area and location of last vehicle.

Table 4.3: Total vehicles delay time during the implementation period in Different Distance for Coverage Area without calculating sub-flows

Coverage Area	Delay (second)	Percentage (%) of reduction in delay
100 m	41172	7.322 ↓
150 m	36950	16.826 ↓
200 m	45950	3.432 ↑
250 m	45978	3.495 ↑
300 m	45821	3.142 ↑

Looking at the results of Table 4.3, where improvement of performance of proposed algorithm appears within (100 and 150 m) of the coverage area ranges. As for the other ranges of coverage area that exceeds 150m, total delay time for vehicles increased with increasing distance. This is because the presence of flows closes to the intersection (as explained in point's No. 4 and 5 in paragraphs 3.4) and the extent to which the intersection is affected by those flows. This appears when considering those flows into the algorithm calculations. Total delay time for vehicles and for all ranges of coverage area (from 100-300 m) was decreased as shown in Table 4.4.

Table 4.4: Total vehicles delay time during the implementation period in Different Distance for Coverage Area with calculating sub-flows

Coverage Area	Delay (second)	Percentage (%) of reduction in delay
100 m	37493	15.603
150 m	36916	16.902
200 m	37840	14.822
250 m	40454	8.938
300 m	37747	15.032

Tables 4.5 showing a sample of vehicles waiting time results obtained from the XML file(i.e. the address of each vehicle through its id and its waiting time in seconds). Where we find that some vehicles have reduced their waiting time for certain distances when sub-streams are entered in the algorithm calculations

compared to the delay time of the same vehicles without taking into account the calculations of the sub-flows near the intersection.

Table 4.5: Sample of vehicles waiting time results

	without calculating sub-flows					*with calculating sub-flows*				
id	**100**	**150**	**200**	**250**	**300**	**100**	**150**	**200**	**250**	**300**
46	30	102	38	33	5	7	73	64	31	30
51	29	57	25	61	77	74	27	11	9	47
67	132	76	75	125	114	89	47	71	38	76
71	30	59	44	87	39	28	36	45	10	36
88	273	185	60	145	98	80	40	54	23	66
134	83	29	54	93	87	64	63	42	56	57
139	57	58	44	91	104	63	53	41	50	57
178	41	146	33	30	45	24	119	28	35	31
220	57	68	126	80	119	68	51	31	47	63
228	42	55	118	121	117	58	52	75	47	48
256	40	57	113	117	132	27	76	60	82	77
267	36	81	105	101	77	41	59	43	72	64
305	50	100	134	141	126	75	126	65	78	79
338	55	120	139	126	97	50	170	64	72	74
348	45	159	160	131	138	80	146	133	92	56
409	48	165	145	148	151	132	153	122	98	59
451	130	80	149	162	112	75	114	53	68	69
459	121	99	189	149	143	129	80	118	95	100
466	158	72	174	107	87	97	55	79	86	71
474	106	118	44	29	62	57	90	53	37	49
494	87	77	173	168	186	76	63	114	66	100
513	77	72	140	91	69	16	29	12	82	29
565	69	66	219	151	166	61	56	164	122	76
583	162	142	189	109	116	107	251	79	94	58
607	87	68	123	135	128	66	68	133	87	86
817	115	173	94	71	43	37	73	72	71	40
940	15	55	42	83	71	5	19	19	67	17

Figures 4.3 and 4.4 shows the performance of the intersection with respect to the ***BestGreenTim***. It also shows the extent to which the intersection needs the ***MaxGreenTime*** period of 46s.

Coverage Area Without sub-flows calculation With sub-flows calculation

100 m

150 m

200 m

250 m

300 m

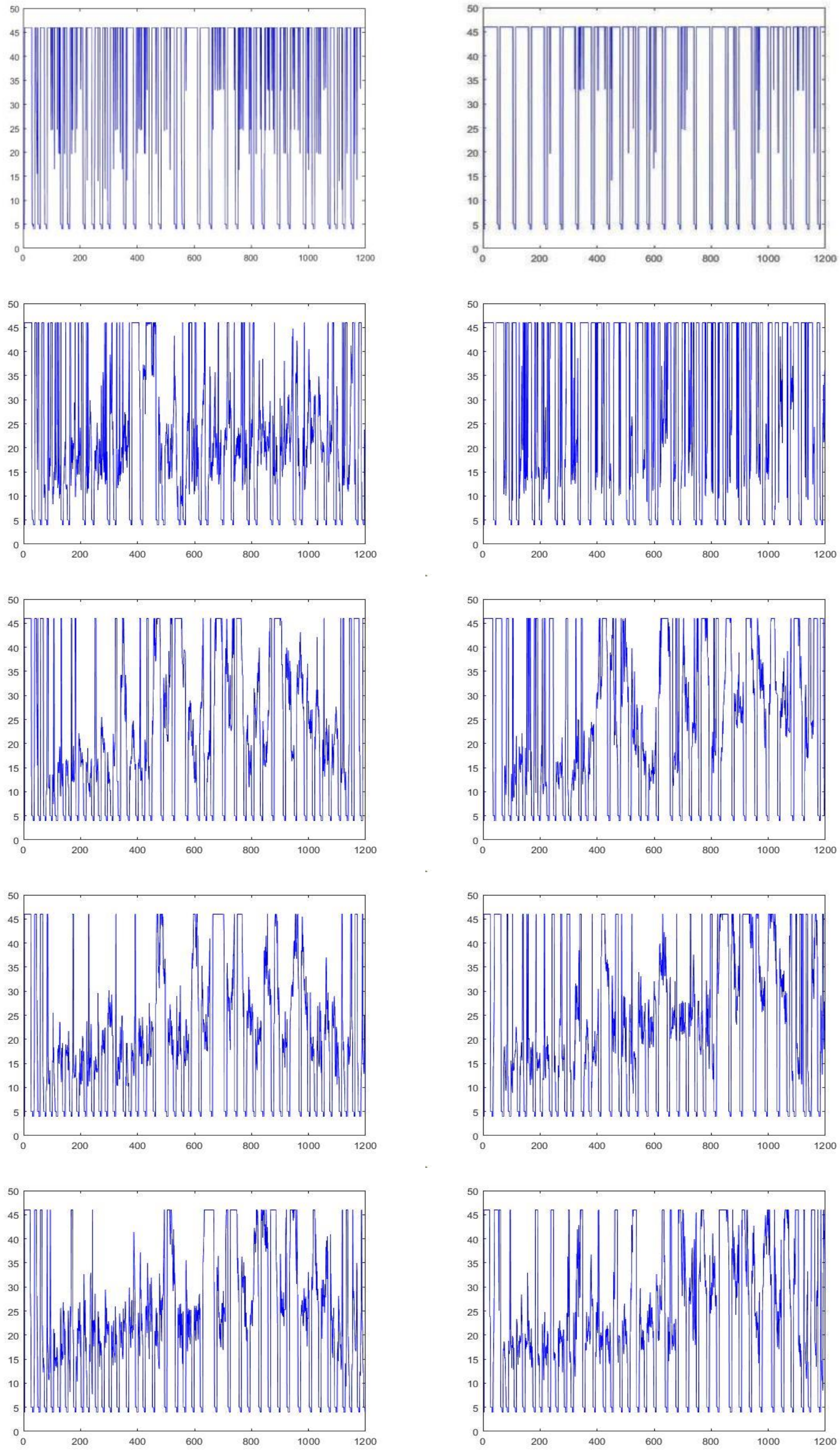


*Figure 4.3 Intersection performance based on the **BestGreenTime** for E-W direction*

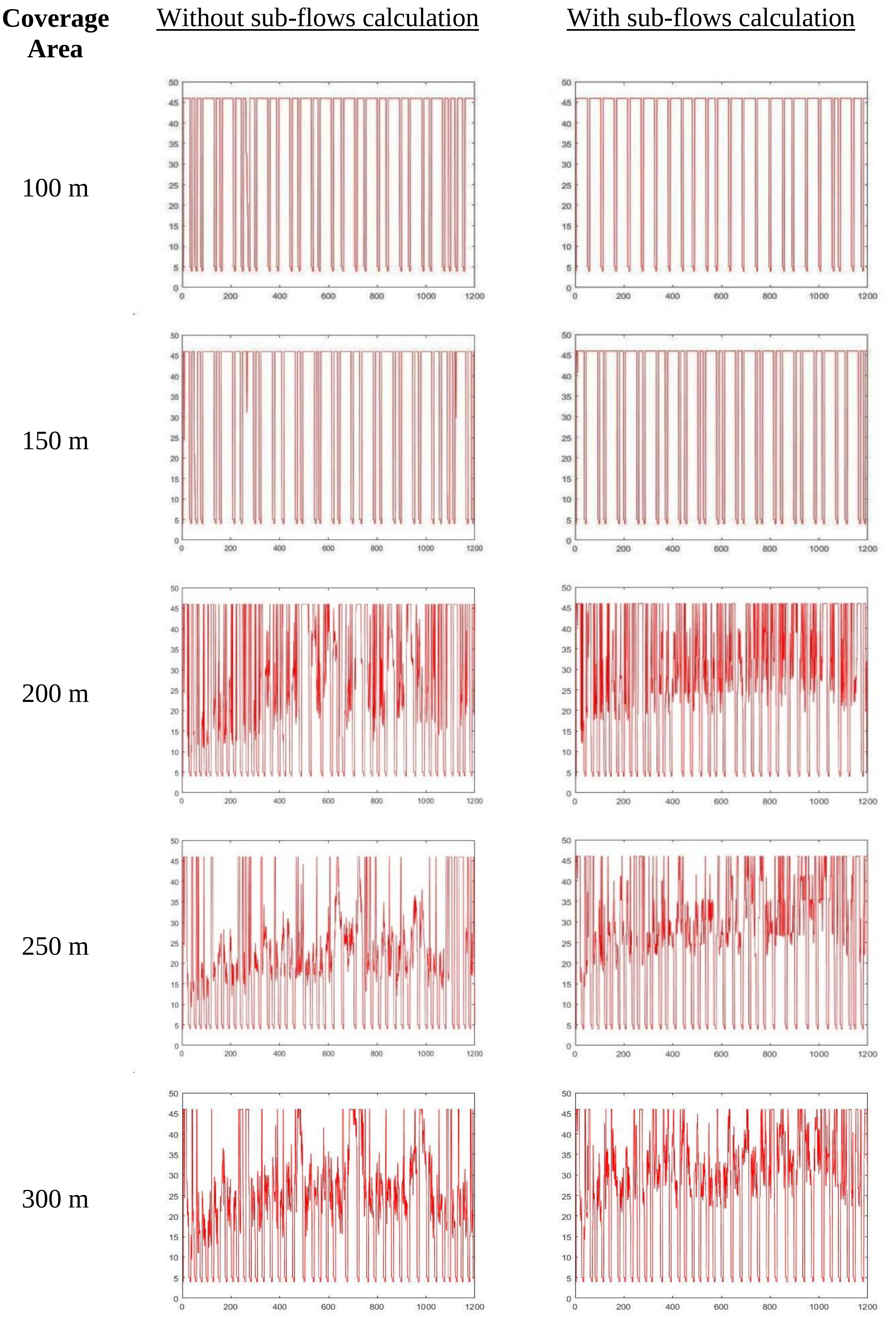
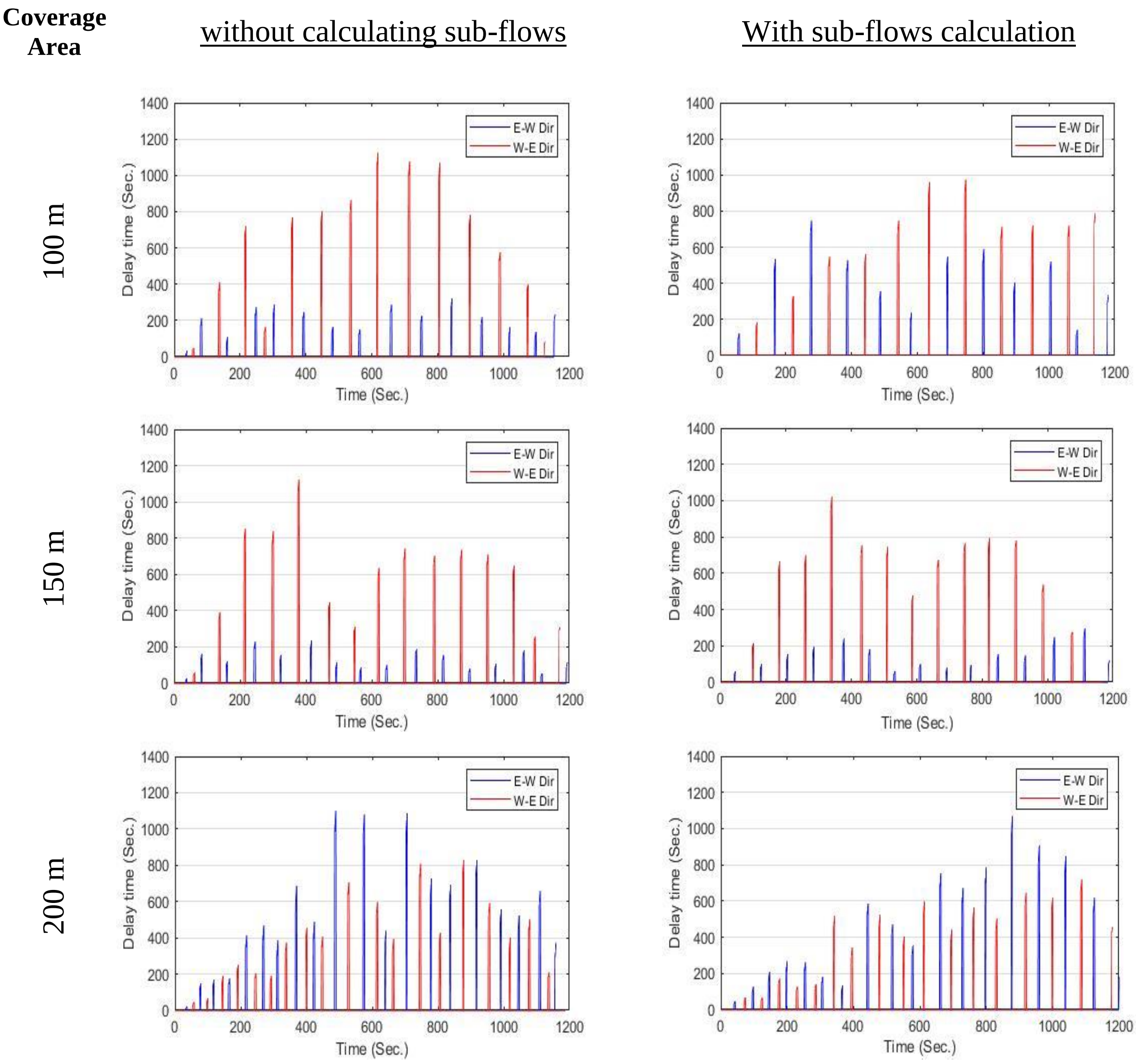


Figure 4.4 Intersection performance based on the ***BestGreenTime*** *for W-E direction*

We conclude from the two Figure s (*Figure* 4.3 and 4.4) that the number of vehicles present at the intersection is very large. Hence the intersection needs a time of more than 46 seconds. This was an incentive for us to study the maximum green time that the intersection can operate in to accommodate more vehicles. This is explained in paragraph No. (4.4).

With regard to the delay in the main edges of each direction in each time step of the red light stage (the safety stage). The total delay time of the vehicles during each cycle was calculated to find out the maximum time the vehicles wait while stopping at the intersection (without calculating sub-flows and with calculating sub-flows). Figure 4.5 shows the maximum delay time during the implementation of different distances for the coverage area.



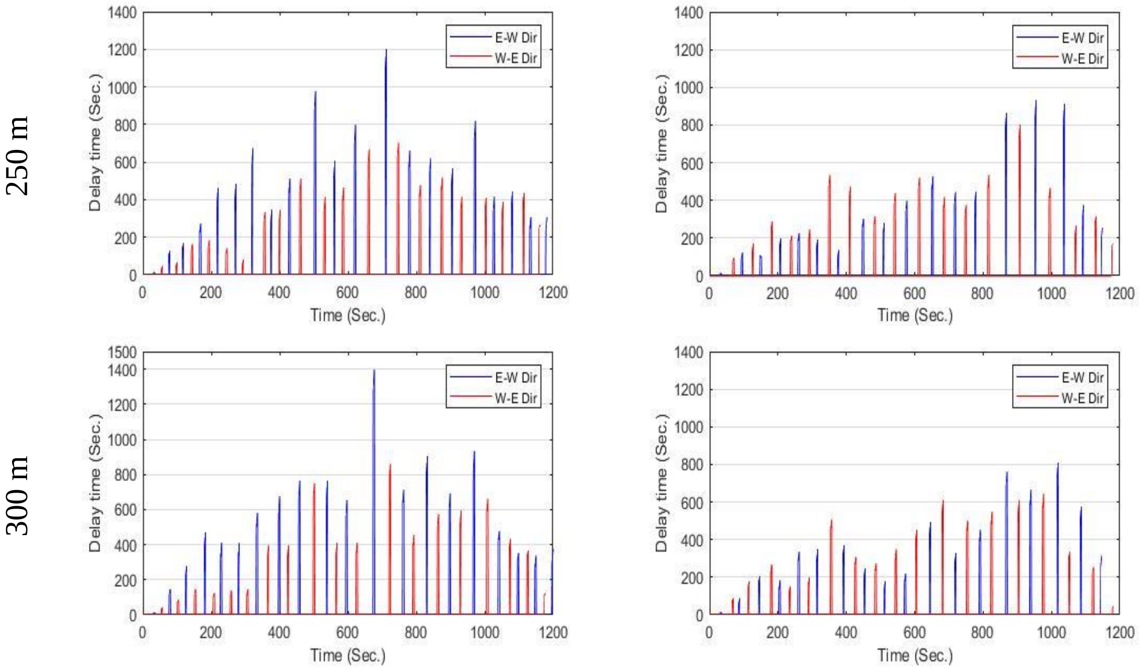


Figure 4.5 The sum of the delay time for each direction in each time cycle

Looking at Figure No. (4.5), we find that the maximum total waiting time for vehicles during each cycle of the algorithm when sub-flows are entered into the algorithm calculations has been reduced for different distances compared to the maximum total waiting time for vehicles without taking into account the sub-flows.

During the simulation period, also we worked on comparing the performance of the intersection by examining track phases to see the number of cycles during implementation. Figure 4.6 shows the mechanism of the intersection implementing the proposed algorithm for different distances of coverage area while studying the effect of sub-flows near the intersection.. Compared with implementing traditional algorithm (Figure 4.2(a)). The results showed an increase for better performance and number of cycles implemented at all distances of the coverage area in the intersection.

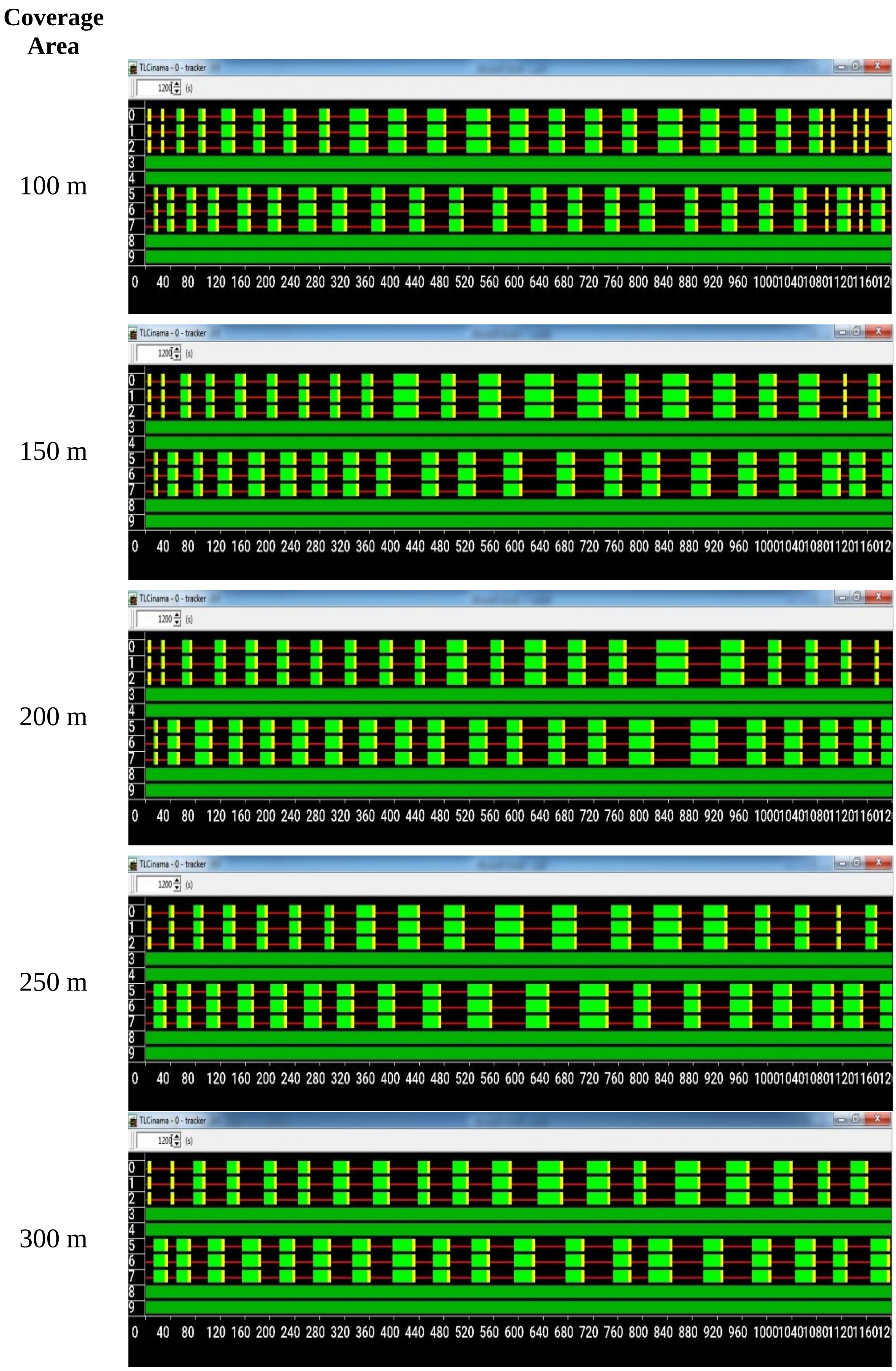
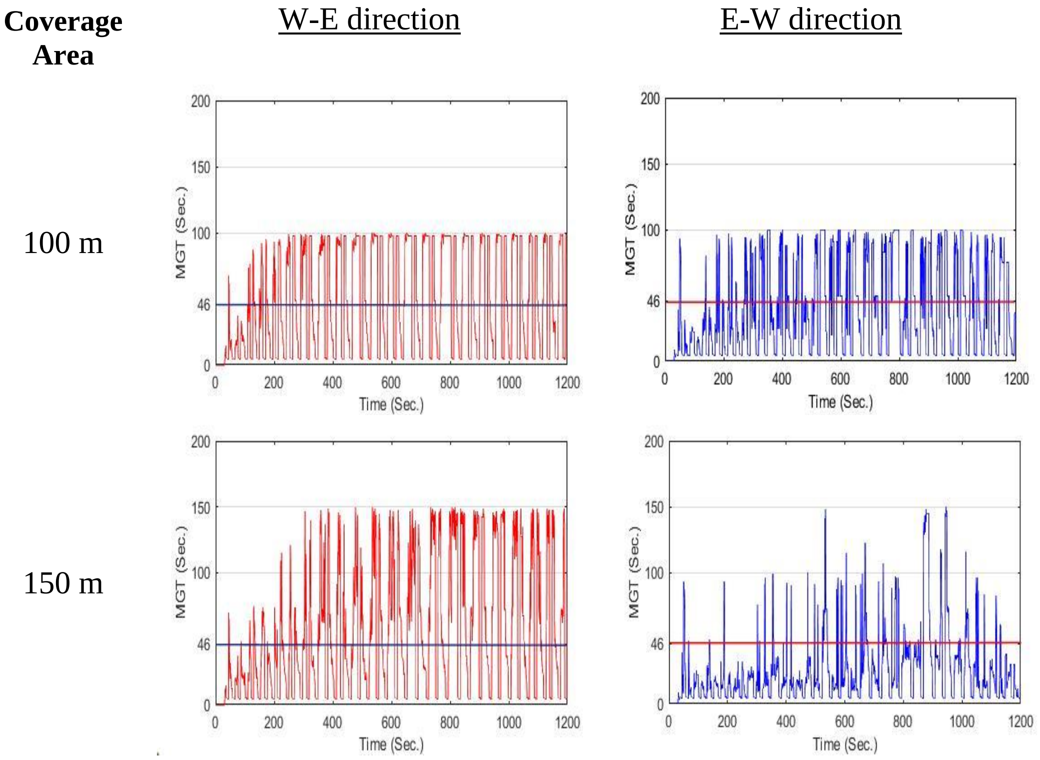


Figure 4.6 Traffic light setting during simulation period for proposed algorithm with calculating sub-flows

The mechanism of adjusting green time for each stage, reduced the waiting time for next competing flows. This is done based on speed of vehicles in each flow within coverage area and location of last vehicle. Thus, leads to an increase in flow rate in the intersection because time is not lost after the last vehicle detected.

4.4 Maximum Green Time Calculation

In this section, maximum green time in which the intersection can operate is going to be investigated. This is done depending on the different traffic load during different times. Making ***MaxGreenTime*** adaptive in contrast to traditional fixed currently used at the intersection (46 seconds) is considered. Results show adaptive ***MaxGreenTime*** that each flow needs with each range of the coverage area. Figure 4.7 shows the performance of the intersection with respect to adaptive ***MaxGreenTime***.



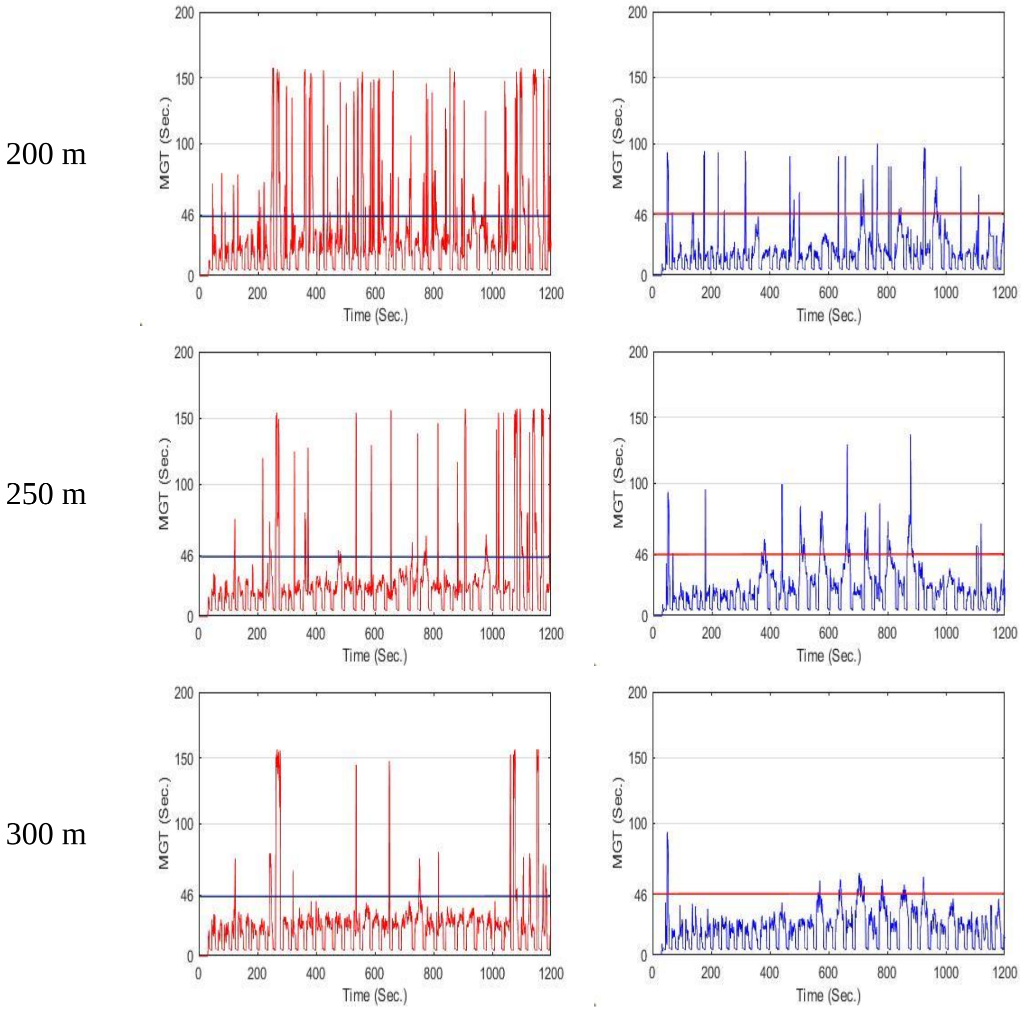


Figure 4.7 Intersection performance depending on MaxGreenTime

Figure (4.7) shows extent to which the intersection needs a green time of more than 46 seconds (especially in the direction from west to east, where in reality this flow is always very crowded). It also shows that there is no ideal value of MGT that can be applied in the intersection under our study because of overload in the intersection and because of increase in coverage area.

4.5 **Summary**

In this chapter, each of the proposed algorithm scenarios is dealt with according to the coverage area (fixed and different), and simulation results are presented and analyzed. A set of performance measures were considered, namely the total delay time of vehicles in the road network surrounding the intersection and the rate of delay at all major edges, and the intersection performance was compared with the traditional traffic light control system and the adaptive system. After that, the best green time for the intersection was studied and displayed in an adaptive manner and an attempt was made to obtain the maximum green time

5

Chapter Five

Conclusions and Future Work

Chapter Five: Conclusions and Future Work

5.1 Introduction

In this chapter, we mention some conclusions and future work. This is done based on the methodology of designing the dynamic scheduling algorithm and implementing the intersection. For simulation purpose to study and analyze the results further future work is also discussed here.

5.2 Conclusions

- ✓ VANET architecture is a good choice used to collect real-time traffic characteristics of vehicles information for each direction.
- ✓ The stages of the traffic light cycle at the intersection are modified according to real-time data.
- ✓ A coverage area (fixed or not) is investigated to determine the maximum allowed best green time ***BestGreenTime*** for each stage so that the maximum green time ***MaxGreenTime*** specified in the traditional mode currently used in the intersection does not exceed specified one (i.e. 46 seconds in our case).
- ✓ ***BestGreenTime*** calculation depends on average vehicles speed within the coverage area and the location of the last vehicle within the coverage area for each direction.
- ✓ We investigated the effect of flows close to the intersection on the calculation of ***MaxGreenTime***. Therefore, the intersection in our study was proofed not isolated.
- ✓ The results showed a reduction in the total delay time for vehicles by different percentages (the lowest was 7.322% and the highest was 16.902%) according to the difference in the coverage area.
- ✓ Depending on the different traffic load at the intersection in different times, we showed the extent to which the ***MaxGreenTime*** intersection

needs more than 46 seconds to cross vehicles and for each range of the coverage area.

- ✓ The value of ***MaxGreenTime*** has become adaptive rather than fixed. But there is no optimum value of ***MaxGreenTime*** that can be applied to the intersection. Because of overload and increasing in the coverage area.

5.3 Future work

- Effect of the algorithm on the intersection according to coverage area, vehicle type, and traffic flow distribution should be investigated.
- All vehicles were supposed to be connected to each other in this scenario. This is not always impossible and leads us to study the algorithm if one or more vehicles without VANET capability is considered.
- Study the probability and impact of a vehicle failure at the intersection is required for future work.
- On 1/8/2021 and while writing this thesis, a traffic light was installed at the intersection of Al Haouz Bridge, which is approximately 2 km from the cinema intersection (the place of our study) to reduce traffic momentum and regulate traffic in that area. This intersection works in the traditional system as well, where a fixed time was given to the signal lights (35 seconds for green and more than 99 seconds for red). In fact, there are several vehicles when they cross this intersection heading towards the cinema intersection. We will study this intersection in the future and the extent of the success of the control system and its impact on the delay of vehicles at the two intersections.

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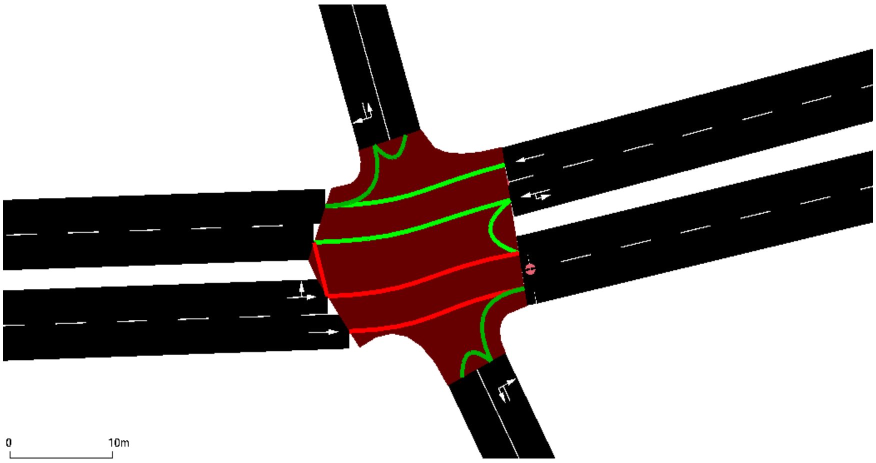
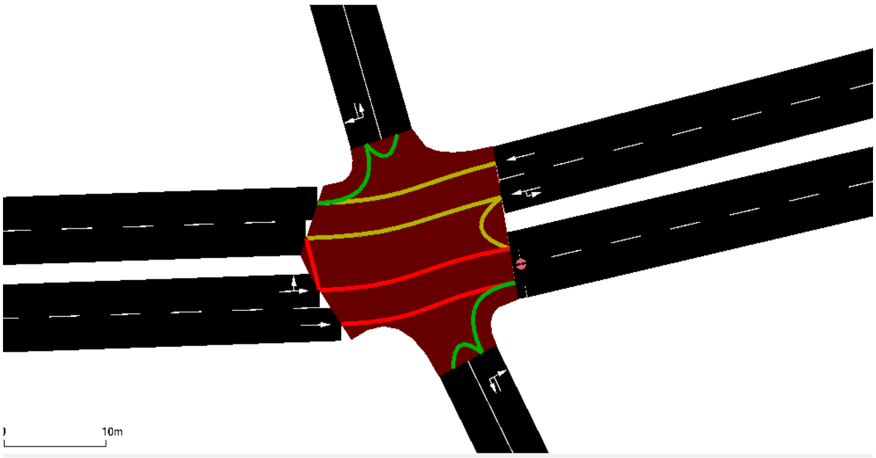
Appendices

Appendix A

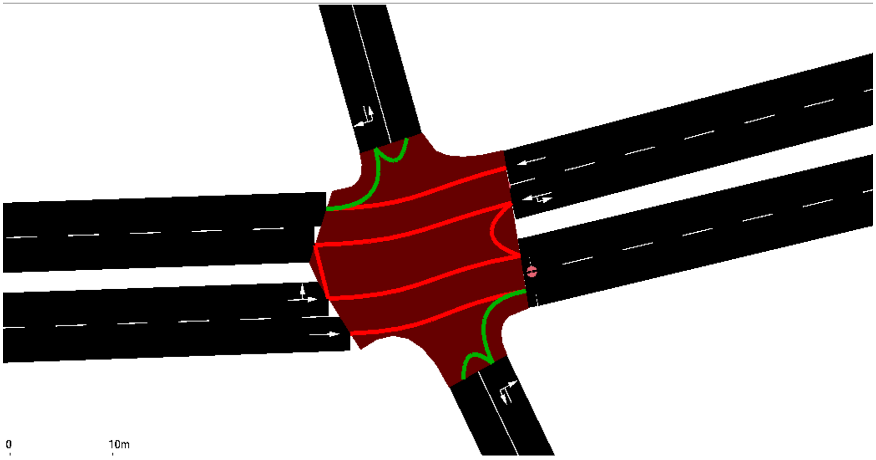
When creating the simulation file for the intersection, the stages of the traffic light at the intersection were designed according to its actual nature using the SUMO simulation program by NetEdit tool. The following figures show the different stages of the traffic light in reality and the light given to each direction in each stage.



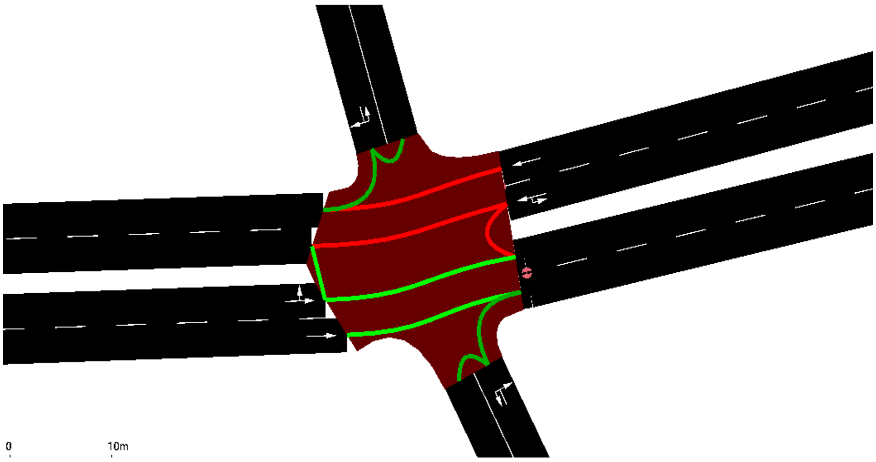
The green phase for the direction from east to west(EGREEN).



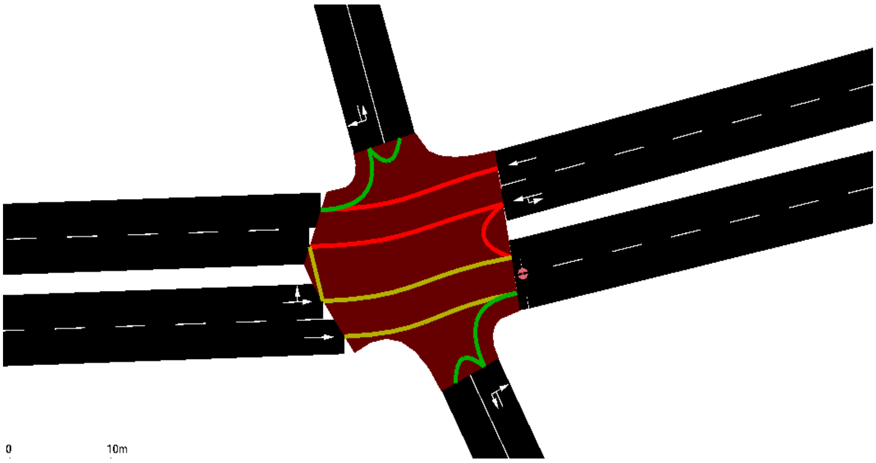
The yellow phase for the direction from east to west(EYELLOW).



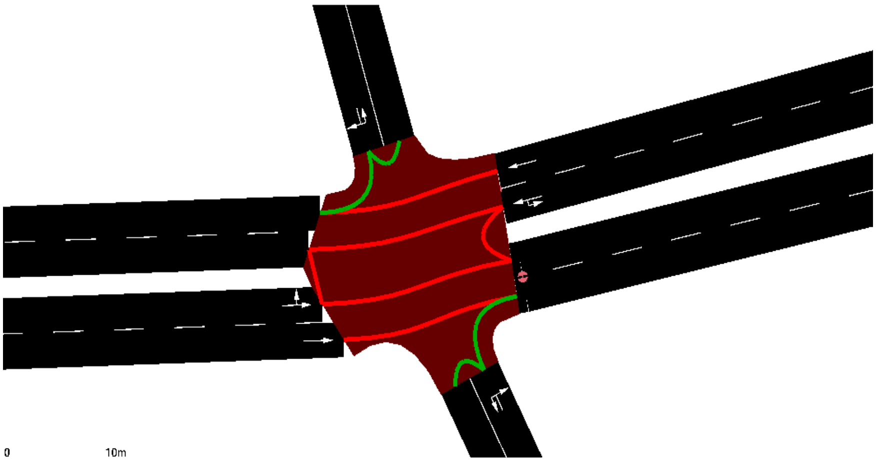
The red phase for the direction from east to west(ERED).



The green phase for the direction from west to east(WGREEN).



The yellow phase for the direction from west to east(WYELLOW).

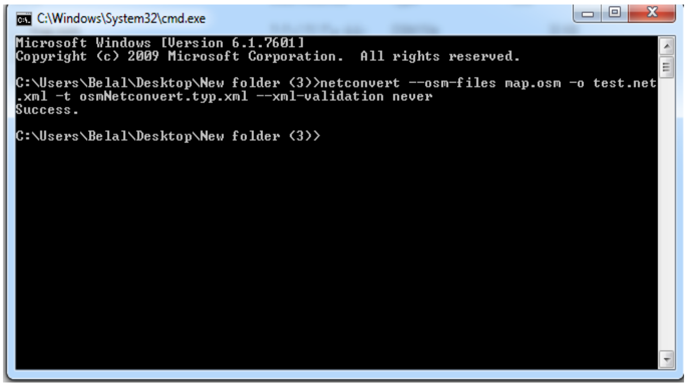


The red phase for the direction from west to east(WRED).

Appendix B

In this appendix, the stages and steps of creating simulation files for the intersection scenario are explained, and the contents of those files are Shown.

1. The following figure shows the implementation of step No.1 to create a file (**test.net**).

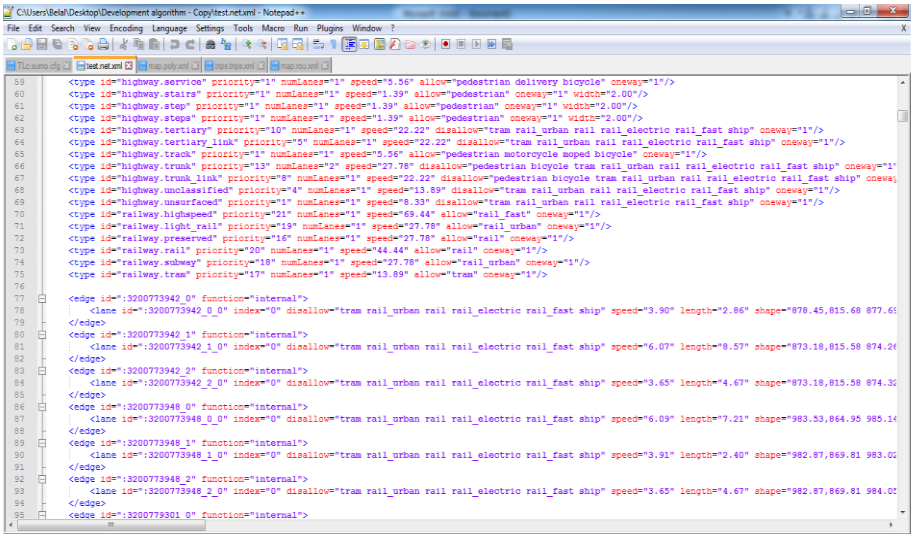


```
Microsoft Windows [Version 6.1.7601]
Copyright (c) 2009 Microsoft Corporation.  All rights reserved.

C:\Users\Belal\Desktop\New folder (3)>netconvert --osm-files map.osm -o test.net
.xml -t osmNetconvert.typ.xml --xml-validation never
Success.

C:\Users\Belal\Desktop\New folder (3)>
```

Step 1

Figure (a, b, and c) shows contents of (**test.net**) file including:

Coordinates of map location, data of edges (addresses, shape, speed, and length), type of vehicles allowed to pass, traffic light information, junctions between roads and method of connection between junctions depending on the direction of each road.



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    <type id="railway.highspeed" priority="21" numLanes="1" speed="69.44" allow="rail_fast" oneway="1"/>
    <type id="railway.light_rail" priority="19" numLanes="1" speed="27.78" allow="rail_urban" oneway="1"/>
    <type id="railway.preserved" priority="16" numLanes="1" speed="27.78" allow="rail" oneway="1"/>
    <type id="railway.rail" priority="20" numLanes="1" speed="44.44" allow="rail" oneway="1"/>
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    <type id="railway.tram" priority="17" numLanes="1" speed="13.89" allow="tram" oneway="1"/>

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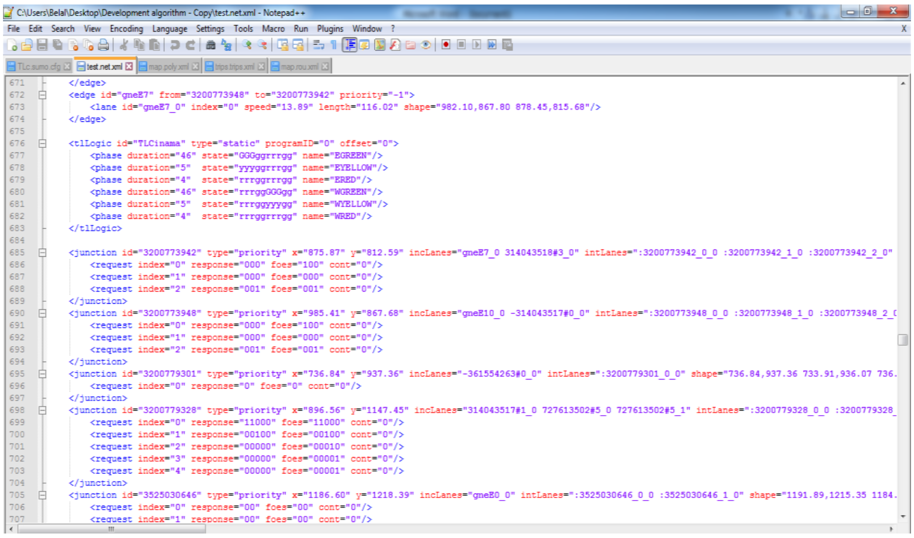
(a)



```
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        <phase duration="46" state="rrrggGGGgg" name="WGREEN"/>
        <phase duration="5"  state="rrrggyyygg" name="WYELLOW"/>
        <phase duration="4"  state="rrrggrrrgg" name="WRED"/>
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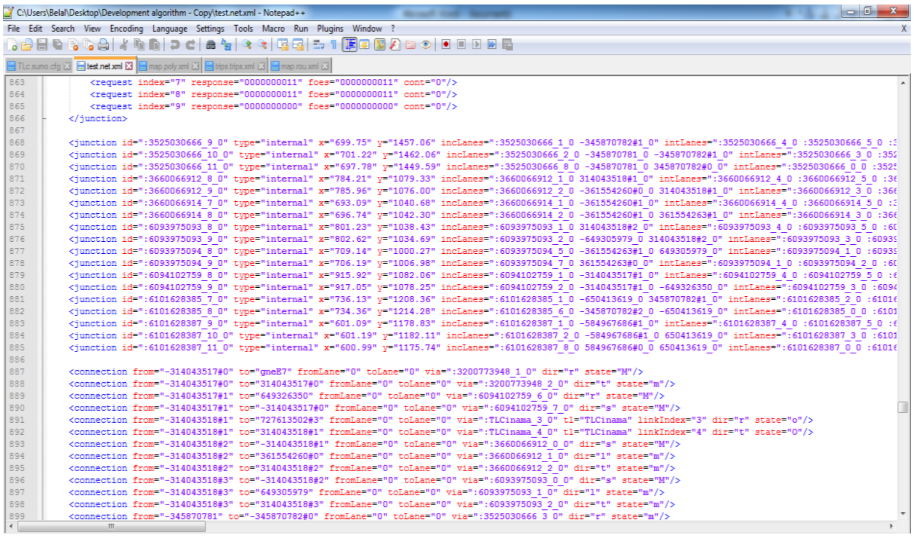
(b)



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    <junction id=":6094102759_9_0" type="internal" x="917.05" y="1078.25" incLanes=":6094102759_2_0 -314043517#1_0 -649326350_0" intLanes=":6094102759_3_0 :6094
    <junction id=":6101628385_7_0" type="internal" x="736.13" y="1208.36" incLanes=":6101628385_1_0 -650413619_0 345870782#1_0" intLanes=":6101628385_2_0 :61016
    <junction id=":6101628385_8_0" type="internal" x="734.36" y="1214.28" incLanes=":6101628385_6_0 -345870782#2_0 -650413619_0" intLanes=":6101628385_0_0 :6101
    <junction id=":6101628387_9_0" type="internal" x="601.09" y="1178.83" incLanes=":6101628387_1_0 -584967686#1_0" intLanes=":6101628387_4_0 :6101628387_5_0 :6
    <junction id=":6101628387_10_0" type="internal" x="601.19" y="1182.11" incLanes=":6101628387_2_0 -584967686#1_0 650413619_0" intLanes=":6101628387_3_0 :6101
    <junction id=":6101628387_11_0" type="internal" x="600.99" y="1175.74" incLanes=":6101628387_8_0 584967686#0_0 650413619_0" intLanes=":6101628387_0_0 :61016

    <connection from="-314043517#0" to="gneE7" fromLane="0" toLane="0" via=":3200773948_1_0" dir="r" state="M"/>
    <connection from="-314043517#0" to="314043517#0" fromLane="0" toLane="0" via=":3200773948_2_0" dir="t" state="m"/>
    <connection from="-314043517#1" to="649326350" fromLane="0" toLane="0" via=":6094102759_6_0" dir="r" state="M"/>
    <connection from="-314043517#1" to="-314043517#0" fromLane="0" toLane="0" via=":6094102759_7_0" dir="s" state="M"/>
    <connection from="-314043518#1" to="727613502#3" fromLane="0" toLane="0" via=":TLCinama_3_0" tl="TLCinama" linkIndex="3" dir="r" state="o"/>
    <connection from="-314043518#1" to="314043518#1" fromLane="0" toLane="0" via=":TLCinama_4_0" tl="TLCinama" linkIndex="4" dir="t" state="O"/>
    <connection from="-314043518#2" to="-314043518#1" fromLane="0" toLane="0" via=":3660066912_0_0" dir="s" state="M"/>
    <connection from="-314043518#2" to="361554260#0" fromLane="0" toLane="0" via=":3660066912_1_0" dir="l" state="m"/>
    <connection from="-314043518#2" to="314043518#2" fromLane="0" toLane="0" via=":3660066912_2_0" dir="t" state="m"/>
    <connection from="-314043518#3" to="-314043518#2" fromLane="0" toLane="0" via=":6093975093_0_0" dir="s" state="M"/>
    <connection from="-314043518#3" to="649305979" fromLane="0" toLane="0" via=":6093975093_1_0" dir="l" state="m"/>
    <connection from="-314043518#3" to="314043518#3" fromLane="0" toLane="0" via=":6093975093_2_0" dir="t" state="m"/>
    <connection from="-345870781" to="-345870782#0" fromLane="0" toLane="0" via=":3525030666_3_0" dir="r" state="m"/>
```
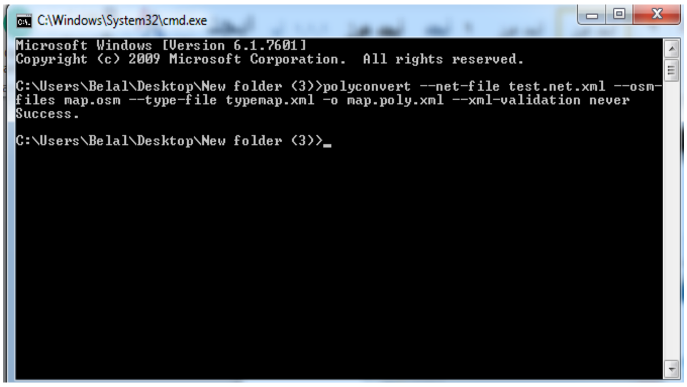

(c)

contents of (test.net) file

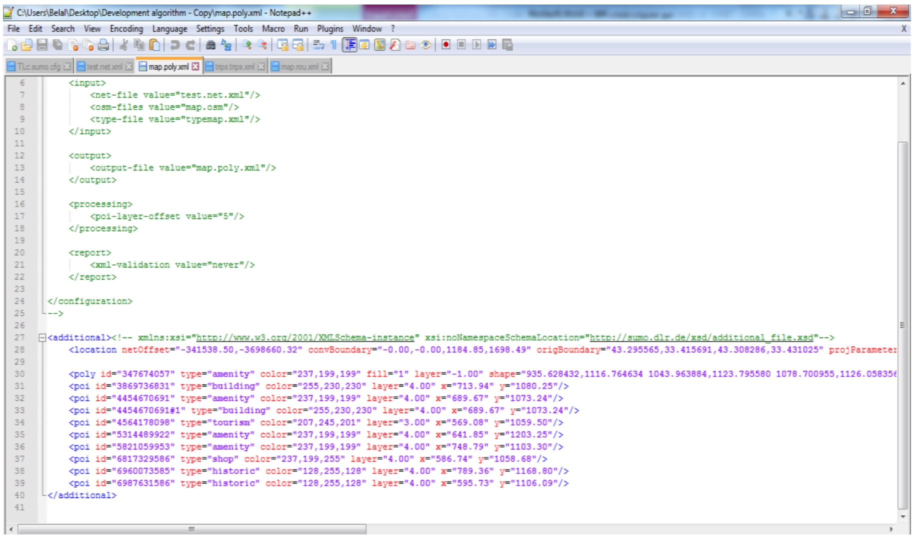
2. The following figure shows the implementation of step No.2 to create a file (**map.poly**) and (**map.rou**).



```
Microsoft Windows [Version 6.1.7601]
Copyright (c) 2009 Microsoft Corporation.  All rights reserved.

C:\Users\Belal\Desktop\New folder (3)>polyconvert --net-file test.net.xml --osm-
files map.osm --type-file typemap.xml -o map.poly.xml --xml-validation never
Success.

C:\Users\Belal\Desktop\New folder (3)>_
```

Step 2

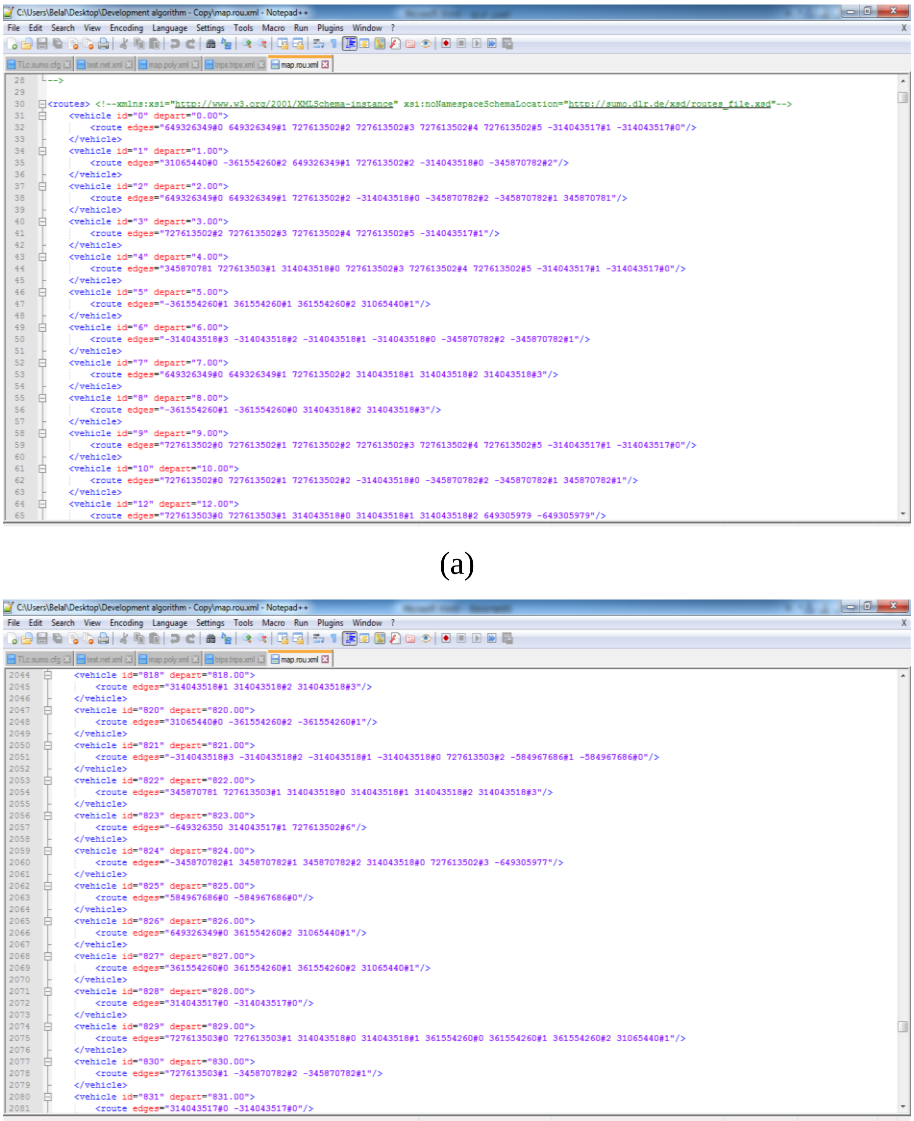
File (**map.poly**) including polygons and shapes of the map, this is shown in following figure.



```
    <input>
        <net-file value="test.net.xml"/>
        <osm-files value="map.osm"/>
        <type-file value="typemap.xml"/>
    </input>

    <output>
        <output-file value="map.poly.xml"/>
    </output>

    <processing>
        <poi-layer-offset value="5"/>
    </processing>

    <report>
        <xml-validation value="never"/>
    </report>

</configuration>
-->

<additional><!-- xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xsi:noNamespaceSchemaLocation="http://sumo.dlr.de/xsd/additional_file.xsd"-->
    <location netOffset="-341538.50,-3698660.32" convBoundary="-0.00,-0.00,1184.85,1698.49" origBoundary="43.295565,33.415691,43.308286,33.431025" projParameter

    <poly id="347674057" type="amenity" color="237,199,199" fill="1" layer="-1.00" shape="935.628432,1116.764634 1043.963884,1123.795580 1078.700955,1126.05835
    <poi id="3869736831" type="building" color="255,230,230" layer="4.00" x="713.94" y="1080.25"/>
    <poi id="4454670691" type="amenity" color="237,199,199" layer="4.00" x="689.67" y="1073.24"/>
    <poi id="4454670691#1" type="building" color="255,230,230" layer="4.00" x="689.67" y="1073.24"/>
    <poi id="4564178098" type="tourism" color="207,245,201" layer="3.00" x="569.08" y="1059.50"/>
    <poi id="5314489922" type="amenity" color="237,199,199" layer="4.00" x="641.85" y="1203.25"/>
    <poi id="5821059953" type="amenity" color="237,199,199" layer="4.00" x="748.79" y="1103.30"/>
    <poi id="6817329586" type="shop" color="237,199,255" layer="4.00" x="586.74" y="1058.68"/>
    <poi id="6960073585" type="historic" color="128,255,128" layer="4.00" x="789.36" y="1168.80"/>
    <poi id="6987631586" type="historic" color="128,255,128" layer="4.00" x="595.73" y="1106.09"/>
</additional>
```

contents of (map.poly) *file*

File (map.rou) contains the automatic routing path for vehicles in the road network, this is shown in following figure (a and b).



```
-->

<routes> <!--xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xsi:noNamespaceSchemaLocation="http://sumo.dlr.de/xsd/routes_file.xsd"-->
    <vehicle id="0" depart="0.00">
        <route edges="649326349#0 649326349#1 727613502#2 727613502#3 727613502#4 727613502#5 -314043517#1 -314043517#0"/>
    </vehicle>
    <vehicle id="1" depart="1.00">
        <route edges="31065440#0 -361554260#2 649326349#1 727613502#2 -314043518#0 -345870782#2"/>
    </vehicle>
    <vehicle id="2" depart="2.00">
        <route edges="649326349#0 649326349#1 727613502#2 -314043518#0 -345870782#2 -345870782#1 345870781"/>
    </vehicle>
    <vehicle id="3" depart="3.00">
        <route edges="727613502#2 727613502#3 727613502#4 727613502#5 -314043517#1"/>
    </vehicle>
    <vehicle id="4" depart="4.00">
        <route edges="345870781 727613503#1 314043518#0 727613502#3 727613502#4 727613502#5 -314043517#1 -314043517#0"/>
    </vehicle>
    <vehicle id="5" depart="5.00">
        <route edges="-361554260#1 361554260#1 361554260#2 31065440#1"/>
    </vehicle>
    <vehicle id="6" depart="6.00">
        <route edges="-314043518#3 -314043518#2 -314043518#1 -314043518#0 -345870782#2 -345870782#1"/>
    </vehicle>
    <vehicle id="7" depart="7.00">
        <route edges="649326349#0 649326349#1 727613502#2 314043518#1 314043518#2 314043518#3"/>
    </vehicle>
    <vehicle id="8" depart="8.00">
        <route edges="-361554260#1 -361554260#0 314043518#2 314043518#3"/>
    </vehicle>
    <vehicle id="9" depart="9.00">
        <route edges="727613502#0 727613502#1 727613502#2 727613502#3 727613502#4 727613502#5 -314043517#1 -314043517#0"/>
    </vehicle>
    <vehicle id="10" depart="10.00">
        <route edges="727613502#0 727613502#1 727613502#2 -314043518#0 -345870782#2 -345870782#1 345870782#1"/>
    </vehicle>
    <vehicle id="12" depart="12.00">
        <route edges="727613503#0 727613503#1 314043518#0 314043518#1 314043518#2 649305979 -649305979"/>
```

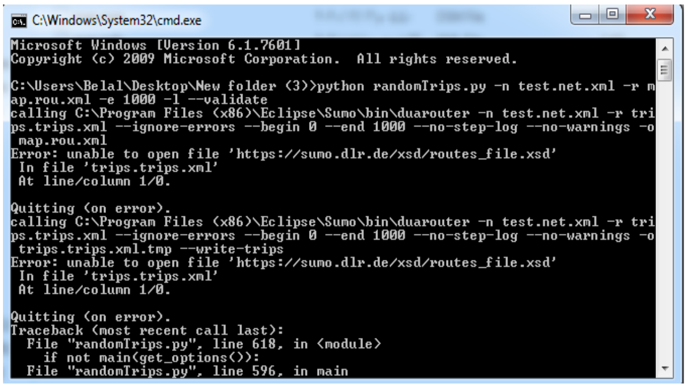
(a)

```
    <vehicle id="818" depart="818.00">
        <route edges="314043518#1 314043518#2 314043518#3"/>
    </vehicle>
    <vehicle id="820" depart="820.00">
        <route edges="31065440#0 -361554260#2 -361554260#1"/>
    </vehicle>
    <vehicle id="821" depart="821.00">
        <route edges="-314043518#3 -314043518#2 -314043518#1 -314043518#0 727613503#2 -584967686#1 -584967686#0"/>
    </vehicle>
    <vehicle id="822" depart="822.00">
        <route edges="345870781 727613503#1 314043518#0 314043518#1 314043518#2 314043518#3"/>
    </vehicle>
    <vehicle id="823" depart="823.00">
        <route edges="-649326350 314043517#1 727613502#6"/>
    </vehicle>
    <vehicle id="824" depart="824.00">
        <route edges="-345870782#1 345870782#1 345870782#2 314043518#0 727613502#3 -649305977"/>
    </vehicle>
    <vehicle id="825" depart="825.00">
        <route edges="584967686#0 -584967686#0"/>
    </vehicle>
    <vehicle id="826" depart="826.00">
        <route edges="649326349#0 361554260#2 31065440#1"/>
    </vehicle>
    <vehicle id="827" depart="827.00">
        <route edges="361554260#0 361554260#1 361554260#2 31065440#1"/>
    </vehicle>
    <vehicle id="828" depart="828.00">
        <route edges="314043517#0 -314043517#0"/>
    </vehicle>
    <vehicle id="829" depart="829.00">
        <route edges="727613503#0 727613503#1 314043518#0 314043518#1 361554260#0 361554260#1 361554260#2 31065440#1"/>
    </vehicle>
    <vehicle id="830" depart="830.00">
        <route edges="727613503#1 -345870782#2 -345870782#1"/>
    </vehicle>
    <vehicle id="831" depart="831.00">
        <route edges="314043517#0 -314043517#0"/>
```

(b)

contents of (map.rou) *file*

3. The following figure shows the implementation of step No.3 to create a file (**trips.trips**).



```
Microsoft Windows [Version 6.1.7601]
Copyright (c) 2009 Microsoft Corporation.  All rights reserved.

C:\Users\Belal\Desktop\New folder (3)>python randomTrips.py -n test.net.xml -r m
ap.rou.xml -e 1000 -l --validate
calling C:\Program Files (x86)\Eclipse\Sumo\bin\duarouter -n test.net.xml -r tri
ps.trips.xml --ignore-errors --begin 0 --end 1000 --no-step-log --no-warnings -o
 map.rou.xml
Error: unable to open file 'https://sumo.dlr.de/xsd/routes_file.xsd'
 In file 'trips.trips.xml'
 At line/column 1/0.

Quitting (on error).
calling C:\Program Files (x86)\Eclipse\Sumo\bin\duarouter -n test.net.xml -r tri
ps.trips.xml --ignore-errors --begin 0 --end 1000 --no-step-log --no-warnings -o
 trips.trips.xml.tmp --write-trips
Error: unable to open file 'https://sumo.dlr.de/xsd/routes_file.xsd'
 In file 'trips.trips.xml'
 At line/column 1/0.

Quitting (on error).
Traceback (most recent call last):
  File "randomTrips.py", line 618, in <module>
    if not main(get_options()):
  File "randomTrips.py", line 596, in main
```

Step 3

File (**trips.trips**) that contains the trip identifiers for each vehicle (the address of edge where vehicle begins to appear in simulation and address of edge from which vehicle departs), this is shown in following figure (a and b).

```
-->
<routes> <!--xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xsi:noNamespaceSchemaLocation="http://sumo.dlr.de/xsd/routes_file.xsd"-->
    <trip id="0" depart="0.00" from="649326349#0" to="-314043517#0"/>
    <trip id="1" depart="1.00" from="31065440#0" to="-345870782#2"/>
    <trip id="2" depart="2.00" from="649326349#0" to="345870781"/>
    <trip id="3" depart="3.00" from="727613502#2" to="-314043517#1"/>
    <trip id="4" depart="4.00" from="345870781" to="-314043517#0"/>
    <trip id="5" depart="5.00" from="-361554260#1" to="31065440#1"/>
    <trip id="6" depart="6.00" from="-314043518#3" to="-345870782#1"/>
    <trip id="7" depart="7.00" from="649326349#0" to="314043518#3"/>
    <trip id="8" depart="8.00" from="-361554260#1" to="314043518#3"/>
    <trip id="9" depart="9.00" from="727613502#0" to="-314043517#0"/>
    <trip id="10" depart="10.00" from="727613502#0" to="345870782#1"/>
    <trip id="11" depart="11.00" from="314043517#0" to="-345870782#0"/>
    <trip id="12" depart="12.00" from="727613503#0" to="-649305979"/>
    <trip id="13" depart="13.00" from="-314043518#3" to="-314043518#2"/>
    <trip id="14" depart="14.00" from="727613502#0" to="314043518#3"/>
    <trip id="15" depart="15.00" from="727613502#0" to="361554260#0"/>
    <trip id="16" depart="16.00" from="361554263#0" to="727613503#3"/>
    <trip id="17" depart="17.00" from="345870781" to="314043518#3"/>
    <trip id="18" depart="18.00" from="727613502#0" to="314043518#3"/>
    <trip id="19" depart="19.00" from="727613502#0" to="314043518#3"/>
    <trip id="20" depart="20.00" from="649326349#0" to="-314043517#0"/>
    <trip id="21" depart="21.00" from="-584967686#1" to="-584967686#0"/>
    <trip id="22" depart="22.00" from="-314043518#3" to="-345870782#2"/>
    <trip id="23" depart="23.00" from="-345870781" to="-584967686#0"/>
    <trip id="24" depart="24.00" from="649326349#0" to="31065440#0"/>
    <trip id="25" depart="25.00" from="314043518#1" to="-345870782#1"/>
    <trip id="26" depart="26.00" from="31065440#0" to="727613503#3"/>
    <trip id="27" depart="27.00" from="649326349#0" to="314043518#3"/>
    <trip id="28" depart="28.00" from="-345870782#1" to="361554260#0"/>
    <trip id="29" depart="29.00" from="-345870782#1" to="31065440#1"/>
    <trip id="30" depart="30.00" from="727613503#2" to="345870781"/>
    <trip id="31" depart="31.00" from="584967686#0" to="345870782#1"/>
    <trip id="32" depart="32.00" from="727613502#0" to="649326349#1"/>
    <trip id="33" depart="33.00" from="-584967686#1" to="-314043517#0"/>
    <trip id="34" depart="34.00" from="314043517#0" to="-361554263#0"/>
    <trip id="35" depart="35.00" from="-361554260#0" to="727613503#3"/>
```

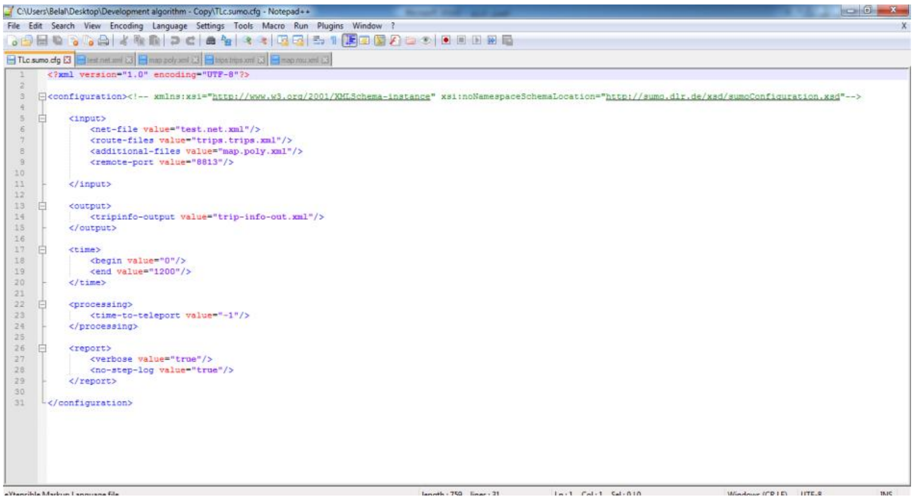
(a)

```
    <trip id="965" depart="965.00" from="649326349#0" to="314043518#3"/>
    <trip id="966" depart="966.00" from="-314043518#3" to="-649305979"/>
    <trip id="967" depart="967.00" from="-314043518#3" to="727613503#3"/>
    <trip id="968" depart="968.00" from="727613503#0" to="-314043517#0"/>
    <trip id="969" depart="969.00" from="727613503#0" to="-314043517#0"/>
    <trip id="970" depart="970.00" from="345870781" to="649305979"/>
    <trip id="971" depart="971.00" from="649326349#0" to="727613503#3"/>
    <trip id="972" depart="972.00" from="649326349#0" to="31065440#1"/>
    <trip id="973" depart="973.00" from="727613503#2" to="31065440#1"/>
    <trip id="974" depart="974.00" from="727613502#0" to="727613503#2"/>
    <trip id="975" depart="975.00" from="345870781" to="345870782#1"/>
    <trip id="976" depart="976.00" from="649326349#0" to="314043518#3"/>
    <trip id="977" depart="977.00" from="649326349#0" to="-649305979"/>
    <trip id="978" depart="978.00" from="-345870782#1" to="314043518#2"/>
    <trip id="979" depart="979.00" from="361554260#1" to="361554260#0"/>
    <trip id="980" depart="980.00" from="-361554260#1" to="-314043517#0"/>
    <trip id="981" depart="981.00" from="-314043518#3" to="-584967686#0"/>
    <trip id="982" depart="982.00" from="649326349#0" to="314043518#3"/>
    <trip id="983" depart="983.00" from="361554260#1" to="727613502#3"/>
    <trip id="984" depart="984.00" from="-649326350" to="-649305979"/>
    <trip id="985" depart="985.00" from="31065440#0" to="727613503#3"/>
    <trip id="986" depart="986.00" from="649326349#0" to="-345870781"/>
    <trip id="987" depart="987.00" from="727613502#0" to="31065440#1"/>
    <trip id="988" depart="988.00" from="649326349#0" to="727613503#1"/>
    <trip id="989" depart="989.00" from="-314043518#3" to="-345870782#1"/>
    <trip id="990" depart="990.00" from="-345870781" to="-314043517#0"/>
    <trip id="991" depart="991.00" from="584967686#1" to="345870782#1"/>
    <trip id="992" depart="992.00" from="-314043518#3" to="361554260#1"/>
    <trip id="993" depart="993.00" from="345870781" to="-361554260#0"/>
    <trip id="994" depart="994.00" from="-361554260#1" to="727613502#6"/>
    <trip id="995" depart="995.00" from="-314043518#3" to="31065440#1"/>
    <trip id="996" depart="996.00" from="314043517#0" to="727613502#2"/>
    <trip id="997" depart="997.00" from="649326349#0" to="-584967686#0"/>
    <trip id="998" depart="998.00" from="584967686#1" to="345870781"/>
    <trip id="999" depart="999.00" from="314043517#0" to="-584967686#0"/>
</routes>
```

(b)

contents of (trips.trips) file

4. Finally, the following figure shows the contents of main emulator file (**name.sumo.cfg**).



```
<?xml version="1.0" encoding="UTF-8"?>

<configuration><!-- xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xsi:noNamespaceSchemaLocation="http://sumo.dlr.de/xsd/sumoConfiguration.xsd"-->

    <input>
        <net-file value="test.net.xml"/>
        <route-files value="trips.trips.xml"/>
        <additional-files value="map.poly.xml"/>
        <remote-port value="8813"/>

    </input>

    <output>
        <tripinfo-output value="trip-info-out.xml"/>
    </output>

    <time>
        <begin value="0"/>
        <end value="1200"/>
    </time>

    <processing>
        <time-to-teleport value="-1"/>
    </processing>

    <report>
        <verbose value="true"/>
        <no-step-log value="true"/>
    </report>

</configuration>
```

contents of (name.sumo.cfg) file

الخلاصة

يعد الازدحام المروري أحد المشكلات الرئيسية التي تواجه بعض السائقين حول العالم، وخاصة في شبكة الطرق الحضرية، حيث يمثل ضياع الوقت واستهلاك الوقود مصدر قلق كبير. تنشأ المشاكل الاقتصادية والاجتماعية والبيئية بسبب التحكم غير الفعال في التقاطع. لذلك، تعتبر أنظمة النقل الذكية (ITS) مهمة في تقليل الازدحام والحوادث، وزيادة السلامة المرورية وتقليل تلوث الهواء. مع التقدم الهائل في تكنولوجيا التنقل والشبكات، جذبت الشبكات المخصصة للمركبات (VANETs) باحثين من الأوساط الأكاديمية والصناعية. يعد الاتصال المحمول وازدحام المرور وإدارة السلامة على الطرق بعض التطبيقات التي تم إنشاؤها ضمن نموذج الشبكات هذا. يمكن أن يكون التحكم في إشارات المرور (TSC) ذاتي التنظيم والتكيف مع التغيرات في ظروف حركة المرور باستخدام تقنية الـ VANET وخوارزمية التحكم الذكي حيث توفر تقنية VANET معلومات شاملة عن المركبات التي تقترب من التقاطعات. يسمح الاتصال بين المركبات بتبادل المعلومات لتحسين السلامة المرورية. أحد انواع اتصالات الـ VANET هو اتصالات V2X حيث يمكنه إرسال واستقبال وإعادة بث رسائل السلامة ، وبالتالي فإن الـ TSC مع اتصال V2X هو حل فعال للغاية لمشكلة الازدحام المروري.

في هذه الرسالة تمت دراسة وتحليل تقاطع في مدينة الرمادي من خلال جمع المعلومات المرورية في الوقت الحقيقي في شبكة الطرق المحيطة بالتقاطع. بعد ذلك ، تم اقتراح خوارزمية جدولة ديناميكية بناءً على سيناريو VANET ، والتي تقوم بجدولة التدفقات المتنافسة في حركة المرور. تهدف الخوارزمية المقترحة إلى زيادة تدفق حركة المرور وأداء التقاطع من خلال الاستفادة من الوقت الأخضر الفائض لتقليل وقت الانتظار وتأخير المركبات المتنقلة اعتمادًا على معلومات المركبات (السرعة والموقع وعدد المركبات) تحت منطقة تغطية مختلفة. بدلاً من استخدام الحد الأقصى الثابت للوقت الأخضر المستخدم حاليًا عند التقاطع ، واعتمادًا على منطقة التغطية ووصول المركبات ، تم اقتراح طريقة تكيفية للوقت الأخضر والتحقيق منها. يتم محاكاة منطقة التغطية والخوارزمية المطورة في محاكي SUMO باستخدام MATLAB من خلال أداة TRACI للحصول على النتائج. أظهرت النتائج تحسنًا كبيرًا في معدل نقل حركة المرور وتقليل وقت التأخير بنسب مختلفة (اقلها ٧,٣٢٢% واعلاها ١٦,٩٠٢%) وفقاً لاختلاف منطقة التغطية مقارنةً بوقت الدورة التقليدي (أي الثابت) المستخدم حاليًا في دراسة الحالة الخاصة بنا.

جمهورية العراق
وزارة التعليم العالي والبحث العلمي
جامعة الأنبار
كلية علوم الحاسوب وتكنولوجيا المعلومات
قسم علوم الحاسبات

تبني طريقة بسيطة لتقاطع الاشارة المرورية

رسالة مقدمة الى

قسم علوم الحاسبات – كلية علوم الحاسوب وتكنلوجيا المعلومات جامعة الانبار،

وهي جزء من متطلبات نيل درجة الماجستير في علوم الحاسبات

قدمت من قبل

بلال رشيد علوان

بإشراف

د. منتصر عبد الواحد سلمان

١٤٤٣ هـ **٢٠٢١م**