VANET-Enabled Signal Preemption Strategy for Emergency Vehicle with Minimum Impact on the Traffic

Hamed Noori
University of Waterloo
hamed.noori@uwaterloo.ca

Liping Fu
University of Waterloo
lfu@uwaterloo.ca

Sajad Shiravi
University of Waterloo
sshiravi@uwaterloo.ca

ABSTRACT
Vehicle to Vehicle (V2V) and Vehicle to Infrastructure (V2I) communication promise major benefits in both mobility and safety applications. Communication between cars often referred to Vehicular Ad-Hoc Networks (VANET) has many advantages such as reducing cars accidents, minimizing the traffic jam, reducing fuel consumption and emissions, etc. One of the VANET applications is connected traffic signal preemption for emergency vehicles enabling the rapid movement of emergency vehicles in urban arterials. This paper describes an innovative signal control strategy proposed to decrease Emergency Vehicle Response Time (EVRT) by employing V2I communication and IEEE 802.11p beaconing concept as well as the predicted queue length, traffic signals are adjusted adaptively to provide an early green at the right time so that the queue at the downstream intersections can be served just in time for the arrival of an emergency vehicle. The strategy is implemented in the microscopic traffic simulator, SUMO and evaluated using the City of Toronto network. In addition, a Python-based program is developed to link the control strategy to SUMO for simulating the traffic with intelligent traffic signals. The simulation results show a significant reduction in EVRT using the proposed method.

1. INTRODUCTION

Emergency Vehicle Response Time (EVRT) is a common measure for benchmarking the efficacy of an emergency service system and there is an important relationship between EVRT and mortality rate*(1, 2)*. For example, statistics has shown that only 10% of death happens just a few minutes after accidents while 75% of the deaths caused by accidents occur within the first hour after accidents (thus commonly called golden hour) *(3)*. It is clear that reducing EVRT can decrease mortality rate especially within the period of the golden hour. In urban areas, one of the main factors affecting the response time of emergency vehicles is the delay caused by traffic congestion and traffic signal controls at intersections.

To reduce the delay caused by traffic congestions and signal controls, many different approaches have been proposed, such as traffic signal preemption, network flow management, and road capacity expansion. Latest advances in Intelligent Transportation System (ITS), especially, Vehicular Ad-Hoc Networks (VANETs) and Connected Vehicle (CV) technology, have presented another opportunity for improving emergency response services. Based on Vehicle to Infrastructure (V2I) and Vehicle to Vehicle (V2V) communication, connected vehicle technologies enable vehicles to communicate with each other and with infrastructure, effortlessly for improved safety and efficiency. One of the CV applications is communication between traffic signals and cars that can create an automatic and dynamic signal control to minimize congestion. This paper focuses on the communication between traffic signals and vehicles, and uses the CV technology to decrease response time of emergency vehicles. To achieve this goal, this paper proposed a traffic signal control method to efficiently clear the paths for emergency vehicles. The proposed control method is implemented in the microscopic traffic simulator, SUMO*(4)* and evaluated through a case study using the city of Toronto network.

2. BACKGROUND AND RELATED WORK

During the last few years, many studies have been conducted on the potential applications of Connected Vehicles (CVs) technology for improving road safety and mobility. However, limited studies have explored on the application of CVs for emergency vehicle preemption. This section provides a brief background on the application of the wireless communication in ITS and reviews related work on CV related emergency vehicle preemption strategies.

Wireless Communication for ITS:

Wireless communications between vehicles have been rapidly developing to make ITS applications available in real world. During the last decade, standard administrations, automobile manufacturers, and researchers in academia have been working together to define new standards for vehicular applications and to develop wireless technology and communication systems for vehicles. Dedicated Short Range Communication (DSRC) is a wireless protocols which is proposed specifically for application in the automotive area and for communication between vehicles. The DSRC protocol, include the IEEE 802.11p and IEEE 1609.x family, for Wireless Access in Vehicular Environments (WAVE). The DSRC foundation is provided by the IEEE 802.11p, and higher communication layers are based on IEEE 1609. DSRC protocol offers a high rate of data communications between two vehicles (V2V) or between a vehicle and a RSU (I2V or V2I).

IEEE 802.11p standards rely on broadcasting information as periodic messages (called Beacons). It means, all vehicles and RSUs broadcast several beacons per second, and these beacons could be received by surrounding RSUs or vehicles. Each beacon contain information about the car (or RSUs), such as coordination, speed, acceleration, position, etc. The broadcasting of the information as a periodic message is called beaconing. This feature allows cars to discover neighboring vehicles and RSUs in real-time and also obtain important information provided by other cars and RSUs. This paper proposed a method based on beaconing concept to improve EVRT.

Recently, numerous studies have been done to evaluate the application of V2X communication in ITS and several scenarios have been proposed. For example, we compared the probability of beacon delivery in large-scale urban areas in *(5)* and *(6)*. Also we proposed a novel method for traffic light control system using V2X communication in *(7)* which focused on platooning concept and V2X communication. In addition, we developed traffic monitoring method for dynamic route planning using IEEE 802.11p in *(8)*. Recently, Noah *et al.(9),* proposed a novel method for traffic light control using connected vehicles technology. In the *(9),* the authors proposed PMSA which is a novel rolling horizon traffic light control system, that can use individual car information such as heading, speed, and location to predict an objective function over a 15-s future horizon. Moreover, Zhou et al *(10)*, developed a decentralized control method to control platoons of cars safely, even in a very high latency communications environment. Authors in *(10)*, combined optimization algorithm with a statistical prediction model to find the best optimal control action. Next section provides a brief study on the emergency vehicle and its performance.

Emergency Vehicles

The term of Emergency Vehicle is defined for any type of vehicles that are authorized and designated to respond to an emergency, such as ambulance, fire truck or a police vehicle. The Emergency Vehicle Response Time (EVRT) is generally defined as follow: the time from when an incident is recognized until the emergency vehicle arrives at the scene. Most cities set a service standard by specifying a maximum EVRT. For example, in the city of Montreal, the response time for 90% of the ambulance trips must be less than 7 minutes *(11)*. Also in many US cities, it is designated that 95% of the emergency request must be served within ten minutes while, in rural areas, the EVRT should be less than 30 minutes *(12)*.

To meet the EVRT standard, several factor must be considered, such as, number of EV stations, locations, and population around them, the coverage areas for each station, number of EV for the stations, etc. In addition to these factors, some studies have been done to decrease the EVRT with different traffic management scenarios. Recently, one study *(13)* proposed a path clearance method for EVs using V2V communication. In this study, a new strategy was proposed to enable EVs to send a message to alert the cars and provide them specific instruction to maneuvering which could allow the EV to pass the signalized intersections faster. In *(14)*, a new method using RFID is proposed to implement a traffic lights control system with priority for emergency vehicles; The mentioned method deals with multi-lane and multi-vehicle area and provides more efficient time management schemes using a dynamic time schedule. However, *(14)* did not simulate their approach to evaluate the impact of the method in realistic scenarios. Also *(15)* employed wireless sensor network (WSN) to implement intelligent signal control to prioritized EVs; *(15)* developed a dynamic signal control based on WSN that can build a communication between two neighboring traffic signal to provide more clear path for emergency vehicles. In *(16)*, we also proposed a method using communication between emergency vehicle and traffic light to decrease the EVRT; The basic idea in *(16)*, is to change the traffic signal status to green for emergency vehicle (and red to others) based on the distance between the EV and traffic signal. We evaluate the proposed method with different communications schemes (DSRC, Cellular, etc.) and different distances, using large scale simulation with real traffic data and real map. The simulation in *(16)* done as follow: first, we import a real traffic data and real map to traffic simulator. Then, an emergency vehicle with origin and destination, is added to the simulation. During the simulation, the traffic signals in the EV's route are considered and if the distance between the EV and traffic signal become less than a pre-defined values (e.g. 50, 300, 1000 meters), the signal status changed to green for EV and red for others. However, in our proposed method in *(16)*, we just consider the distance between the traffic signal and the emergency vehicle and we did not consider the traffic volume in the link (and number of vehicle stopped on the traffic signal). In order to overcome this disadvantage we developed a novel method which was to also consider the number of the vehicles stopped at traffic signal (those located at EV's route) in providing early green to serve the queue before the emergency vehicle arrives while also minimizing the amount of lost green time. Also, there are very limited large scale simulation scenarios for emergency vehicles and this paper attempts to evaluate the proposed preemption strategy in a large scale realistic simulation environment using a developed program in Python (as a controller) and traffic simulator, SUMO.

3. SIMULATION ENVIRONMENT

Proposed Method

The basic idea of the proposed method is simple: it considers all traffic signals along the EV route, and finds the number of vehicles stopped at each traffic signal, and based on these number, changes the signal status to provide early green before the EV reaches the signal. In this way, the EV route is cleared for the EV while also minimizing the amount of lost green time. FIGURE 1 shows a simulated sample of an EV at an intersection.

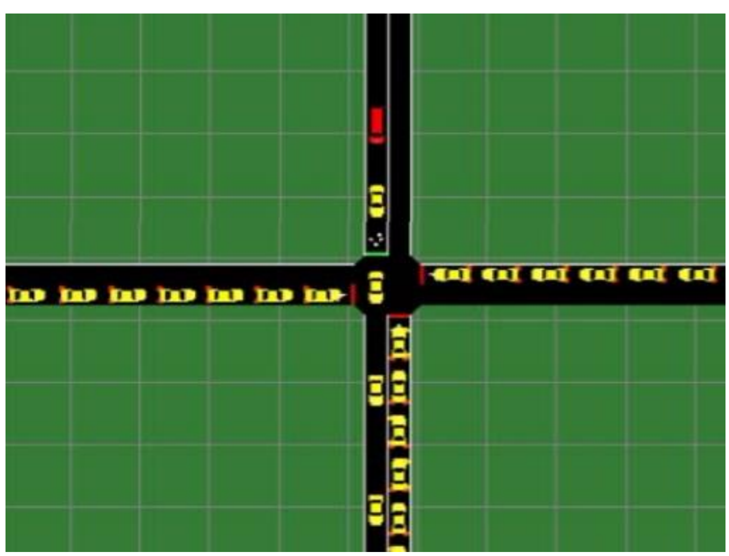

FIGURE 1. An emergency vehicle at signalized intersection.

In the proposed method, we assume that all vehicles are broadcasting beacons containing information on their speeds and locations using DSRC (IEEE 802.11p standard). Also all traffic signals are assumed to be able to communicate with vehicles using beaconing.

The proposed control is simulated with the following steps:

1) At first, when an emergency situation occurs and EV is assigned to respond to the incident, the shortest path between the EV's location and the incident location is calculated and all the traffic signals in the route are identified. Then, the EV starts traveling in the mentioned path.
2) In the next step, while traversing the route, the distance between the EV and the traffic signals are calculated continuously, and if the distance become less than a pre-defined threshold (e.g. 2 km), the EV will send a request to the traffic signal about its impending arrival, along with an approximate estimate of the arrival time. The pre-defined distance can vary depending on the congestion levels in the cities and the traveling distance. The communication between the EV and traffic signal in this step, can be easily done using DSRC communication, or even with a cellular communication to connect to a centralized signal control and inform the signal from the control center. If the distance is larger than DSRC communication range, multi-hop communication scenarios can be used. In the wireless communication network, a multi-hop communication is defined, when a messages between two nodes, are carried out through several intermediate nodes. In DSRC, multi-hop is defined when a vehicle (or RSU) re-broadcast a received message from neighboring vehicles or RSUs. The multi-hop used for transferring information when the distance between vehicles or RSUs are larger than communication range, and also for safety purposes, when an important event occurs (such an accident) that all vehicles must be aware of *(17)(18)(19)*.
3) The next step is about the traffic signals. When a traffic signal receives a request from a coming EV, following scenarios could happen:
    a. The Signal status is STOP (light is red) for the EV's route: In this situation, the traffic signal will calculate the number of vehicles that are stopped at the signal. This calculation can be easily done using the V2I communication and beaconing concept. All the vehicles broadcast their locations and speeds, and the traffic signals can calculate the exact number of the vehicles based on the received beacons. After this step, the traffic signal will calculate the required green time to clear the vehicles' queue (discharging time) from the EV's path, (sum of Start-up Lost Time and Saturation Headway for all the vehicles at each lane). Then, the traffic signal considers the estimated discharging time, and compares it with the EV's approximate arrival time. Based on this comparison, the traffic signal will decide when to change the status to green for EV. This mean that, the traffic signal will try to provide a green status for the EV's route so that when the EV reaches the traffic signal, there is no queue at the approach of the intersection to be used by the EV. As an example, if the discharging time is 100 seconds, and the EV's arrival time is

2 minutes, the traffic signal will change the traffic status to green for the EV after 20 seconds, and will continue the green phase until the emergency vehicle passes the traffic signal.

    b. Signal status is Go (light is green) for the EV route: In this situation, the signal will decide whether to extend the green or change to red based on the remaining green duration and the expected arrival time of the EV. The proposed method assumes that, all vehicles are broadcasting beacons and traffic signals have information about the traffic volumes in the roads. With this information, the discharging time can be estimated on the basis of the previous cycles and the traffic situation at the emergency incident time.

4) After the emergency vehicle passes the traffic signal (with a pre-defined value, e.g. 20 meters), the traffic signal will return back to its original states. Note that as the EV broadcasts beacons too, the traffic signal can easily find out whether or not the EV has already passed the signal.

This simple approach of using emerging wireless communication technologies and V2X communication can be implemented in a real world system, which could save numerous lives. Next sections provide a detailed explanation of the implemented simulation environment and the developed program and algorithm for the proposed strategy.

SUMO Simulator

This paper chooses the well-known microscopic traffic simulator, SUMO (Simulation of Urban MObility), to evaluate the proposed EV control strategy. SUMO simulator includes a Traffic Control Interface - TraCI that allows integration with other software and control of the simulation over TCP-based client/server architecture. For evaluating the proposed system, a program in Python is developed that connects to SUMO as a controller using TraCI and controls the entire simulation. The developed program is able to simulate the traffic in a city with intelligent traffic signals and change the signals status according to different traffic situations. In addition, SUMO requires two types of inputs, namely, traffic demand and street networks.

As one of the main contributions of this paper, the city of Toronto is selected as an example for the large scale realistic simulation experiment. A total vehicle trips of 150,000 are added to the simulator as demand, each with a minimum of 5 km trip length to simulate the rush hour traffic situation. The next section provides information about the network.

For the street network, this paper used the real map of Toronto from OpenStreetMap (OSM)*(20)* and imported into the SUMO in following steps:

1) Due to download size restriction in original OSM website, the map of Ontario is downloaded from Geofabrik's website*(21)*, (OSM Data Extraction), and using a JAVA-based tool, called OSMOSIS, the map of Toronto is extracted. The extracted OSM files provide very detailed and realistic information covering an area of approximately 400 km^2 around the city of Toronto.
2) In the next step, the map is imported to the another JAVA-based application, JOSM, (a powerful OSM file editor), and the required changes are made, including fixing some of

the disconnected streets, adjusting traffic signals, editing some speed limits, etc. As an example, FIGURE.2 shows the map of Toronto in JOSM - an area around Queen's Park in downtown Toronto.

3) Finally, the edited map is converted to the SUMO street network using NETCONVERTER tools, which is available from the SUMO package. FIGURE.3 shows the imported map in the SUMO environment.

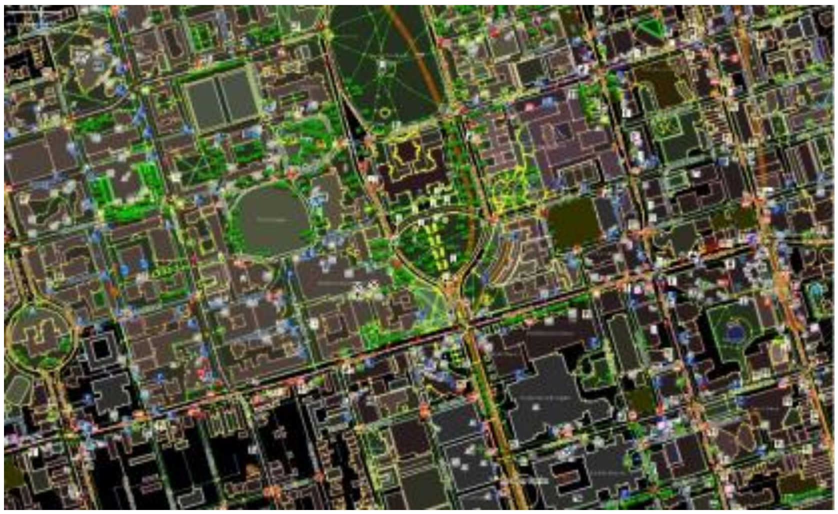

FIGURE.2. City of Toronto's OSM map, edited in JOSM.

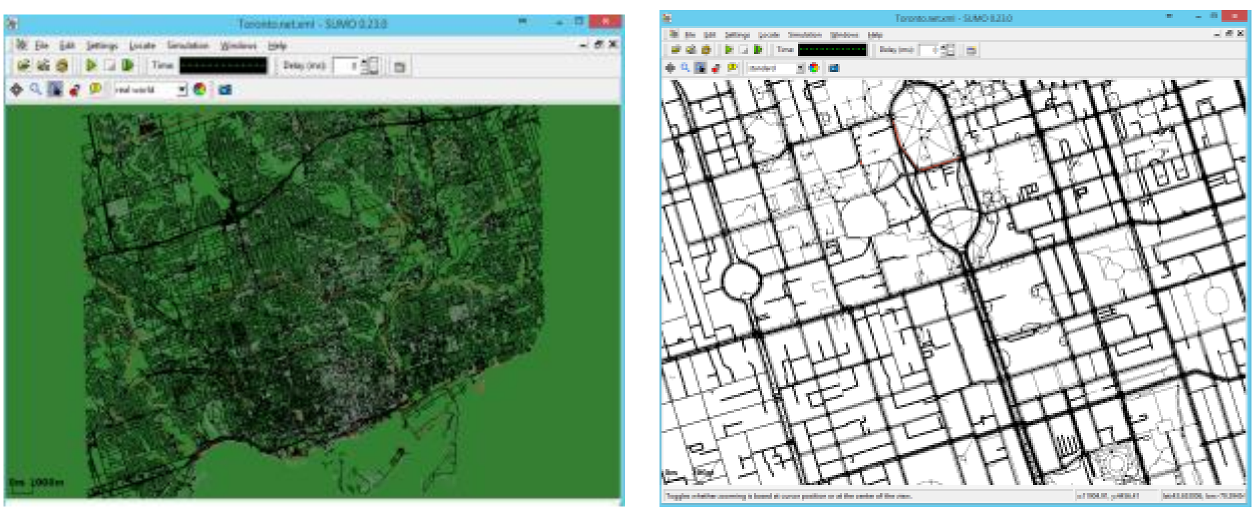

FIGURE.3. Map of Toronto in SUMO environment; Left figure: 400 km2 area; Right figure: area around Queen's Park in downtown (zoom).

Traffic Signal Controller for Emergency Vehicles

As mentioned before, a Python-based Controller is developed in this research to simulate the proposed method. This section provides detailed information about the controller and the used algorithm. At startup, the controller requests the map data, traffic data, and also information of the emergency vehicle (name, origin and destination). Then, the controller assigns the shortest path from the origin to destination for the EV and adds an emergency vehicle (which has higher priority than other cars) to the traffic data. Before starting the simulation, the controller finds all the traffic signal located on the EV's route and adds them to a list with their detailed information such as: location, controlled streets, phases, cycles, etc. Then, the simulation is started using the imported map data, traffic demand, and the emergency vehicle.

At the each simulation step, the controller calculates the distance between the EV and the traffic signals in the list. If the distance become less than a pre-defined specified value ($EV_{D,D}$, Desired Distance), the controller changes the signal to the emergency mode and at each simulation step, calculates the approximate remaining time of reaching the EV to the signal ($T_{EV,R}$), and also the current status of the signal for EV's route. The following processes are then executed:

1) **The light is Red**: Controller calculates the number of stopped vehicles (the speed being less than 0.1 m/s) at the EV's route ($N_{S,r}$). Then, the controller calculates the total required green time to clear all vehicles in the route (Queue Discharging time) by following equation (1):

$$T_{G,QD} = N_{S,r} \times h + \sum_{1}^{n} t_{s,l} \tag{1}$$

where the $T_{G,QD}$ is the total required green time to clear the path, h the "Saturation Headway", $t_{s,l}$ the start-up lost time for the first n vehicles at the traffic signal which have headways larger than h. The parameters $(h, n, t_{s,l})$ are pre-defined in the controller. The controller assigns the last step $T_{G,QD}$ to "the current required queue discharging time for the signal". Then, as soon as the following condition (2) is met, the controller changes the signal status to green, which remains green until the emergency vehicle passes the signal with the distance of 20 meters; otherwise, it will stay in the emergency mode (with the previous cycles and phases), and calculate the $T_{G,QD}$ and $T_{EV,R}$ at the next simulation step:

$$T_{EV,R} \geq T_{G,QD} \tag{2}$$

2) **The light is Green:** In this situation, the controller tries to calculate the approximate flow of the vehicles and the possible queue length (and related $T_{G,QD}$ for the possible queue), which can happen if the light changes to red. The controller counts the number of vehicles that passed the signal in the last 10 seconds (N_{10s}), Based on following equation (3), the controller finds an estimated number of vehicles that will stop at the signal at upcoming red phase of the signal ($T_{n,r}$: The signal's next red phase in seconds):

$$N_{S,r} = \frac{N_{10s} \times T_{n,r}}{10} \tag{3}$$

Based on (3) and (1), the controller calculate the current $T_{G,QD}$ for the signal; then, if the following condition (4) is met, the controller keeps the signal status in green phase until the emergency vehicle passes the signal with a distance of 20 meters; otherwise, the signal will stay in emergency mode (with the previous cycles and phases) and calculate the $T_{G,QD}$ and $T_{EV,R}$ at the next simulation step.

$$T_{EV,R} \geq T_{G,QD} + t_{r,g} \quad (2)$$

where the $t_{r,g}$ is the remaining green time of the current green phase.

FIGURE.4 summarizes the algorithm for the controller (developed program in python):

Algorithm 1 Controller

$MAP \leftarrow$ Get Information about the streets network
$Traffic \leftarrow$ Get Traffic Demand Data
$[O, D] \leftarrow$ Get Emergency Vehicle's Origin and Destination
$EV_{path} \leftarrow$ Calculate Shortest path from Origin to Destination [O,D]
$TS_{EV}[i] \leftarrow$ Calculate List of all traffic signals in EV's route
procedure START SUMO SIMULATION()
  while *Simulation* **do**
    $EV_{C,D}$ Calculate the current Distance between EV and $TS_{EV}[i]$
    if $EV_{C,D} \leq EV_{D,D}$ **then** ▷ Pre-defined value $EV_{D,D}$
      $T_{EV,R} \leftarrow$ Calculate required time for EV to reach $TS_{EV}[i]$
      Change $TS_{EV}[i]$ to Emergency Mode, Check the Light Status
      if Light is Red **then**
        $N_{S,r} \leftarrow$ No. of stopped vehicles at traffic signal $TS_{EV}[i]$
        $T_{G,QD} = N_{S,r} \times h + \sum_1^n t_{s,l}$
        if $T_{EV,R} \geq T_{G,QD}$ **then**
          Stay Green till $EV_{C,D} \leq -20$
        end if
      else
        $N_{10s} \leftarrow$ No. of passed Vehicles in the last 10 seconds
        $N_{S,r} = \frac{N_{10s} \times T_{n,r}}{10}$
        $T_{G,QD} = N_{S,r} \times h + \sum_1^n t_{s,l}$
        if $T_{EV,R} \geq T_{G,QD} + t_{r,g}$ **then**
          Stay Green till $EV_{C,D} \leq -20$
        end if
      end if
    end if
  end while
end procedure

FIGURE.4. Python-based signal controller algorithm

4. LARGE SCALE TRAFFIC SIMULATION SCENARIOS AND RESULTS

This section provides information related to final simulation, aiming at evaluating and investigating the proposed controller described previously.

Simulation Scenarios

To evaluate the impact of the proposed method on the emergency vehicle response time (EVRT), the map of Toronto was divided to 20 zones of varying traffic densities based on the traffic demand described previously. Subsequently, 10 emergency vehicles were added at each zone, with an approximately 5 km traveling distance. In order to observe the impact of the changing traffic signal status to green for EV using the proposed method on EVRT, the following large scale simulation scenarios are defined:

1) First, 200 emergency vehicles travel in the simulated city without any traffic signal and any other vehicles (Ideal EVRT). Their traveling times are obtained.
2) Next simulation is performed which involves the abovementioned 150,000 vehicles (background traffic) plus 200 EVs, and with normal traffic signal control system (fixed signal timing). The traveling times of 200 EVs are obtained.
3) In the next simulation, besides the 150,000 vehicle and 200 EVs, the developed program is employed and the status of the traffic signals located in the EVs' route are changed based on the proposed method (with following parameters: $h = 3, n = 6$, $EV_{D,D} = 2.5\ km$, $t_{s,l} = 5$). It means that, the signals tries to provide a clear path for EVs, while providing green light for EVs' route and red light for others. The traveling times of these EVs are obtained in this simulation.
4) The final simulation aims to compare the proposed method with traditionally used traffic signal pre-emption method, i.e., the traffic signals change when the emergency vehicle is at a pre-specified distance from the traffic signal. This method is simulated as follows: the route of EV is considered and if the distance between the EV and signal is less than 1 km, the signal automatically changes to green for EV to pass through and provides a red light for the other approaches. When the EV passes the signal with the distance of 20 meters, the signal returns to its original state. The emergency vehicles traveling times are also obtained in this simulation.

Simulation Results

The simulations with the aforementioned scenarios are run in SUMO and the all the required information are obtained. For each zone, average traveling time of the 10 emergency vehicles (EVRT) are calculated. Then, the average EVRT for all 20 different zones are ordered by traffic intensity from low to high and illustrated in the Figure.5. Each point in this figure presents the average traveling time (EVRT) for 10 EVs from the same zone. The results illustrate that, the proposed method has noticeable impact on the EVRT and it is able to decrease emergency vehicles traveling time significantly. For example, in average, the proposed method decreases the EVRT by 46.7% compared to fixed-time signal control system and 25.3% compared to the current advanced method (changing signals status based on the distance).

It can also be noticed from Figure.5 that the proposed method has different impact for zones of different traffic density. For example, for low-density areas (zones 1-7), the average reduction is 43.1% (and 9.27% compared to distance-based changing), for zones 7-14 (medium density) the reduction is 50.94% (and 28.12% compared to distance-based changing), and for the high density area (zones 14-20), the reduction in emergency vehicle response time is 44.4% (and 26.52% compared to distance-based changing).

In addition to EVRT, in order to better understand the impact of the proposed method on the traveling time of other vehicles, another analysis is done to find the delays due to the change in the traffic signal status. In order to observe this impact, the EVs' route is considered and the time delays for the vehicles that stopped at signals due to the signal status change are calculated, and maximum delay is obtained. Similar to the previous analysis, the average delays for 10 vehicles at each zone are considered and illustrated in FIGURE 6. As it is observed in FIGURE 6, the proposed method causes different delay for the vehicles in different zones and the delays are much higher in the high-density areas. However, the reduction in the EVRT in high-density areas is higher than others. Compared to the traditional distance-based pre-emption method, the proposed method only increases the maximum delays by 3.75% on average, while it decrease EVRT by 28.60%. As can be seen in FIGURE 6, in the proposed method, the delays are lower in the low traffic area, and increase with the traffic density, but, for the distance-based method, the delays have a more steady change. This is mainly because in areas with higher traffic volume due to longer queue lengths the effect of providing more accurate pre-emption is more visible.
The results demonstrate the proposed method potentially offers improved safety and saves more lives with decreasing emergency vehicles response time in the urban area.

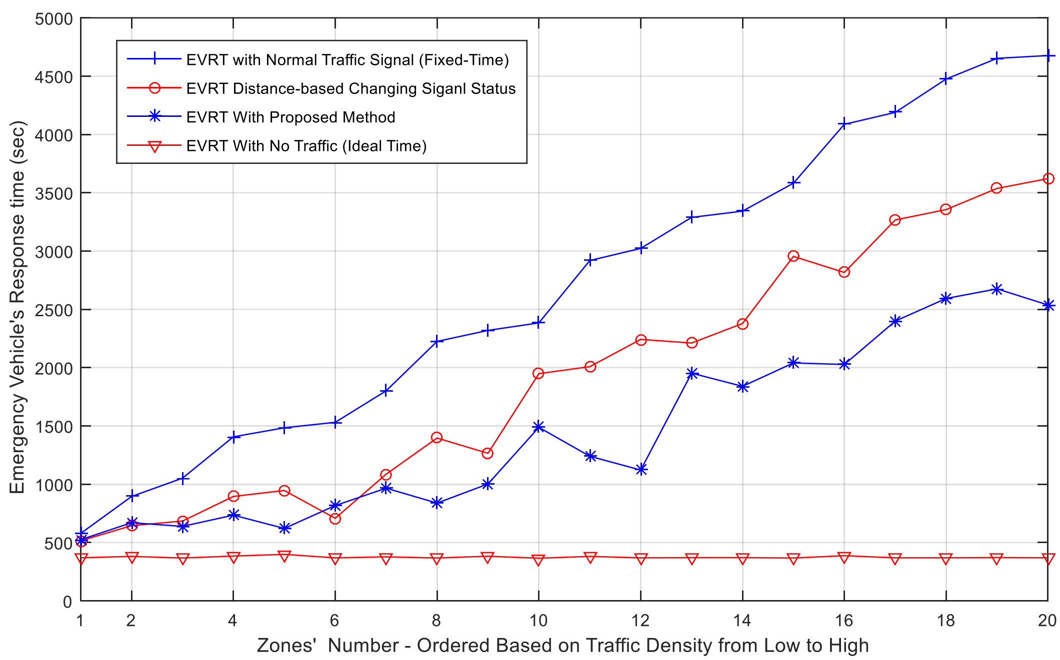

FIGURE 5. Emergency vehicles' response time (EVRT) using the proposed method, distance-based preemption method and fixed-time signal control.

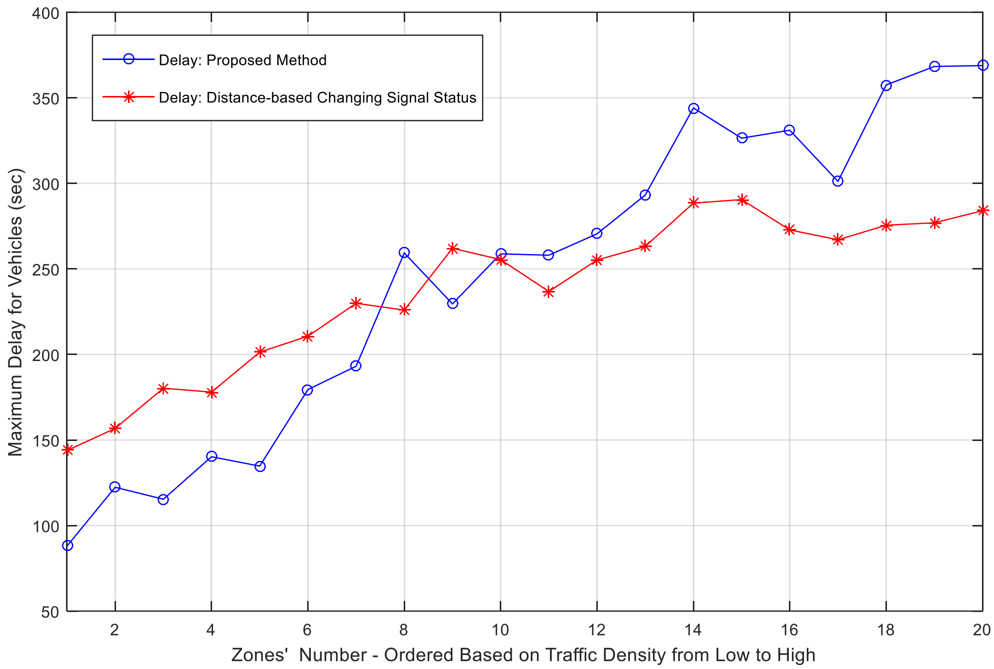

FIGURE 6. Maximum Delays of non-emergency vehicles in the EV's route

5. CONCLUSIONS

A novel connected vehicle based strategy is proposed to improve the operations of emergency vehicles in an urban network. The proposed strategy integrates traffic signal controls with emergency vehicle dispatching based on the vehicle to infrastructure (V2I) communication and Beaconing concept in IEEE 802.11p. It estimates the approximate required time to clear the path for emergency vehicle at the traffic signal and adjusts the traffic signals so that the directions along the EV route are given priority. The method considers all traffic signals at EV's route, and finds the number of vehicles stopped at traffic signals, and changes the signal status to green before the EV reaches the signal. The key logic is to ensure that when the EV reaches the traffic signals, there would be little interruptions caused by other vehicles.

In order to evaluate the control strategy, a new program is developed in Python to connect to SUMO using TraCI and with TCP client/server architecture. The program is able to simulate a city with intelligent traffic signals with a specific consideration on emergency vehicles. Then, as one of the main contributions of this paper, a large scale simulation has been conducted using a realistic network from the city of Toronto with a total of 150,000 individual vehicles being modelled.

The benefit of the proposed method was investigated under different scenarios. The results shown a significant reduction in EVRT using the proposed method. For example, in high density area, the proposed method reduced the EVRT by 50.94% (and 26.52% compared to distance-based changing), in the medium density area, reduction was 44.41% (and 28.12% compared to distance-based changing), and in the low density area the reduction was 43.17% (and 9.27% compared to distance-based changing).

REFERENCES

1. Sánchez-Mangas, R., A. García-Ferrrer, A. De Juan, and A. M. Arroyo. The probability of death in road traffic accidents. How important is a quick medical response? *Accident Analysis and Prevention*, Vol. 42, No. 4, 2010, pp. 1048–1056.
2. Gonzalez, R. P., G. R. Cummings, H. a. Phelan, M. S. Mulekar, and C. B. Rodning. Does increased emergency medical services prehospital time affect patient mortality in rural motor vehicle crashes? A statewide analysis. *American Journal of Surgery*, Vol. 197, No. 1, 2009, pp. 30–34.
3. Fogue, M., P. Garrido, F. J. Martinez, J. C. Cano, C. T. Calafate, and P. Manzoni. Automatic accident detection: Assistance through communication technologies and vehicles. *IEEE Vehicular Technology Magazine*, Vol. 7, No. 3, 2012, pp. 90–100.
4. Simulation of Urban MObility (SUMO). http://sumo.dlr.de/.
5. Noori, H; Olyaei, B. B. A Novel Study on Beaconing for VANET-based Vehicle to Vehicle Communication:Probability of Beacon Delivery in Realistic Large-Scale Urban Area using 802.11p. *Smart Communications in Network Technologies (SaCoNeT), 2013 International Conference on*, Vol. 01, 2013, pp. 17–19.
6. Noori, H. Realistic Urban Traffic Simulation as Vehicular Ad-Hoc Network (VANET) via Veins Framework. *Proceedings of 12th Conference of Open Innovations Framework Program, FRUCT*, 2012.
7. Noori, H., B. Silverajan, and M. Valkama. A Platoon-Based Intelligent Traffic Light Control System Using IEEE 802 . 11p. *IEEE Transactions on Vehicular Technology*, Vol. Submitted, 2015.
8. Noori, H., and M. Valkama. Impact of VANET-based V2X communication using IEEE 802.11p on reducing vehicles traveling time in realistic large scale urban area. *Connected Vehicles and Expo (ICCVE), 2013 International Conference on, Dec*, 2013, pp. 654–661.
9. Goodall, N., B. Smith, and B. Park. Traffic Signal Control with Connected Vehicles. *Transportation Research Record: …*, Vol. 2381, No. 2, 2013, pp. 65–72.
10. Zhou, H., R. Saigal, F. Dion, and L. Yang. Vehicle Platoon Control in High-Latency Wireless Communications Environment. *Transportation Research Record: Journal of the Transportation Research Board*, Vol. 2324, No. -1, 2012, pp. 81–90.
11. Gendreau, M., G. Laporte, and F. Semet. A dynamic model and parallel tabu search heuristic for real-time ambulance relocation. *Parallel Computing*, Vol. 27, No. 12, 2001, pp. 1641–1653.
12. Ball, M. O., and L. F. Lin. A reliability model applied to emergency service vehicle location. *Oper. Res*, Vol. 41, No. 1, 1993, pp. 18–36.
13. Jordan, C., M. Cetin, and R. Robinson. Path Clearance for Emergency Vehicles Through the Use of Vehicle-to-Vehicle Communication. *Transportation Research Record: Journal of the Transportation Research Board*, Vol. 2381, 2013, pp. 45–53.
14. Sharma, S. Traffic Light Priority Control For Emergency Vehicle Using RFID. *International Journal of Innovations in Engieering and Technology (IJIET)*, Vol. 2, No. 2, 2013, pp. 7–10.
15. Goel, A., S. Ray, and N. Chandra. Intelligent Traffic Light System to Prioritized Emergency Purpose Vehicles Based on Wireless Sensor Network. *International Journal of Computer Applications*, Vol. 40, No. 12, 2012, pp. 36–39.
16. Noori, H. Modeling the impact of VANET-enabled traffic lights control on the response time

of emergency vehicles in realistic large-scale urban area. *2013 IEEE International Conference on Communications Workshops, ICC 2013*, 2013, pp. 526–531.

17. Luong, H. P., S. H. Nguyen, H. L. Vu, and B. Q. Vo. One-hop vs . multi-hop broadcast protocol for DSRC safety applications. *World of Wireless, Mobile and Multimedia Networks (WoWMoM), 2014 IEEE 15th International Symposium on a*, pp. 1–3.
18. Ohyama, T., Y. Kaneko, K. Asano, and M. Hamaguchi. Multi-hop communication and multi-protocol gateway by using plural ITS. *Wireless Personal Multimedia Communications (WPMC), 2012 15th International Symposium on*, Vol. 1, 2012, pp. 217–220.
19. Atallah, R., M. Khabbaz, and C. Assi. Modelling of Multi-Hop Inter-Vehicular Path Formation For Connecting Far Vehicles to RSUs. *Wireless Communications and Networking Conference (WCNC)*, 2015, pp. 1954–1959.
20. Open Street Map (OSM). http://www.openstreetmap.org/.
21. Geofabrik, OpenStreetMap Data Extracts free download server. http://www.geofabrik.de/.