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Research paper

An adaptive warning message scheme for emergency vehicles using vehicular ad hoc communication

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Abstract

Nowadays, traffic management has been a challenging task due to the growing number of vehicles. More specifically, operation management of Emergency Vehicles (EVs) such as ambulances, police force and fire fighting vehicles require extensive industrial and academic studies. The research community has been placing a great deal of emphasis for reducing the travelling time of the EV between the starting point and the destination point. In the foreseeable future, all vehicles are assumed to be fully equipped with wireless technology. This facilitates communication and coordination between vehicles and traffic lights, and shortens the time needed for EVs to reach their destinations. This paper focuses on developing an efficient broadcast algorithm, namely, Adaptive Warning Message Scheme (AWMS), using Vehicle-to-Vehicle (V2V) communication, to deliver a Warning Message (WM) as quickly as possible to a target traffic light. In the AWMS, a high priority message dissemination is given to WMs, which are responsible for informing the traffic light about any approaching EVs, while a low dissemination priority is assigned to normal Information Messages (IMs), (i.e. messages that carry general information about a vehicle). In addition, the EV direction toward a traffic light is considered in our scheme when broadcasting the WM to reduce the broadcast storm problem. Time delay between two consecutive WMs is calculated based on the EV speed and traffic density. The simulation results have shown that the AWMS has the capacity and ability to disseminate WMs with minimum number of retransmissions, collision rate and end-to-end delay.

Keywords: *Warning Message; Information Message; the Broadcast Storm Problem; V2V; Traffic Light.*

1. Introduction

Vehicle-to-Vehicle (V2V) wireless communication has gained a considerable attention in the past few years from both the academic community and the automotive industry, due to its applicability in a wide range of promising applications such as safety, non-safety applications and transport efficiency. Modern vehicles are equipped with GPS, wireless cards and several types of sensors allowing them to collect and share traffic flow information with other surrounding roadside units and wireless devices. This can enable a more efficient management of road environment. In this context, the traffic light preemption system is considered as one of undergoing active research fields. The purpose of such a system is to provide the vehicles with a clear right-of-way until reaching their destination by dynamically adjusting traffic signals through their trajectories using V2V or Vehicle to-Infrastructure (V2I) communication, which reduces the EVs traveling times and enhances traffic safety.

A wide spectrum of approaches have been proposed to implement traffic preemption systems, including line-of-sight-based systems [1] [2], sound-based systems[3], GPS-based systems [4] [5], radio-based systems [6 8], sensor-based systems[9][10], V2V or V2I communication [11] [12]. In line-of-sight-based systems, the EV propagates infrared or visual light transmissions directly to the traffic light controller forcing the traffic light to change its color mode dynamically. GPS-based systems require a software application and wireless communication to keep a tracking record of the EV that includes its direction, speed and location with regard to the target traffic light. Sound-based systems are used to detect the EV siren by using directional microphones. The traffic light responses to any pre-determined siren and clear the path accordingly. In the radio-based system, the EV can control the traffic light using directional antennas, which must be installed on both (i.e. the EV and the traffic light). In such a system, the EV requests a preemption via a radio frequency pulse that traffic light receiver responses to it immediately. Sensors-based systems enable the EV to control the operation of a traffic light with a smart algorithm and a special type of sensors to detect the presence of vehicles.

Although the above preemption systems have presented effective solutions to manage traffic light operations, several drawbacks have appeared in real-life implementations. For instance, sound-based systems, radio-based systems and line-of-sight-based systems may occasionally fail to work due to the presence of some obstacles as a sound wave, sometimes is reflected by obstacles, or block the direct visual contact between the EV and traffic light. In addition, the need to install special devices at every EV and traffic light represents another bottleneck that limits the efficiency of other proposed systems due to the extra cost they incur for acquiring and installing them.

Recently, vehicular communication has exploited the features of Intelligent Transport Systems (ITS) communications architecture in order to implement a low cost and a reliable preemption system. This paper sheds the light on V2V communication and how preemption systems can benefit from its capability. The majority of V2V applications require broadcasting/disseminating a query message to all nearby vehicles to take a proper action or to ask for a service which is (i.e. the required action/service), located away of nearby vehicles. Therefore, broadcast messages must be propagated via intermediate vehicles towards a target destination or location. In this paper, we consider the problem of classification of these broadcast messages and forwarding them between EVs and traffic lights in a timely and efficient manner using V2V communication. Hence, in all simulation scenarios that are presented in section 4, vehicles initiate two types of broadcast messages with a different class priority, the WM and the IM. Although the WM is used for several safety application purposes, it is designed in our study to be delivered from the EV to the traffic light destination. The AWMS makes this possible by selecting a specific group of vehicles with the aim of fast delivery and reducing the excessive number of WMs. Furthermore, while broadcasting of WM, in the most relevant studies [13] [14], takes place every fixed period of time, the AWMS adjusts dynamically the length of the period based on speed and density of vehicles.

The main contribution in this work is to: (i) develop Adaptive Warning Message Scheme (AWMS), (ii) and to adjust broadcast reputation rate between two successive WMs adaptively, (iv) which eventually mitigates side effect of the broadcast storm problem.

The rest of the paper is organized as follows. Section 2 reviews the related work on the traffic light management systems, the broadcast storm problem and adaptive safety-message schemes in VANETs. Section 3 presents the proposed adaptive warning message scheme. Section 4 shows the simulation environment used to validate the AWMS. Section 5 presents and discusses the obtained results. Finally, Section 6 concludes this paper and presents future directions for this work.

2. Related work

In the last few decades, research activities on deploying vehicular communication to manage various aspects of traffic conditions have increased widely. Obviously, some research works focus on using vehicles' information to design an adaptive traffic light controller[11] [15 - 18], while others are dedicated to design smart algorithms to propagate safety messages between VANETs components [19 - 21] [13]. An overview of various research studies in this context is given next.

2.1. Traffic light

This section provides an overview about how to design a dynamic and a smart traffic light system using various vehicle information, such as velocity, position and distance. This information helps the traffic light system to be adjusted in real-time to traffic condition, to response to unexpected situations and to reduce traffic congestion.

In [15], each vehicle sends a message information contains its location, direction, distance and speed to traffic light receiver regularly. This information is used to assist the traffic light to take a decision if a coming vehicle can pass this intersection. A similar method has been proposed in [11], in which each vehicle transmit its information to a nearby traffic light. Based on such information, traffic density around the intersection is estimated and the signal timing is adjusted accordingly. A multi-detection method is proposed in [16], in which the loop detectors and a Road Sid Unite (RSU) are used to collect vehicle information. Specifically, a vehicle broadcasts its movement information once it is in the RSU communication range. A loop detector device is used also beside the RSU to collect traffic density information. Both information is used to optimize signal control before the arrival of vehicles at the traffic light intersection. A new Intelligent Road Traffic Signaling System (IRTSS) based on the VANET architecture is proposed in [17] with the goal to improve traffic flow and increase road safety. The IRTSS dynamically controls the traffic signaling sequences and cycle, by collecting traffic information from individual vehicles. This is done by having the RSU periodically sends a broadcast message to all coming vehicles. Any vehicle receives this message should unicast its own information such as speed, position and the required time to reach the intersection ahead. Then, the RSU broadcasts the current traffic signal state every second to all vehicles allowing them to take necessary actions such as whether to decelerate or to continue its current speed. A case study of an adaptive traffic light control system has been proposed in [18], which used V21 communication and a new algorithm to reduce vehicles' travel time and delay at the intersection. To set the traffic light timing dynamically, both traffic density and vehicles' relative position are used in this case study.

Several similar studies have been suggested in [22 -24], which exploited vehicles information as a mean to manage traffic light systems and increase public traffic safety. Interested readers can refer to these studies to gain deep knowledge and understanding.

2.2. Safety message

Clearly, aforementioned studies discussed how a traffic light, an RSU and vehicles can cooperate together to design adaptive traffic light systems. On the other hand, this section provides the work related to safety message dissemination techniques using vehicular communications. Generally, most of the following studies focus on addressing broadcast storm problem, which occurs because of uncontrolled flooding of safety messages.

In [19], a novel broadcast scheme has been introduced for delivering safety-related messages in fast and reliable mechanism. The scheme has classified safety-related messages in a vehicular communication into three classes and assigned different priorities to them. Class-1 messages are emergency WMs, class-2 messages are long-range emergency notification messages, and class-3 messages are periodic beacon messages, which contain vehicle's position, speed, travel time, and moving directions.

In [20], a street-based broadcast scheme is presented, in which each vehicle periodically broadcasts a HELLO message carrying the vehicle's movement information, or on demand emergency message (e.g. in the case of a traffic accident) to neighboring vehicles. A received message is further broadcasted and forwarded by the farthest neighboring vehicle to other vehicles to ensure the greatest reachability.

A cross-layer broadcast protocol is presented in [21] to disseminate warning messages efficiently using vehicular communication. A forwarding vehicle is selected according to its distance, relative velocity, and packet error rate compared to other neighbors.

An enhanced Street Broadcast Reduction (eSBR) scheme is proposed in [13] as a further improvement to SBR [14], to operate in urban VANETs. The proposed scheme deals with two types of messages; warning messages and normal messages (i.e. messages that carry the information of vehicle's locations), and priorities each type according to its importance. Warning messages are assigned high priorities and broadcasted only in the case of abnormal event whereas normal messages are assigned low priorities and broadcasted periodically.

Authors in [25] proposed two protocols, namely Ad hoc Multihop Broadcast (AMB) and Urban Multihop Broadcast (UMB) to address the broadcast storm, hidden node, and reliability problems in multi-hop broadcast. The AMB is designed to enable the furthest vehicle from a sender to forward and acknowledge emergency messages without a priori topology information. The UMB handles the broadcasting of an emergency message at an intersection by installing a repeater where the communication between road segments are blocked by buildings or obstacles.

In addition to these studies, other similar protocols and schemes have been proposed to control broadcasting safety messages and mitigate the broadcast storm problem in vehicular communication systems. Readers can investigate [26 - 29] for more information and details, and for comprehensive reviews and comparison between numerous existing multi-hop data broadcast protocols in VANETs, they can refer to [30].

3. The adaptive warning message scheme (AWMS) procedures

This section describes in detail how the AWMS works. The following assumptions are used through this work to make sure the correct function of the AWMS:

- All the vehicles are equipped with a Global Positioning System (GPS).
- An embedded digital road map is equipped with each vehicle to locate target traffic lights.
- The AWMS is responsible for efficient WM forwarding among vehicles until it reaches a traffic light destination. The interpretation of the WM content at the traffic light needs further works and hardware implementing. This is considered beyond this work scope and several related works tackle this issue as discussed in section 2.1.

Generally, vehicles send several types of messages to other vehicles on the road. Each type of these messages serves a different purpose and must be prioritized carefully. In this paper, we classified them into two types; WMs and IMs. WMs are often sent by vehicles to inform other vehicles about serious events, such as an accident ahead, road constructions, or other hazards that may meet vehicles on a road. Hence, this type of messages must have the highest priority at the MAC layer and must be rebroadcasted by other vehicles. On the other hand, the IMs are used to carry normal information (e.g. vehicle's speed, direction and position) and are exchanged periodically among neighboring vehicles to exchange information among each other. The IMs have a lower priority compared to WMs and are not rebroadcasted by other vehicles.

For this study, we consider the WM as a message sent by EVs (such as ambulance, police or fire-engine vehicles) to other nearby vehicles. The receiving vehicles convey it in a multi-hop fashion until it reaches a traffic light ahead. The WM is intended to make the trip of the EV safer and faster, as it is assumed to switch traffic lights to green before the EV reaches the intersection.

Therefore, in all simulation scenarios, each vehicle can play the role of either EV or Normal Vehicle (NV). The EV informs NV that they need to switch all traffic lights ahead to green in advance, by sending the WM periodically (every T_{WM} second). The T_{WM} interval period must be set adaptively according to several crucial parameters such as vehicles speed and density. The main idea is to guarantee a high WM reachability with minimum message delivering cost. Basically, the EV travels with a high speed when it moves in a street of low traffic densities. This means that it is rarely to allocate NVs to carry out the WM using V2V communication. Hence, the T_{WM} interval period must be set very short to make sure that there is at least one source broadcasting (i.e. EV). Yet, the low speed of an EV, indicates that it moves on a street of high traffic densities. Hence, the T_{WM} interval period must be set very long as other NVs are able to deliver the WM until it reaches its target. So, we can conclude that nature of the relationship between vehicle density, speed and T_{WM} interval period is invertible. For further details about the speed-density curves, we refer the reader to [31].

To calculate the number of NVs in front of EV with regard to vehicles speed and density, the following formula in [32] is used. Assume that in a section of a two-way street with L meters long, V_d represents the vehicle density per meter on each way. Thus, the total number of the vehicles on the section of a two-way street is $2V_dL$. The speed of the EV and average speed of the NMs are defined as S_{EV} and S_{NM} respectively. Then, the number of NVs that the EV would encounter from the same direction is defined as follows:

$$NV_{same\_dirction} = |(S_{EV} - S_{NM})| \times \frac{L}{S_{EV}} \times V_d \quad (1)$$

Then the T_{WM} interval period is calculated:

$$T_{WM} = NV_{same\_dirction} \times \Delta t \quad (2)$$

Where Δt is a small random delay time. On the other hand, NVs are requested to forward the WM, and they also send IMs periodically (every T_{IM} second). IMs are usually sent every second follows HELLO message time slot standard.

To achieve priority principle between WMs and IMs, the Wireless Access for Vehicular Environment (WAVE) standard offers a multi-channel concept which can be used for this purpose. Hence, Several Access Classes (ACs) are implemented with different channel access settings to guarantee that a highly important message can be exchanged timely and reliably. ACs are categorized into four different classes, where AC0 has the lowest priority and AC3 the highest priority [33].

Sender: Emergency Vehicle (EV)
1-AC1: IM // Information Message
2-AC3: WM // Warning Message
3-EV // Emergency Mode Vehicle
4-NV // Normal Mode Vehicle
5-While (True) do
6-IF (EV needs to broadcast WM) Then
7-WM = AC3 //Set the priority of WM to be high
8-Broadcast (WM) // Broadcast the WM to all vehicles
9-Wait(T_{WM}) // Set the waiting time based on equation (2)
10-Else
11-Create IM // Information Message
12-IM = AC1// Set the priority of IM to be low
13-Broadcast(IM)
14-Wait(T_{IM})
15-End_IF
16-Receiver: Normal Vehicle (NV)
17-Seq_Num_Counter = 0
18-For (every WM received at NV and Seq_Num is received for first time) do
19- Seq_Num_Counter++
20-If $((\overrightarrow{(EV', EV)}, \overrightarrow{(NV', NV)})$ and $(\overrightarrow{(EV', EV)}, \overrightarrow{(EV, NV)})$ is $0^{\circ}\sim 90^{\circ}$) Then // Direction of EV as NV, and NV is ahead of EV.
21- While($T_{wait}(WM)$ is not expired) set the differ time based on equation (3) {
22- Seq_Num_Counter ++
}
23- IF (Seq_Num_Counter<1) Then
24- Rebroadcast(WM)
25- Else
26- Drop(WM)
27- End_IF
29- Else
30- Drop(WM)
31- Else
32- Drop(WM)
33- End_IF

Fig. 1: Pseudo Code Shows Steps of AWMS.

In Fig.1, (which illustrates logical steps of the AWMS) sender section describes how each vehicle acts upon sending a message. If the vehicle is an EV and needs to disseminate a WM, the following scenario is followed. The high priority (AC3) is assigned to the WM, the sequence number of the WM is incremented, and it is broadcasted to its neighboring vehicles. T_{WM} is the interval time between two consecutive WMs. While if the vehicle is a NV, the IM is created and broadcasted with a low priority (AC1). T_{WM} and T_{IM} are the interval between two consecutive WM and NM respectively.

3.1. Warning message broadcasting direction

Applying traditional broadcast scheme to deliver WMs from the EV via intermediate vehicles to a traffic light destination leads to many disadvantages. The most important ones are messages redundancy, contention and collisions, which all together refers to the broadcast storm problem [34]. Therefore, moving direction information for the EV, NVs and traffic light's location is used to alleviate serious effects of this problem.

Each EV must classify NVs in its neighborhood before sending the WM. Hence, suppose that the position of two vehicles, EV and NV at time T are (X_{EV} , Y_{EV}),(X_{NV} , Y_{NV}), and at Time $T+\Delta t$ (where Δt *is small short time*) is (X'_{EV} , Y'_{EV}), (X'_{NV} , Y'_{NV}) .The algorithm makes use of the three vectors to classify NV as follows. $(\overrightarrow{EV',EV})$ is denoted as the vector from EV' previous tion (X'_{EV} , Y'_{EV}) $at\ time\ T+\Delta t$ to its current position (X_{EV} , Y_{EV}) $at\ time\ T$. $(\overrightarrow{NV',NV})$ is denoted also as the vector from NV' previous position (X'_{NV} , Y'_{NV}) $at\ time\ T+\Delta t$ to its current position (X_{NV} , Y_{NV}) $at\ time\ T$. Finally, the vector from EV's current position to NV's current position is denoted as $(\overrightarrow{EV,NV})$.

The IM is used to retrieve current position and previous position for EV and NV. Each vehicle creates a table that contains neighbourhood information through IM broadcast from its neighbour vehicles. Each vehicle broadcasts IM periodically every second. The cosine angle $\angle$ between $(\overrightarrow{EV',EV})$ and $(\overrightarrow{NV',NV})$ is used to determine whether EV and NV move in the same direction, opposite direction, and if NV is located before or after EV. $If\ \angle$ between

$((\overrightarrow{EV',EV}),(\overrightarrow{NV',NV}))\ and\ ((\overrightarrow{EV',EV})(\overrightarrow{EV,NV}))\ is\ 0^{\circ}\sim 90^{\circ}$

then EV and NV move in the same direction, and NV is regarded as being ahead of EV. So, NV belongs to group 1. Otherwise, NV either moves in the same direction but behind EV and belongs to group 2, or it moves in a different direction, and belongs to group 3. Vehicles of group 2 and 3 are not included in forwarding the WM process as they cannot assist the EV to forward it to a traffic light ahead. Only vehicles of group 1 can do so.

3.2. Format structure of warning message

When the EV needs to communicate with any traffic light, it would issue the WM that has a format as shown in Fig.2. Source ID and Sequence number fields together uniquely identify the WM. The third and fourth fields denote the current and previous position of the EV. The field of "Message Priority" is used to set traffic event to AC3. Because that the EVs are of several types (i.e. ambulance, fire-engine or police), and each type has a different priority to pass a traffic light, the field of "type" is used for this purpose. For instance, the fire-engine must pass a traffic light before the ambulance and the police vehicle. In this paper, the fire-engine is set to a high priority =1, ambulance = 2, and other police vehicles are set to low priority = 3. The field of "type" is assumed to be interpreted by the traffic light microcontroller. Each EV must determine a target traffic light that should change its mode when approaching it, using the field of Traffic ID. List of traffic lights IDs or positions are assumed
to be included with each EV by using a specific database or using google map option.

Source ID	Sequence Number	Current Position	Previous Position	Message Priority	Type	Traffic ID

Fig. 2: Format Structure of Warning Message.

3.3. Format structure of information message

IMs uses a slightly different message format compared to WM format structure. As stated previously, IMs contain generic information about vehicles (such as a vehicle speed, direction and position), and are not allowed to be rebroadcasted by other vehicles, they are only broadcasted to one-hop neighbor. Fig.3 shows the message format of IM. The first four fields are similar to WM field's description. "Hop count" field is used to limit the broadcast of an IM to one-hop neighbor only. "Lifetime" field checks if a local connectivity between neighbors is existed within a lifetime period.

Source ID	Destination ID	Current Position	Previous Position	Message Priority	Hop count	Life time

Fig. 3: Format Structure of Information Message.

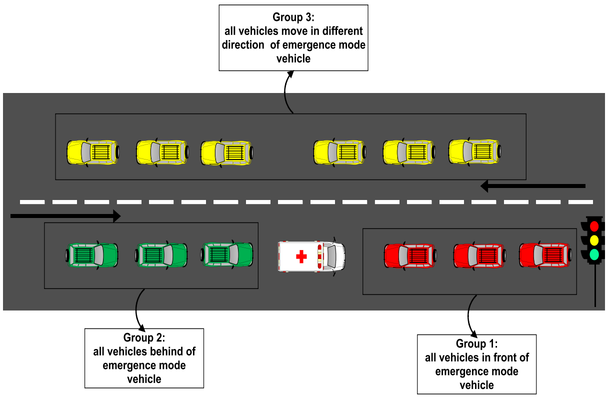

Fig. 4: Example on How AWMS Can Eliminate the Broadcast Storm Problem.

3.4. AWMS description

In order to address the broadcast storm problem, only relevant vehicles are privileged to retransmit WMs. As shown in Fig.4, in the primitive broadcast technique, when an EV sends a WM to switch the traffic light colour to green, all vehicles inside group 1,2 and 3 receive and retransmit the WM all neighbouring vehicles. This technique is called flooding and it is the cause of the broadcast storm problem. To prevent serious side effects of this problem in our proposed technique, only vehicles inside group 1 can forward the WM to the next vehicle until it reaches the traffic light ahead. Any retransmission from vehicles inside group 2 and 3 is suppressed as it does not help the EV in changing traffic light color mode. This can mitigate the side effect of the broadcast storm problem dramatically. However, a local broadcast storm problem is highly probable inside group 1. Once NV1, NV2 and NV3 receives the WM from the EV, they will rebroadcast it simultaneously. To tackle the local broadcast storm problem inside group 1 which is represented in Fig.5, the following technique is deployed. NV 1 and NV2 are delayed retransmission operation since the traffic light is outside of their transmission range. They cause redundant WMs and do not reach the traffic light by one hop retransmission.

It is apparent that vehicle NV3 is the appropriate candidate for relaying competition, but NV1 and NV2 should be ignored. NV3 retransmits the WM immediately as it is the furthest vehicle from the EV and the closest one to the traffic light. It would be better to relay the WM by the farthest vehicle inside the transmission range of the EV when the distance between vehicle 1 and 2 is approximately the same and does not reach the traffic light as quickly as possible. To achieve this, the following producer is used. Thus, every vehicle is able to share its geographical location with other vehicles within transmission range. When the EV start broadcasting the WM, all vehicles that received the WM do not forward it to other vehicles immediately. Instead, each vehicle runs a random delay time T_{wait} based on its distance from the EV as follows:

$$T_{wait} = RAND(0,10^{-3}) \times \frac{C_{range}-D_{ij}}{C_{range}}$$

Where C_{range} is the vehicle communication range, D_{ij} is the distance between EV vehicle i and NV j. This equation allows furthest vehicle (vehicle 3 in Fig.5) from the EV to wait for a less time and to retransmit the WM before other vehicles (vehicle 1 and 2). Table 1 shows T_{wait} for each vehicle. When the threshold interval time expires (i.e. T_{wait}),each vehicle checks whether it has received the same WM from the furthest vehicle within its communication range. Hence, Seq_Num_Counter is used to count the number of the similar received WMs. If Seq_Num_Counter is

> 1, that means the current vehicle has received a redundant WM from other vehicles, and, thus, it must drop such a redundant WM. For instance, in Fig.5 if vehicle 1 and 2 receive the WM from vehicle 3, that means the rebroadcast operation has been done successfully and Seq_Num_Counter is >1. Otherwise, they assume that vehicle 3 has failed to rely the WM and Seq_Num_Counter<1. In this case, vehicle 2 is responsible to relay the WM, and so on.

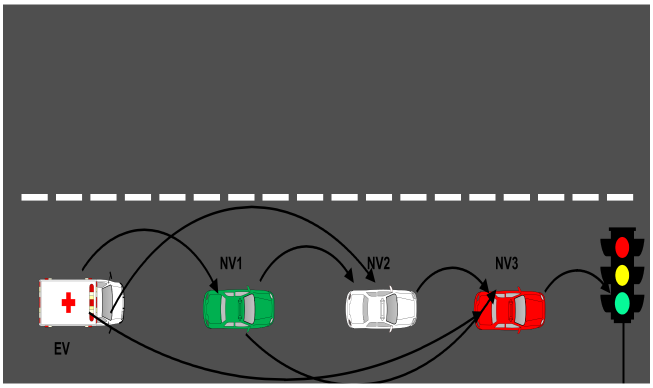

Fig. 5: Example on How AWMS Can Eliminate the Local Broadcast Storm Problem.

4. Simulation environment

The process of selecting the simulation environment for evaluating the algorithm performance compared to others is very important as selecting the wrong simulation environment may cast doubts on the credibility of the evaluations and simulation results. Hence, the well-known simulator NS-2 [35] with a Simulation of Urban Mobility (SUMO) platform and the simple Manhattan model [36] is used to carry out the simulation experiments. One advantage of using SUMO with NS-2 is that it allows us to simulate the same conditions existed in the real environments such as adding traffic lights, controlling vehicle movement and speed limitations.
In all simulation scenarios, each road is assumed to have two lanes (forward and reverse), and the vehicle speed is limited to a range between 10 m/s and 20 m/s. All used parameters for MAC and physical layer communication follow the IEEE 802.11p and WAVE standards. The maximum data rate for packet broadcasting is set to 6 Mb/s as in 802.11p. The MAC layer is also extended to meet the requirement of ACs classes; AC1 and AC3. The communication range of all vehicles is set to 250m. In each simulation experiment, three vehicles are used to play the role of the EVs who send out the EM. The rest of simulation parameters are listed in Table 1.

Table 1: Summary of the Simulation Settings.

Parameters	Value
Transmission range	250m
Simulation time	100s
Number of vehicles	50-350
MAC and physical layer	802.11p
Vehicle speed	10 m/s - 20 m/s
Network size	1000 m × 1000 m
Number of EV	3
WM priority	AC3
IM priority	AC1
T_{WM}	Adaptively
T_{IM}	1 second

To evaluate the performance of the proposed algorithm, we compare it with the SBR scheme [13] as it is the most related research study to our proposed scheme paper. We used Simple Flooding (SF) as the baseline for both schemes in our comparison. The following cost metrics are used in the comparison:

- End-to-End Delay Time: the average required time for a vehicle to receive the WM from the EV.
- Number of Retransmissions: represents the number of WMs that are retransmitted by intermediate NVs.
- Collision Rates: shows the total number of dropped WMs at the MAC layer as a result of collisions between WMs.

4.1. Evaluation of the impact of the vehicle density

The impact of traffic density on the performance of the AWMS is examined in terms of number of retransmissions and end-to-end delay. The traffic density has been varied by changing the number of vehicles deployed over a 1000m x 1000m area. Other parameters such as network area, vehicle speed and communication range are set to constant values, (1000X1000 m), (10m/s) and (250m), respectively.

- Number of retransmissions

Fig.6 illustrates the number of retransmissions in the compared schemes under various densities. This metric indicates how much each scheme being able to alleviate the broadcast storm problem. As it can be observed from the figure, simple flooding has the highest number of retransmissions, since all vehicles rebroadcast the WM without any heuristic technique. Clearly, the AWMS has the lowest number of retransmissions compared to the simple flooding and SBR schemes. The superiority of the AWMS over the SBR can be attributed to the fact that the AWMS limits the retransmission operation only within the interested area (i.e. toward the target traffic light direction). The AWMS also mitigates the effect of the local broadcast problem in the interested area by assigning the furthest forwarding vehicle the highest priority to retransmit the received messages.

- End-to-end delay

Fig.7 shows the average end-to-end delay time for all schemes. This metric indicates how fast the WM has traveled from the EV via the NVs until it reaches the traffic light target. The figure shows that The SF has largest end-to-end in comparison with other approaches due to the broadcast storm problem. The figure also shows that the AWMS has achieved the lowest end-to-end delay compared to the SF and the SBR. This is because that the rebroadcast technique in the AWMS privileges forwarding the WM only by last vehicle within the source transmission range. Hence, the WM travels toward destination with minimum hops, consequently minimizing the delay.

- Collison Rate

Fig.8 shows the number of WM collisions occurred at the MAC per second against number of vehicles. It can be seen from the figure that when the network density is increased, the collision rate for the SF, the SBR and the AWMS is also increased. Normally, collision rate is expected to be high when there are a large number of vehicles rebroadcasting the WM at the same time. However, the superiority of the AWMS over the SBR and the SF is very clear over different traffic densities.

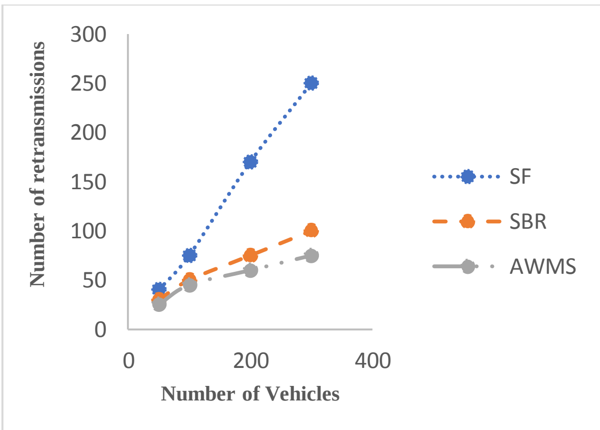

Fig. 6: Number of Retransmission vs Number of Vehicles.

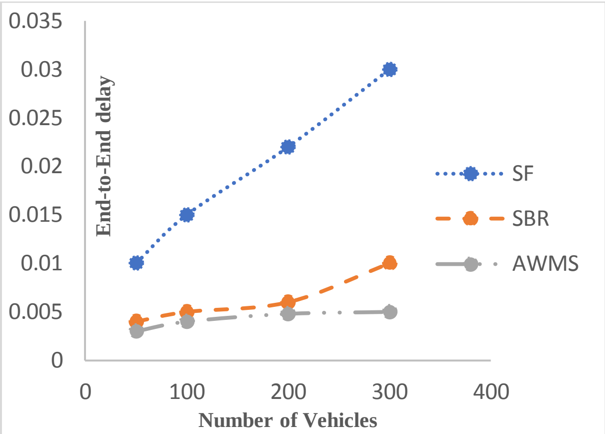

Fig. 7: End-To-End Delay vs Number of Vehicles.

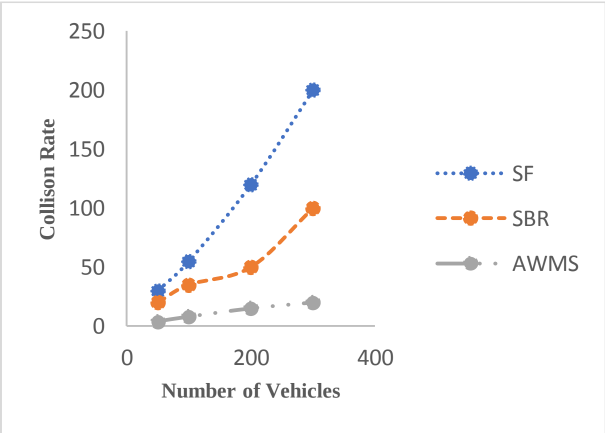

Fig. 8: Collison Rate vs Number of Vehicles.

5. Conclusion and future works

In this work, we propose the AWMS using V2V communication to help EVs reach quickly to an accident spot. To achieve this aim, the AWMS uses different methods to guarantee that the WM will be delivered on time to a target destination (i.e. traffic light). The EV speed with respect to the speed of the other NVs method is used in the AWMS to adjust the delay time between consecutive WMs broadcast operation. A cosine angle value between the EV and other surrounding NVs is also used to limit broadcasting of the WM only to the relevant group. As a result, the broadcast storm problem is well handled as the WM redundancy and collisions are reduced, while minimum end-to-end delay of the WM delivery is incurred.

5.1. Traffic light on-board unite framework

This paper handles the message delivery problem between the EV and NVs until it reaches the target traffic light. Time management algorithms to organize traffic light slot time are widely discussed in [37 - 39]. How to design a smart traffic light is also addressed and discussed in the related work section. Although only simulation-based test is used in this paper to investigate the algorithm performance, our future work will aim to operate this algorithm in a real-life scenario. Therefore, this section shows the general framework of traffic light components as shown in Fig.9, and how it can interact with the proposed algorithm.

- Microcontroller

A microcontroller is a mini computer used for a special purpose. It has a dedicated input and output device and ports to control the device components. The purpose of the traffic light microcontroller is to receive a signal from EV and adjust the traffic light timing slots according to a current road condition. The commonly used Microcontroller is PIC 16F877A [40], which is made by Microchip.

- LCD display: is short for Liquid Crystal Display (LCD) [41] can be used in several digital and electronic circuits. When designing the traffic light LCD is used to display alert message such as "An EV Is Coming".
- Buzzer: A buzzer is an electrical device that is used to make a special buzzing sound when an EV approaches the traffic light.
- Receiver: The traffic light microcontroller is attached with a receiver unit to receive a signal either directly from the EV or via NVs. XBee model [42] is provided a reliable wireless point-to-point or a mesh network communication. It is used to send WMs from the EV and to receive it at the requested traffic light.
- Solar power supply: provides an electronic circuit with required voltage. Standard lights red, yellow and green are used to organize traffic operation modes.

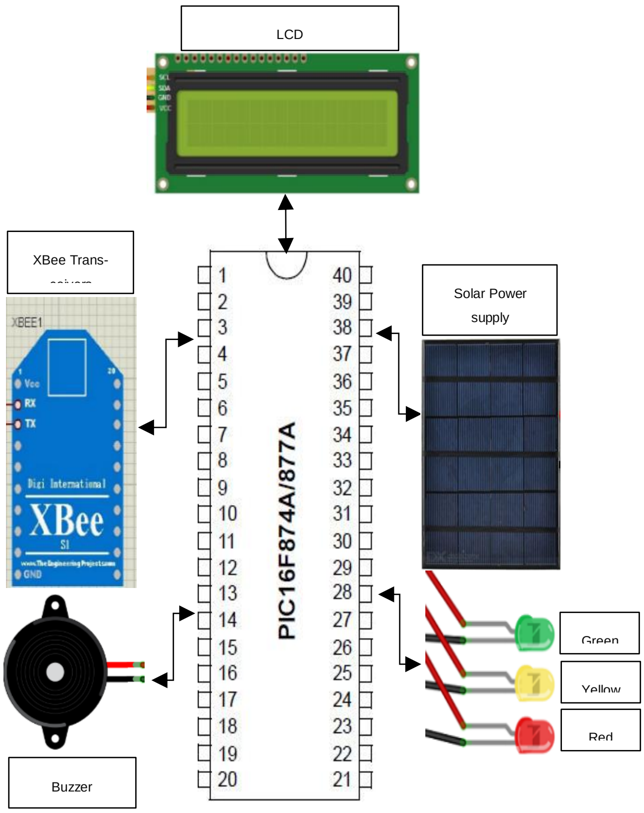

Fig. 9: Traffic Light On-Board Unite Components.

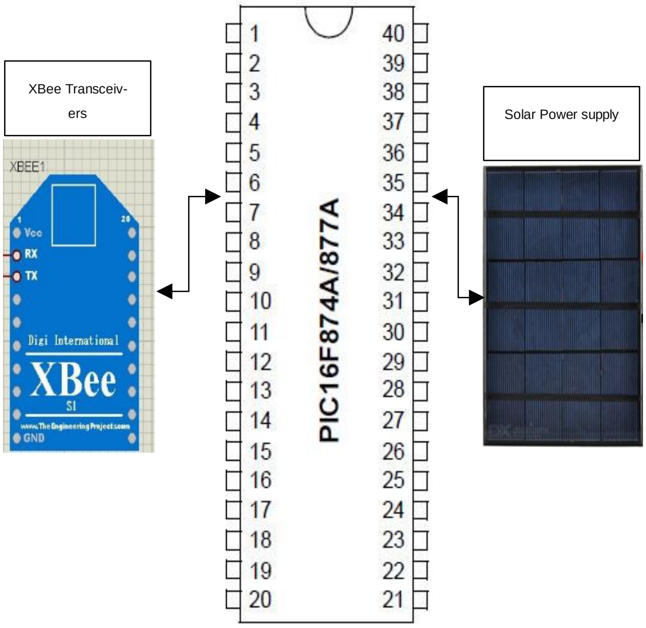

Fig. 10: Vehicle On-Board Unite Components.

5.2. Emergency and normal vehicles on-board unit

We assume that every vehicle is equipped with On-Board Unit (OBU) [43], which enables V2V or V2I communication. Real-life implementation of the OBU for this work requires the similar hardware components of the traffic light. The only difference GPS module is connected to the OBU and broadcast location information of every vehicle using the Xbee module. This location information is used by the AWMS to calculate a cosine angle between vehicles. Fig.10 shows its components.

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