# Scheduling algorithm for adaptive traffic light under VANET scenario

**Conference Paper** *in* AIP Conference Proceedings · October 2022

DOI: 10.1063/5.0112708



Muntaser Salman
University of Anbar

# Scheduling algorithm for adaptive traffic light under VANET scenario

Cite as: AIP Conference Proceedings **2400**, 020009 (2022); https://doi.org/10.1063/5.0112708
Published Online: 31 October 2022

**Belal R. Alwan and Muntaser A. Salman**

# Scheduling Algorithm For Adaptive Traffic Light Under VANET Scenario

*Belal R. Alwan*[1,a) ] *Muntaser A. Salman*[2,b)]

[1]*College of Computer Science and Information Technology*
*Computer Science Department*
*University of Anbar, Anbar, Iraq*
[2]*College of Computer Science and Information Technology*
*Information Systems Department*
*University of Anbar, Anbar, Iraq*
[a)] *bel19c1014@uoanbar.edu.iq*
[b)] *Corresponding author: co.montasser.salman@uoanbar.edu.iq*

**Abstract.** Traffic congestion is one of the main problems facing drivers around the world and especially in urban road network where wasted time and fuel are major concern. Improving the city's transportation system requires improving traffic signal controllers and adopting new technology. Therefore, intelligent transportation systems are important in reducing congestion and accidents, increasing traffic safety and reducing air pollution. In this paper, scheduling algorithm based on VANET scenario is proposed to analysis an isolated intersection (in Ramadi city) as a case study. This has been done by implementing a dynamic scheduling algorithm that schedules competing traffic flows. The proposed algorithm (called Scheduling Traffic Light STL) aims to increase traffic flow by utilizing the excess of green signal time to reduce the waiting time for mobile vehicles at the intersection. The results show a significant improvement in traffic transmission rate and reduced waiting time compared to traditional (i.e. fixed) cycle time currently used in our case study.

**KEYWORDS: Isolated intersection, Scheduling algorithm, Vehicular ad-hoc network, Traffic light.**

## INTRODUCTION

With the increase in car ownership in the city, traffic congestion has become dangerous and consuming time and effort, as well as movement has become restricted. There is an urgent need to find a way to improve traffic efficiency at the intersection. A traffic light has been installed at the intersection with the aim of controlling traffic and its flow, but the problem of heavy traffic congestion at the intersection has not been solved. Working to find a solution to this problem is done here. The traditional traffic light time setting is fixed, predetermined, easy to implement, cost-effective, and is widely used. An improved version is used for different time settings during the day in order to reduce traffic congestion more dynamically. However, it does not provide effective traffic routing when the traffic load varies during the day and it cannot handle the ever-increasing traffic of vehicles.

Conventional traffic control systems use radar, camera and inductive sensor to detect traffic conditions, but their high costing, constant maintenance needing, and complex handling make these techniques useless. On the other hand, technological advancements in wireless communication, especially VANET made the possibility of using them in traffic light control systems. Making traffic light control system adaptive instead of conventional, based on vehicle data, opens a wide scope for us to improve the traffic light of our interest.

Several researchers have presented some studies to improve traffic light algorithms through wireless network technology. For instance, in [1] an Intelligent Traffic Light Controlling ITLC algorithm was presented, and priority is given to the schedule with greater density, and the researchers themselves worked to improve this algorithm to deal with the emergence of any emergency car in [2]. A new algorithm is proposed for scheduling an intersection [3] based on VANET information such as velocity and direction. In [4] researchers also suggested a mechanism for controlling the intersection light, which was assisted by obtaining the remote vehicle information by the roadside unit (RSU) so that the waiting time can be calculated. Researchers in [5] used fuzzy logic to improve traffic light control through a simulator to improve time management so that this device has the intelligence to predict the right time. Researchers in [6] have developed a collaborative light control algorithm that adopts speed and location data sets from vehicles equipped with a Cooperative Adaptive Cruise Control (CACC) system that is combined with traditional fixed traffic sensors (traditional fixed traffic sensors) to predict traffic conditions in advance. Researchers

*1st Virtual International Conference on Sciences*
AIP Conf. Proc. 2400, 020009-1–020009-8; https://doi.org/10.1063/5.0112708
Published by AIP Publishing. 978-0-7354-4248-1/$30.00

in [7] provides a model for smart traffic light control using a collaborative game theoretical framework based on decision-making framework (A game theoretical based on decision-making operations) where each incoming link was considered as an individual player communicating with each other to generate the best game strategy and consideration of a situation. The light signal represents decisions made by these players, and they also presented a fixed control method called (Nash equilibrium) which is a decentralized control with a non-cooperative game structure. They concluded that their first cooperative method is better than the second non-cooperative method. In this research, a smart algorithm was implemented to schedule traffic lights based on the best green time for each stage, and to use the surplus green time to schedule other stages.

The rest of our research is organized as follows: In Section (2), algorithms and related research for adaptive traffic light are investigated. In Section (3), the isolated intersection scenario for case study is explained. In Section (4), STL scheduling algorithm and it's detail (i.e. how to calculate the best green time) is introduced. Proposed STL algorithm performance is evaluated in Section (5). Finally, this research is concluded in section (6) with some future works.

## RELATED WORK

Several solutions have been proposed to address traffic congestion. Researchers and transport engineers worked jointly to create appropriate traffic light systems. Systems that could achieve the goals of intelligent transport systems, as the traffic light control system needs to respond more quickly to traffic variables in the real time of the road network. Traffic lights are managed using different methods and techniques, including:

Intelligent algorithms such as genetic, augmented learning, fuzzy logic, and evolutionary algorithm. Researcher used the augmented learning in [8] by proposing a multi-agent Deep Q-Network (DQN) algorithm to determine the best phase of the light. Researchers in [9] designed a decentralized adaptive traffic light controller using an asynchronous n-step Q-Learning augmented learning algorithm that extracts information through an artificial neural network. Also, fuzzy logic was used in traffic light management. Researchers in [10] presented a comprehensive survey of intelligent transport systems and showed that the use of fuzzy logic provides better control performance at the isolated intersection or intersection of both directions.

Many other researchers [11] , [12] have discussed managing a traffic light depending on surveillance cameras and the use of image processing. This technique focuses on knowing the number of vehicles, the length of the queue and where the image was taken. Based on this information that is considered input, an algorithm will be expected to know the flow of vehicles and the duration of the traffic light cycle.

RFID and IoT technologies have been used to develop intelligent traffic control systems to collect and monitor traffic information in real time and to make the timing dynamic for the traffic light by sensing the traffic density such as the research conducted in [13] , [14].

In addition to a large number of studies, they used WSN wireless sensor networks that detect the presence of vehicles and communicate with traffic control units, including [15].

VANET information and an improved Virtual Traffic Light (O-VTL) algorithm was used in [16] to prioritize the intersection and allow more vehicles to cross the intersection without collision by taking into account different vehicle directions. Several researchers proposed an adaptive system to control the traffic light based on the VANET information. For instance, in [17] they depended on the speed of vehicles only. While in [18] they proposed an algorithm that depends on the position of the vehicles in relation to the intersection. In contrast, there are studies that rely on a combination of real-time speed and location information, of which researchers in [19] used this information to improve traffic light scheduling at the intersection to reduce delay.

From the above survey, a lot of researchers relied on raw data (mostly speed and location of vehicles) with an algorithm for an idealized intersection can be seen. Here, a study and analysis of real life intersection (in Ramadi city) with an adaptive scheduling algorithm under VANET scenario is considered.

## ISOLATED INTERSECTION

The goal of mobile vehicles is to cross the intersection safely with minimal delay. An intersection is controlled by a traffic light, which in turn controls the competing traffic flows at the intersection. Most of intersections are isolated (in other words, without taking into account the effect of adjacent intersections). For every conventional isolated intersection, traffic light timing is constant including cycle length, phases, interval divisions and displacement parameters are set according to statistical traffic characteristics.

Due to the nature of traffic surrounding an intersection in concern, there are states where traffic is congested (i.e. during peak time hours). Those responsible for managing the intersection did not consider it and find a solution to these congestions, and the lack of registered and approved data (such as number of vehicles in each direction, traffic intensity, and traffic flow difference during the day). In order to have the ability to change the signal timing with the changes detected in traffic conditions, traffic light control systems need to monitor the intersection traffic conditions in real time. This proposed to improve signal timing based on VANET scenario. This scenario fits with the nature of intersection through smart algorithm and controls the traffic light adaptively. An isolated intersection in Ramadi city (called cinema intersection) is considered as our case study. With medium density (since our case city is not a big city) road traffic had been simulated with SUMO simulation platform [20]. The simulated scenario created in SUMO is based on an intersection of a four-way road in Ramadi city that is divided between 6 streams (considering 2 main ones, each one contains two lanes, and the other minor ones contains one lane). The major axes have a higher priority than the secondary axes. taking into consideration not allowing more than one flow of treatment at the same time. Vehicles will arrive at different estimated times, and large vehicles are not permitted to pass through this intersection. In fact, currently the secondary flows have been closed for security reasons related to the city and the intersection has become only two major flows. This scenario covers an area of size 1000m x 500m, with vehicle speed 0-50 km/h. Based on the real-time traffic characteristics of the competing streams at the intersection, the time was set for the green light for 46 second, the yellow light for 5 second, and the red light as a safety stage for all stages for 4 second, so the total time duration for each cycle is 110 second. VANET scenario assumes that vehicles equipped with some form of communication device are able to communicate through Vehicle-to-Everything (V2X) technology (i.e. vehicle-to-vehicle V2V and vehicle-to-infrastructure V2I). Within this scenario an infrastructure unit is set in the middle of the intersection (i.e. RSU). It collects comprehensive information about the vehicles approaching the intersection. Such information transmitted by the vehicles (such as speed, location, direction, time ... etc.) is used to configure the traffic light settings. This configuration require real time information to be process and implement through an algorithm. Therefore, scheduling algorithm for adaptive traffic light is going to be described next section.

## SCHEDULING ALGORITHM

The proposed STL algorithm for traffic light scheduling is provided in this section. Vehicles can cross the intersection safely and efficiently if phases of each traffic signal cycle are dynamically adjusted. With vehicles arriving during each cycle, the scheduled time of the component phases can be set and adjusted adaptively. In any scheduling algorithm for adaptive traffic light, time must be schedule to allow all competing traffic flows to pass through an intersection fairly and safely. As consecutive traffic light cycles, sequence of stages is scheduled periodically. Given the scenario of the intersection under study, it is not allowed for simultaneous flows in different directions. In a typical intersection, any vehicle on a specific section of the road can cross the intersection in three different ways: straight, right turn, and left turn. As for the intersection under study, for security reasons the directions of each flow have been restricted. Therefore 6 different streams were configured and a specific number was assigned to each competing traffic flow at the intersection as shown in **FIGURE 1.**

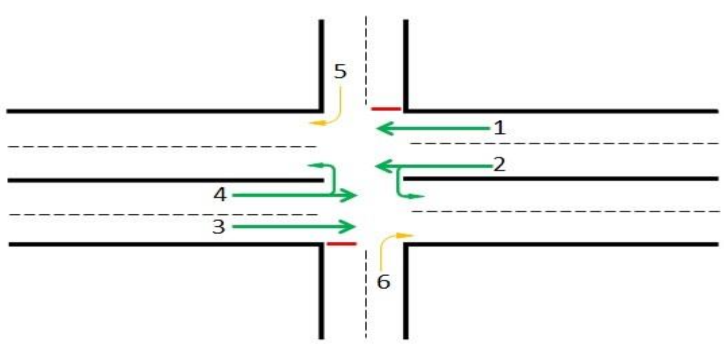


**FIGURE 1. Isolated Intersection case study**

The two flows (1 and 3) are compulsorily straight, because the turn to the right is blocked. The two flows (2 and4) have two directions, either straight or left turning. For the two streams (5 and 6) they are considered secondary and have a lower priority, so their light is always green. Hence turning right of vehicles, without interfering with other flows, are not considered in the scheduling algorithm. As a result, only two main road axes (i.e. flows (1 and 2) and flows (3 and 4)) can be scheduled in the algorithm.

In each traffic light cycle, a certain period of time is assigned to each stage that has been configured. This time varies between zero and *MaxGreen* for blank streams and high intensity streams respectively. Where, *MaxGreen* value represents maximum green time can be devoted to any stage. Hence, all competing traffic flows can ensure fair participation of the intersection. *MaxGreen,* in this paper, is a constant value equals 46 seconds (taken from real intersection setting). Depending on traffic density in the traffic flows for the specified stage, the BestGreen time is calculated for each stage and its value is constraint according to Equation 1.

$$Zero <= BestGreen <= MaxGreen \qquad (1)$$

## Best Green Time Calculation

In an intersection, for medium-intensity traffic flow, sometimes it remains with no vehicles that managed to cross early before the end of *MaxGreen* duration and enabling the next stage to begin. Hence, time is wasted in the remaining green time to reach the *MaxGreen* value. This is shown in **FIGURE 2.**(b). On the other hand, for high-intensity traffic flow, vehicles continue to cross the intersection during the entire *MaxGreen* time. This is shown in **FIGURE 2.**(a). Finally, low-intensity traffic flow, vehicles under coverage area is almost zero. Hence time is wasted to reach the *MaxGreen* value. This is shown in **FIGURE 2.**(c).

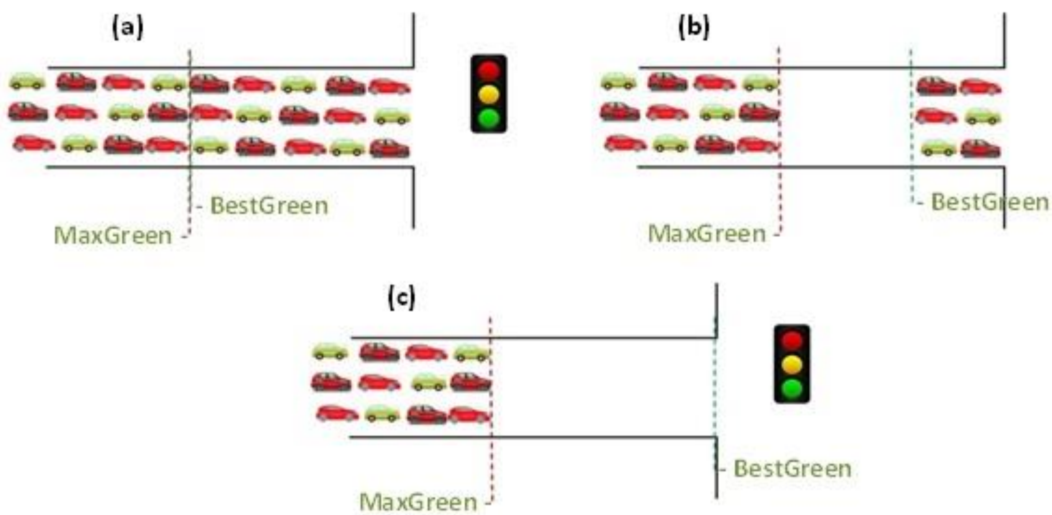


**FIGURE 2. Relationship between green time and.**
**(a). high vehicles density (b). medium vehicles density. (c). low vehicles density**

In this paper we focus on calculating the best green time (*BestGreen*) in order to reduce wasted time. First, *BestGreen* time is checked separately based on the traffic flow for each direction. Depending on the traffic flow in each edge, vehicles that can pass through intersection during *MaxGreen* time can be identified using the mean speed of traffic. *BestGreen* is the time needed to pass the intersection for the *LastVehicle* under coverage area. It can be determined based on the latest vehicle information (i.e. traffic speed, vehicle distance from the intersection and direction). For each traffic direction this is done according to Equation 2.

$$BestGreen = LastVehicleDistance / TrafficSpeed \qquad (2)$$

Where *LastVehicleDistance* is the farthest distance from the intersection to the last vehicle within the coverage area. *TrafficSpeed* is the traffic speed of a traffic flow in one direction.

## Proposed STL Algorithm

An algorithm in [1] is adopted and modified to be implemented in Ramadi case study. Setting the *MaxGreen* time value is really the first step of our algorithm. After that, for each direction, the *DistanceGreenArea* and the farthest point at which the driving vehicles will pass through the intersection in *MaxGreen* duration is calculated depending on the traffic speed (i.e. *TrafficSpeed*), as given in Equation 3.

$$DistanceGreenArea = MaxGreen * TrafficSpeed \qquad (3)$$

When implementing such scenario for the intersection, a benefit from this equation to calculate the green time distance area is not possible. Hence, this region was imposed by fixed numbers according to the nature of the flows surrounding the intersection and its total distance and distance from the intersection.

After calculating distance, the phases of each cycle are determined and the best green time for each phase is calculated. Details of the scheduling algorithm are systematically illustrated in the proposed STL algorithm below.

***Proposed STL Algorithm:***

Set ***MaxGreen*** value
Read ***TrafficSpeed*** for each direction
Compute ***DistanceGreenArea*** for each direction
Read all vehicle in the ***DistanceGreenArea***
Compute ***LastVehicleDistance*** in each direction inside the ***MaxGreen*** area
Compute ***BestGreen***= ***LastVehicleDistance / TrafficSpeed*** for each direction
    if ***BestGreen*** < ***MaxGreen***
    Schedule current phase time by ***BestGreen***
    else
    Schedule current phase time by ***MaxGreen***
    End

## SIMULATION RESULTS

In this section, the performance of the implemented algorithm is evaluated. SUMO simulation program is used to generate the intersection scenario and create the road and vehicle network. Then, Matlab program is written through the tool (TraCI) to implement the algorithm. **TABLE 1.** shows the variables that were identified in the scenario.

**TABLE 1. SIMULATION PRAMETERS**

| Simulator | SUMO |
|---|---|
| Duration time | 1200 seconds |
| Study area | 1000 * 500 $m^2$ |
| Number of traffic lights | 1 |
| Number of vehicles | 0-1000 |
| Maximum speed | 50 km/h |

In this experience, the total delay time of all vehicles in the traditional fixed algorithm (which is currently used in reality) is compared with the proposed STL algorithm. The results show a significant improvement in the delay time when the algorithm is implemented. **TABLE 2**. shows the total delay time.

**TABLE 2. TOTAL DELAY TIME**

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

At the same time, a comparison between traditional and proposed algorithm delay time at each time step for each direction shows the effective adaptive behavior behind the proposal. This is clearly shown in **FIGURE 3**.

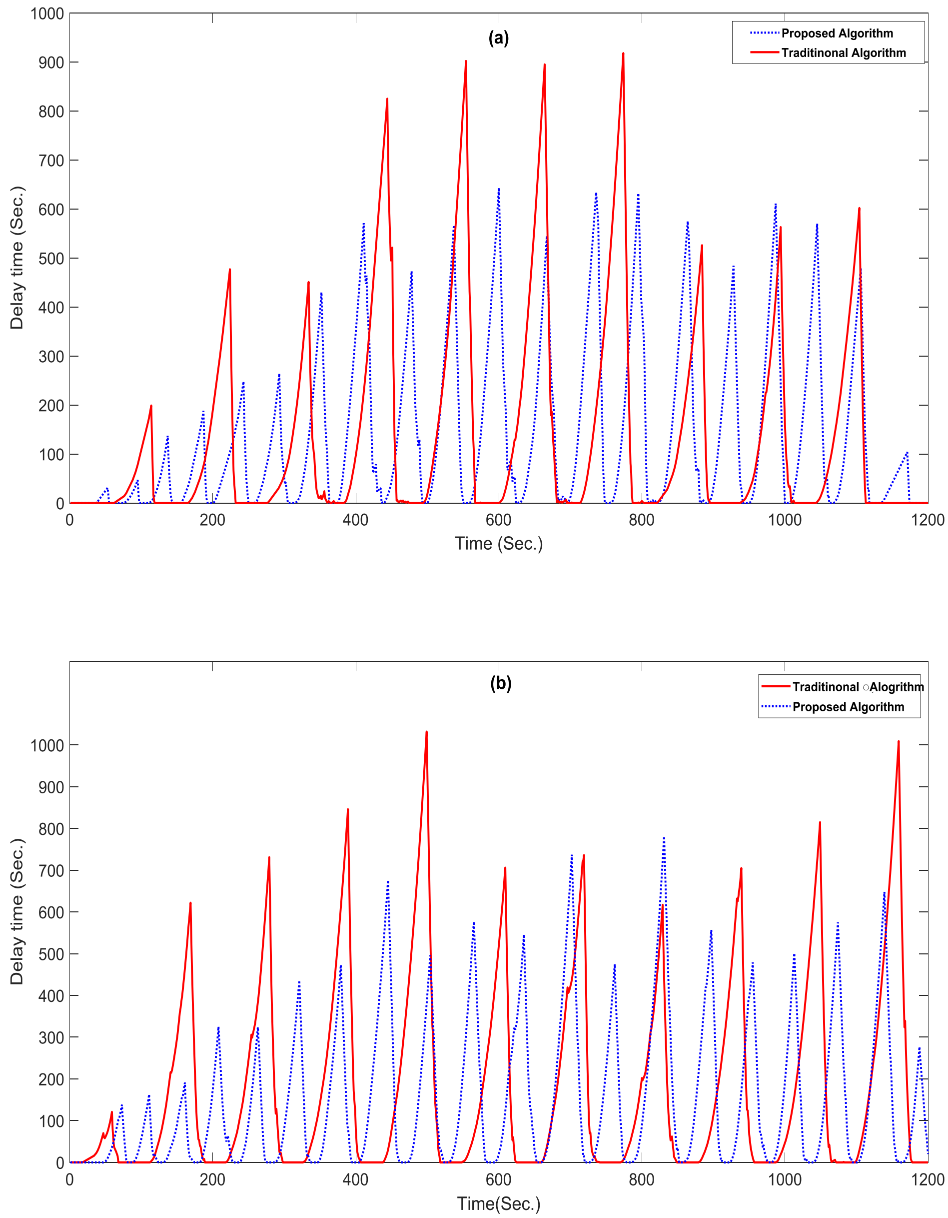


**FIGURE 3**. **Traditional and proposed STL algorithm delay time at each time step for (a) east to west direction and (b) west to east direction.**

Figure 4 shows the time setting mechanism for traditional (i.e. **FIGURE 4**.(a)) and proposed STL algorithm (i.e. **FIGURE** 4.(b)) with respect to simulation period. It is clear that for the first 100 second of the proposed STL algorithm, low intensity required low best green time. As a result, an improvement is required for future work in this field.

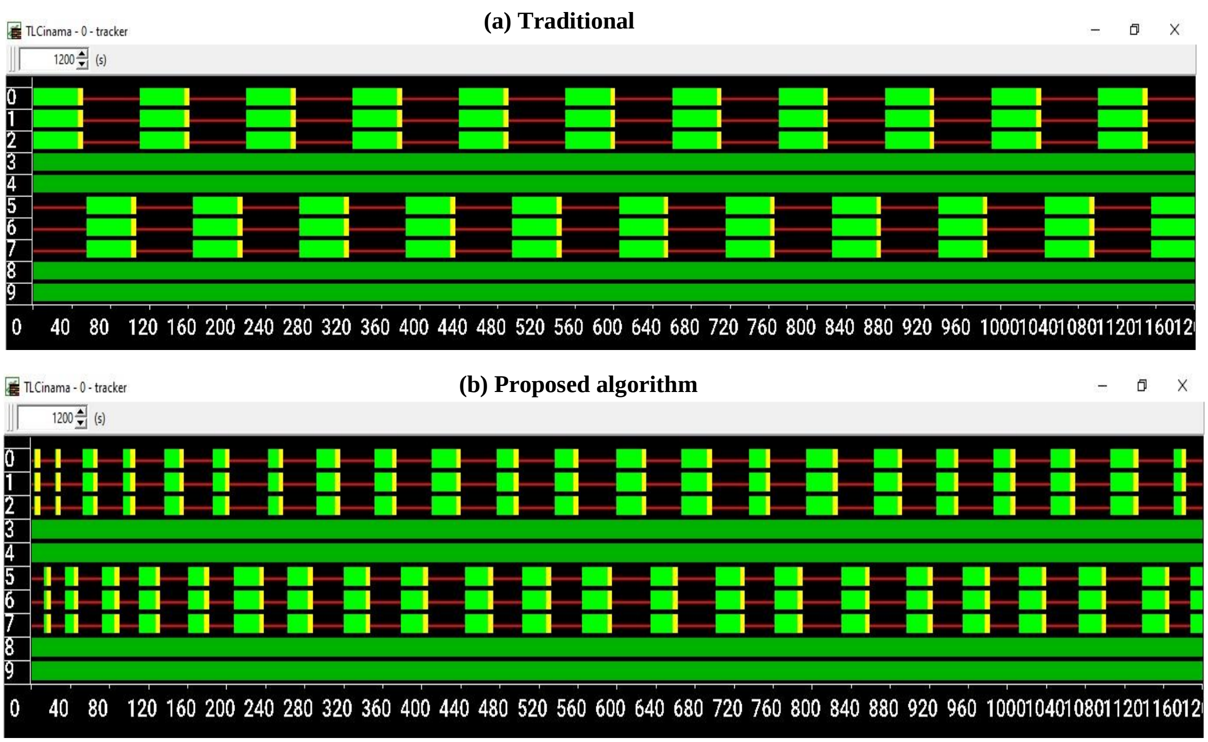


**FIGURE 4. Traffic light setting during simulation period for (a) traditional and (b) proposed algorithm**

## CONCLUSION AND FUTURE WORK

The proposed STL algorithm is simulated and evaluated for an intersection in Ramadi city as a case study. In order to collect real-time traffic properties for each direction, this algorithm uses dedicated VANET architecture. Phases of traffic light cycle are adjusted according to real-time data. A coverage area is defined to determine the maximum allowed *BESTGREEN* time for each stage so that it should not exceed *MAXGREEN* time. The *BESTGREEN* time calculation depends on the farthest vehicle for each operation within the ready zone for each direction. From the experimental results, we conclude that the performance of the algorithm achieved better performance in terms of delay time, as it reduced the delay time.

For 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 assumed to be connected to each other in this scenario. This is not always impossible and leads us to study the algorithm if one of the vehicle was found without VANET technology. Also study the probability and impact of a vehicle failure at the intersection is required for future work.

# REFRENCES


1. M. Bani Younes and A. Boukerche, "An Intelligent Traffic Light scheduling algorithm through VANETs," *Proc. - Conf. Local Comput. Networks, LCN*, vol. 2014-Novem, no. November, pp. 637–642, 2014, doi: 10.1109/LCNW.2014.6927714.
2. M. B. Younes and A. Boukerche, "An efficient dynamic traffic light scheduling algorithm considering emergency vehicles for intelligent transportation systems," *Wirel. Networks*, vol. 24, no. 7, pp. 2451–2463, 2018, doi: 10.1007/s11276-017-1482-5.
3. D. Shao, J. Wu, and C. Fu, "V2I based intersection scheduling algorithm," *Int. J. Smart Home*, vol. 10, no. 4, pp. 33–46, 2016, doi: 10.14257/ijsh.2016.10.4.04.

4 Z. Cai, Z. Deng, J. Li, J. Zhang, and M. Liang, "An intersection signal control mechanism assisted by vehicular Ad Hoc networks," *Electron.*, vol. 8, no. 12, 2019, doi: 10.3390/electronics8121402.

5 D. Hartanti, R. N. Aziza, and P. C. Siswipraptini, "Optimization of smart traffic lights to prevent traffic congestion using fuzzy logic," *Telkomnika (Telecommunication Comput. Electron. Control.*, vol. 17, no. 1, pp. 320–327, 2019, doi: 10.12928/TELKOMNIKA.v17i1.10129.

6. H. Liu, X. Y. Lu, and S. E. Shladover, "Traffic signal control by leveraging Cooperative Adaptive Cruise Control (CACC) vehicle platooning capabilities," *Transp. Res. Part C Emerg. Technol.*, vol. 104, no. January, pp. 390–407, 2019, doi: 10.1016/j.trc.2019.05.027.
7. J. Guo and I. Harmati, "Optimization of traffic signal control based on game theoretical framework," *2019 24th Int. Conf. Methods Model. Autom. Robot. MMAR 2019*, pp. 354–359, 2019, doi: 10.1109/MMAR.2019.8864629.
8. D. Li, J. Wu, M. Xu, Z. Wang, and K. Hu, "Adaptive Traffic Signal Control Model on Intersections Based on Deep Reinforcement Learning," *J. Adv. Transp.*, vol. 2020, 2020, doi: 10.1155/2020/6505893.
9. W. Genders and S. Razavi, "Asynchronous n-step Q-learning adaptive traffic signal control," *J. Intell. Transp. Syst. Technol. Planning, Oper.*, vol. 23, no. 4, pp. 319–331, 2019, doi: 10.1080/15472450.2018.1491003.
10. S. H. An, B. H. Lee, and D. R. Shin, "A survey of intelligent transportation systems," *Proc. - 3rd Int. Conf. Comput. Intell. Commun. Syst. Networks, CICSyN 2011*, pp. 332–337, 2011, doi: 10.1109/CICSyN.2011.76.
11. S. Sarath and L. R. Deepthi, "Priority Based Real Time Smart Traffic Control System Using Dynamic Background," *Proc. 2018 IEEE Int. Conf. Commun. Signal Process. ICCSP 2018*, pp. 620–622, 2018, doi: 10.1109/ICCSP.2018.8524501.
12. B. M. Gebregeorgis and D. K. Sarmah, "Smart Traffic Light Controlling and Violation Detection System Using Digital Image Processing," *Interantional Jopurnal Eng. Res. Online*, vol. 4, no. 2, 2016.
13. A. Dubey and M. Lakhani, "Internet of Things based Adaptive Traffic Management System as a part of Intelligent Transportation System (ITS)" *IEEE Access Int. Conf. Soft Comput. its Eng. Appl. (icSoftComp)2017 Int. Conf. Soft Comput. its Eng. Appl.*, 2017.
14. A. Atta, S. Abbas, M. A. Khan, G. Ahmed, and U. Farooq, "An adaptive approach: Smart traffic congestion control system," *J. King Saud Univ. - Comput. Inf. Sci.*, 2018, doi: 10.1016/j.jksuci.2018.10.011.
15. A. K. Khlaif, "Traffic Flow Management System based on Ad-hoc Wireless Sensor Networks," 2015. https://www.academia.edu/11815762.
16. M. W. Tin, Y. Than and O. Z. May, ". Implementation of an Optimized Virtual Traffic Light Algorithm in SUMO," *Int. J. Adv. Sci. Res. Eng.*, vol. 05, no. 11, pp. 151–156, 2019, doi: 10.31695/ijasre.2019.33559.
17. J. Li, Y. Zhang, and Y. Chen, "A Self-Adaptive Traffic Light Control System Based on Speed of Vehicles," *Proc. - 2016 IEEE Int. Conf. Softw. Qual. Reliab. Secur. QRS-C 2016*, pp. 382–388, 2016, doi: 10.1109/QRS-C.2016.58.
18. S. Kwatirayo, J. Almhana, and Z. Liu, "Adaptive traffic light control using VANET: A case study," *2013 9th Int. Wirel. Commun. Mob. Comput. Conf. IWCMC 2013*, pp. 752–757, 2013, doi: 10.1109/IWCMC.2013.6583651.
19. M. K. Avzekar and A. Moon, "Adaptive Traffic Signal Control with VANET," vol. 2, no. 3, pp. 30–32, 2014.
20. Simulation of Urban Mobility .Online available https://sumo.dlr.de.