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Dynamic multiagent method to avoid duplicated information at intersections in VANETs

Mohammed I. Habelalmateen[1], A. H. Abbas[2], L. Audah[3], N. A. M. Alduais[4]
[1,2,3]Wireless and Radio Science Centre (WARAS) Faculty of Electrical and Electronic Engineering, Universiti Tun Hussein Onn Malaysia, Malaysia
[2]Communication Engineering Techniques, Imam Jaafar Alsadiq University, Iraq
[1]Department of Computer Technical Engineering, College of Technical Engineering, the Islamic University, Iraq
[4]Department of Information Security and Web Technology, Faculty of Computer Science and Information Technology, Universiti Tun Hussein Onn Malaysia, Malaysia

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ABSTRACT

Vehicular ad hoc networks (VANETs) allow vehicles to contact one another to provide safety and comfort applications. However, mobility is a great challenge in VANETs. High vehicle speed causes topological changes that result in unstable networks. Therefore, most previous studies focused on using clustering techniques in roads to reduce the effect of vehicle mobility and enhance network stability. Vehicles stop moving at intersections, and their mobility does not impact clustering. However, none of previous studies discussed the impact of vehicle stopping at intersections on base stations (BSs). Vehicles that have stopped moving at intersections continue to send the same information to BSs, which causes duplicated information. Hence, this study proposes a new method named dynamic multiagent (DMA) to filter cluster information and prevent duplicated information from being sent to BSs at intersections. The performance of the proposed method was evaluated through simulations during the use of DMA and without-DMA (W-DMA) methods based on real data collected from 10 intersections in Batu Pahat City, Johor, Malaysia. Overall, the proposed DMA method results in a considerable reduction in duplicated information at intersections, with an average percentage of 81% from the W-DMA method.

Corresponding Author:

A. H. Abbas,
Wireless and Radio Science Centre (WARAS)
Faculty of Electrical and Electronic Engineering,
Universiti Tun Hussein Onn Malaysia, Malaysia.
Email: alsalamy1987@gmail.com, hanif@uthm.edu.my

1. INTRODUCTION

The increase in land vehicles over the last few decades has led to traffic congestion and road accidents. This reason makes research on connections among vehicles that exchange information a necessity. This information can be collected from intelligent vehicle networks that are part of intelligent transportation systems. Intelligent vehicle networks enable vehicles to communicate with one another in what is called VANETs. VANETs are a subpart of mobile ad hoc networks that have attracted the attention of researchers and industries [1]. VANETs have two types of communication. The first type is vehicle-to-vehicle communication in which a vehicle communicates directly with other vehicles within the same transmission range (TR). This type of communication does not incur costs and has easy-to-establish networks, but it faces disconnection problems when vehicle density is low [2, 3]. Therefore, vehicle-to-vehicle communication cannot be applied in sparse areas. The second type is vehicle-to-infrastructure communication in which vehicles communicate with roadside units (RSUs). This communication type can be expensive, and RSUs have a limited coverage area (500 m to 800 m) and may not be allowed to be installed in several places [4, 5].

Clustering was proposed to address these challenges [6]. Clusters are groups of vehicles in a specific TR. This group has a leader called cluster head (CH), and all remaining vehicles are called cluster members (CMs). The CH is the manager of the group, and all CMs can communicate with one another and send information to the CH. Only the CH can communicate with the base station (BS) and send information about its CMs [7]. High vehicle mobility affects cluster stability and data dissemination. Thus, most previous studies focused only on cluster stability [8-12], data dissemination among cluster vehicles [13], detected the traffic congestion in the city by using clustering techniques in [14] and analyzed routing protocols of clustering in VANETs [15, 16]. Only a few studies have focused on clustering at intersections. When vehicles stop at intersections, mobility ceases to affect clusters, but clusters continue to send vehicle information to BSs. Most information sent to BSs at intersections is consequently duplicated information. Clusters should be stopped from sending vehicle information at intersections due to network stopping, and clusters should be reformed and the CH be re-elected after intersections. This study proposes the dynamic multiagent (DMA) method to solve the problem of duplicated information being received from immobile vehicles at intersections. The main contributions of this study are as follows:

– It proposes a new method called DMA to prevent unnecessary information from being resent to BSs when vehicles stop at an intersection.
– This is the first study based on real data collected from monitoring the intersections in Batu Pahat City, Johor, Malaysia by using Arduino Uno, Global Positioning System (GPS) and external antennas to form accurate locations.
– It provides evaluation and validation by comparing the use and disuse of DMA using MATLAB simulations.

2. RELATED WORK

This section introduces previous works that used clustering at intersections in VANETs. The main challenge at intersections is the high number of vehicles (N.O.V), which results in a large number of connections that increase network load, disconnections, flooding and packet drop. In [17] proposed a direction-based clustering algorithm to estimate vehicle density at intersections. The authors assumed that immobile vehicles do not disseminate information, which causes network disconnections. CHs must know CM information during this time.

In [18] proposed a real-time vehicular communication (RTVC) framework that enables stable communication among vehicles in urban and highway scenarios. In [19] proposed a multiagent-driven dynamic clustering scheme to dynamically form clusters and efficiently disseminate information after vehicles pass through intersections. In [20] proposed the cluster-based location service (CBLS) protocol to avoid sending and receiving upgrade and query packets from a location server (BSs).

In [21] proposed geographic routing over VANETs (GROOV) to select the best path to send vehicle information at intersections based on specific relay vehicles. In [22] introduced the nearest intersection location-dependent dissemination of traffic information (NILDD) to reduce channel congestion by forwarding traffic update messages to a specific destination. This method reduces the number of forwarded messages but duplicates messages sent to the BSs at intersections. In [23] proposed the traffic-aware intersection-based geographical routing (TIGeR) protocol to improve packet dissemination efficiency at intersections.

In previous [24] suggested an efficient road-based directional (ERD) broadcast protocol to disseminate vehicle information in all directions at intersections using a relay vehicle. This method disseminates vehicle information at intersections, but data continue to be duplicated which increases the number of unnecessary information sent to BSs. Most previous works that discussed intersection clustering did not focus on a number of duplicated messages sent from clusters to BSs. Therefore, the current study proposes a new method named DMA to avoid unnecessary information from being sent to BSs at intersections with no lost connections among vehicles. The DMA method uses a specific intelligent agent vehicle (IAV) that receives and stores cluster information for comparison with future information. The IAV drops duplicated information and only sends new information to the BS. Table 1 summaries previous studies.

3. RESEARCH METHOD

Based on related works, most of previous methods studied vehicles stop at intersection not focus on the load at BSs that result from number of uplinks connection and duplicated information sent from vehicles to the BSs. Therefore, to solve these issues proposed DMA method. The work of the DMA method starts after a cluster is formed therefore, the DMA method used the same cluster formation method as in [25]. In this study proposed the DMA method to control the uplink connections between BSs and CHs at intersections to prevent duplicated information from being broadcasted to BSs at intersections. Table 1 represent the related work.

Table 1. Summary of related works

Ref.	Method name	Problem	Purpose	Software	Simulated area	Outcome
[4]	Direction-based clustering algorithm	Data dissemination	Managing traffic at intersections	NCTUns tools	3000 × 3000 m	Decrease in packet flooding
[5]	RTVC	Maintaing message dissemination	Establishing stable communication among vehicles	NS 2	NaN	Lower overhead
[6]	Multiagent-driven dynamic clustering scheme	Link failures	Cluster formation	‘C’ programming	NaN	Controlled overhead
[7]	CBLS	Number of messages	Avoiding upgrade packets	OMNET++	2000 × 2000 m	Avoidance of network congestion
[8]	GROOV	Varying topographies	Selecting the best route at intersections	GloMoSim	1600 × 1600 m	Increased packet delivery ratio
[9]	NILDD	Updating traffic messages	Reducing channel congestion by forwarding traffic update messages	NS 2	5000 × 3000 m	Reduction in unnecessary bandwidth utilisation
[10]	TIGeR	Packet dissemination	Electing the best routes towards a destination	TraNS v1.2	3500 × 4000 m	Improved packet delivery ratio
[11]	ERD	Data dissemination	Increasing the chance of propagating data in all directions	NS 2	1200 × 600 m	Increased packet efficiency

3.1. DMA election

Each vehicle at an intersection broadcasts an intersection message (INT-MES) that contains information on CMs and the number of CHs (N.O.CH) within its TR. The vehicle with the highest N.O.CH broadcasts an agent beacon (AgB) to inform other vehicles to change their state to agent CH (ACH). If more than one vehicle has the highest N.O.CH, then the first vehicle to broadcast an AgB becomes the ACH. Other vehicles stop competing after receiving the AgB. Figure 1 shows a flow chart for ACH election. Table 2 shows the symbols used in this paper.

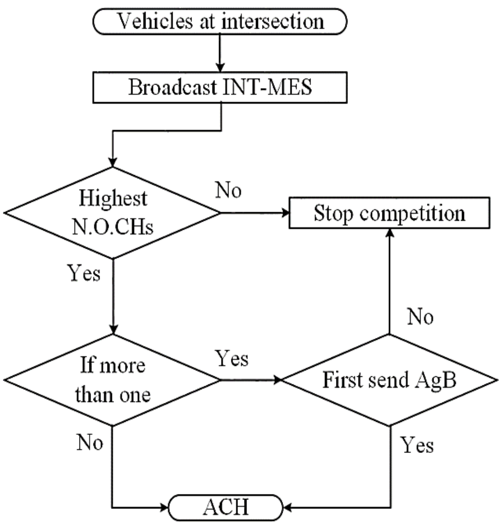

Figure 1. ACH election flow chart

Table 2. List of symbols

Symbol	Description
DMA	Dynamic multiagent
INT-MES	Intersection message
N.O.CH	Number of CHs
AgB	Agent beacon
ACH	Agent CH
BSCH	Base station CH
INCH	Inter-CH
ETM	End time messages
BS	Base station
TR	Transmission range
NL	Number of road lanes
d	Distance between two vehicles
VL	Vehicle length
$N.O.V$	Number of vehicles
CM	Cluster member
CH	Cluster head
W-DMA	Without dynamic multiagent
NPS-to BS-at intersections	Number of packets sent to BSs at intersections

3.2. ACH operations

The operation of ACH explain in the following stepes:

- After a vehicle becomes an ACH, it sends a message to stop other vehicles from trying to become the ACH and inform CHs to contact the ACH.
- The ACH broadcasts a message containing the ID of the CH with the highest receiving signal strength (RSS). If more than one CH has the same RSS, then the one closest to the BS is selected. When CHs receive this message, they check its ID. The CH with a matching ID remains connected to the BS and becomes a BS-CH (BSCH); otherwise, it disconnects from the BS and becomes an inter-CH (INCH). Clusters in this state send cluster information to the ACH and not to the BS. The INCH sends cluster information to the ACH every 3 s. The ACH filters this information by comparing it to previous information for the same cluster. ACHs drop vehicle information similar to information previously received from a cluster. The remaining INCH information is sent to the BS through the BSCH to prevent unnecessary messages and reduce the number of BS uplinks.
- When a traffic light turns green, ACHs send end time messages (ETMs) before a red traffic light changes to inform INCHs to re-establish communication with the BS before they move, after which the ACH returns to its previous state. Figure 2 shows a flow chart for ACH operations.

3.3. Benefit using ACH

The benefits of using ACHs are as follows:

- ACHs filter cluster information and remove duplicate CM vehicle information. Duplicate CH information is retained; thus, the BS can track the N.O.CH in the network.
- ACHs reduce the number of uplinks between CHs and BS at intersections by making only one CH (BSCH) connect to the BS. The BSCH relays CH information to the BS with the help of ACHs. Instead of every cluster within 300 m being connected, the use of an ACH means that only one cluster needs to be connected every 300 m when vehicles stop moving.

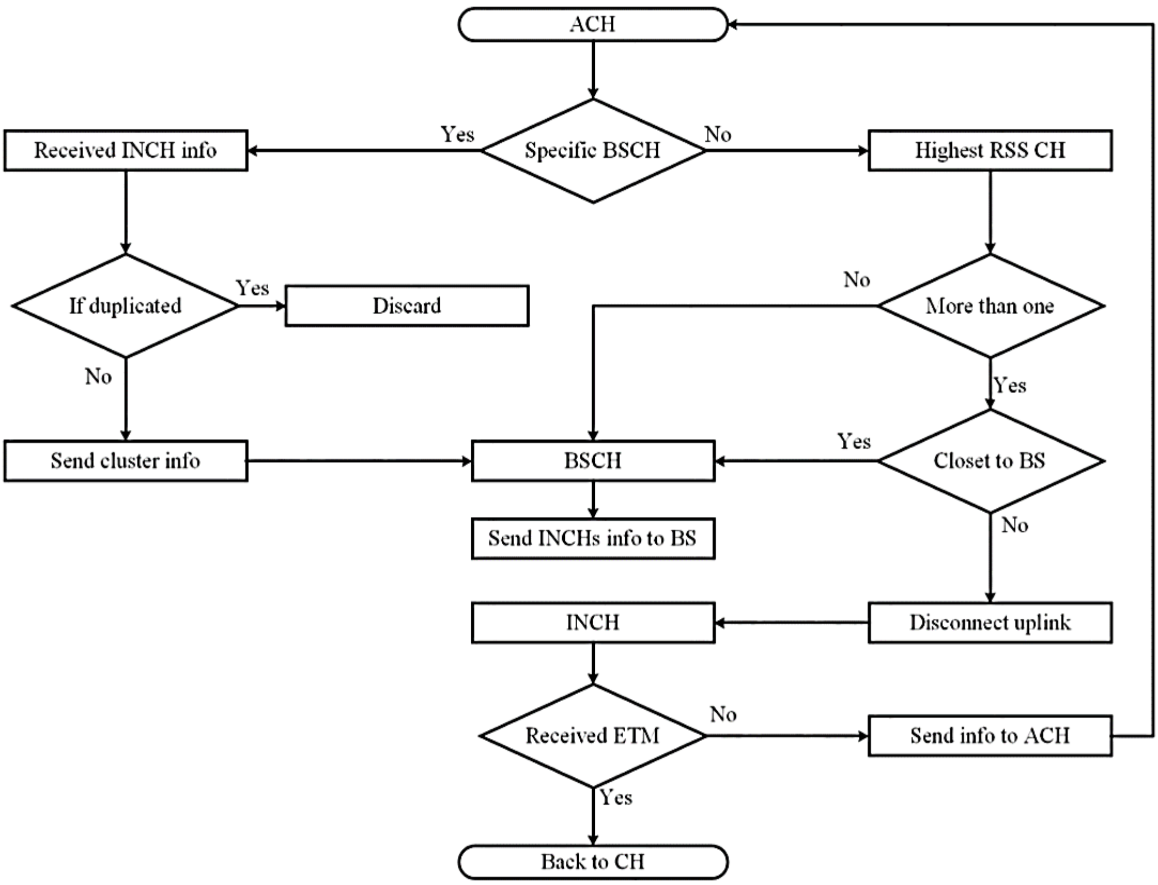

Figure 2. ACH operation flow chart

3.4. Reasons for using DMA at intersections and numerical analysis

Vehicles at intersections stop moving, which makes the information they send to CHs unimportant. Most of this information is duplicated, because vehicles do not change their speed, location, direction, relative distance and relative speed whilst they stop. Stopping vehicles from broadcasting their information also destroys networks, because each cluster must know the situation of its members. Using DMA at intersections solves these issues by preventing duplicated messages from being sent to the BS, thereby improving network efficiency.

Based on [26-28], TR was 300 m. The N.O.V within a TR was calculated by [29] using (1).

$$N.O.V = NL * \frac{TR}{d + VL} \quad (1)$$

This study focused on Batu Pahat City in Johor, Malaysia with a TR of 300 m and three lanes for each road (NL). The average vehicle length (VL) was 3 m. This study focused on times when roads were crowded; hence, the distance between any two vehicles (d) was 1 m. The N.O.V within a 300 m TR was as follows:

N.O.V = 3 * 300/(1 + 3) = 225 vehicles

each cluster at an intersection had 225 vehicles. A cluster had a limited number of CMs (maximum number of CMs in each cluster was 20) according to [21]. Therefore, these vehicles were divided into several clusters. The number of clusters (N.O.C) resulting from 225 vehicles was calculated by using (2).

$$N.O.C = \frac{N.O.V}{CMs + CH} \quad (2)$$

The N.O.C was 11, which meant that 11 uplinks exist within 300 m of each intersection. According to the Malaysian traffic light system, the minimum waiting time at an intersection is 30 s, with 3 s for standby (yellow light traffic) and a maximum waiting time of 99 s. The total waiting time at an intersection varied between 33 and 102 s. Each CH transmitted cluster information every 3 s in this study. The number of messages sent from each CH whilst waiting varied between 11 and 34, which made the total number of messages sent from 11 clusters in the same TR vary between 121 and 374. Most of these messages were duplicates, because vehicles had stopped moving. This condition led to reduced network efficiency and increased BS load. This study proposed the DMA method to solve these issues. The DMA aims to reduce the number of uplink connections that come from a large N.O.CH at BSs and to filter unnecessary cluster information by removing duplicated vehicle information from being resent to BSs.

4. SIMULATION

Cluster formation and CH election were based on our previous work in [25]. The current study provided an in-depth analysis of unnecessary messages from the use and disuse of DMA method at intersections based on real data. The data were collected by monitoring an intersection in Batu Pahat, Johor, Malaysia, that is, at Jalan Kluang, 83300 Sri Gading, Johor (1.85574, 103.01377) to Jalan Tanjong Laboh Batu 8 1/2, Johor, 83200 Senggarang, Johor (1.79225, 102.96596).

4.1. Simulation parameters

Evaluation and validation were performed according to the following parameters.

- For an intersection with 100 vehicles, the N.O.CH varied randomly between 1 and 4 for a 300 m TR.
- For an intersection with 200 vehicles, the N.O.CH varied randomly between 4 and 6 for a 300 m TR.
- For an intersection with 300 vehicles, the N.O.CH varied randomly between 6 and 8 for a 300 m TR.
- For an intersection with 400 vehicles, the N.O.CH varied randomly between 8 and 10 for a 300 m TR.
- For an intersection with 575 vehicles, the N.O.CH varied randomly between 9 and 11 for a 300 m TR.
- Crowded areas before an intersection were set as 300 m for the scenario with 100 vehicles, 300 m for the scenario with 200 vehicles, 600 m for the scenario with 300 vehicles, 900 m for the scenario with 400 vehicles and 1.2 km for the scenario with 575 vehicles. Table 3 shows a summary of intersection simulation parameters, and Table 4 shows a summary of network simulation parameters.

Table 3. Intersection simulation parameters

N.O.V	N.O.CH at intersection	Crowded area before intersection
100	1 to 4	300 m
200	4 to 6	(300-600) m
300	6 to 8	(400-700) m
400	8 to 10	900 m
575	9 to 11	1.2 km

Table 4. Simulation parameters used in the network

Parameters	Values
Average vehicle length	3 m
Space between cars	1 m when crowded and more than 4 m in other scenarios
Road length	17.8 km
Area of work	Batu Pahat, Johor, Malaysia between Jalan Kluang, 83300 Sri Gading, Johor and Jalan Tanjong Laboh Batu 8 1/2, Johor, 83200 Senggarang, Johor
Transmission range	300 m
Number of vehicles	100, 200, 300, 400 and 575
Time spent by vehicles at intersections	33 s to 102 s
Number of intersections	10
Data collection method	Arduino, external antenna, and GPS
Number of iterations	100

4.2. Result and analysis

This section presents an evaluation of the use (DMA) and without DMA (W-DMA) of the DMA method at intersections. The DMA method was used in this study to reduce the number of unnecessary messages that were sent from vehicles at intersections to BSs. Evaluation was conducted according to the number of packets sent to BSs at intersections (NPS-to BS-at Intersections) for different vehicle densities. Figure 3 shows the simulation results for 100 vehicles at an intersection with a TR of 300 m.

Figure 3 shows that when the DMA method was not used, more packets were sent to intersection BSs, because each vehicle sent scenario updates every 3 s. In contrast, when several vehicles were at an intersection, considerable information that was the same as a previous message was sent, thereby increasing the number of unnecessary messages. Using DMA resulted in a reduction in the number of messages being sent to intersection BSs, because DMA prevents duplicated messages from being resent. Without DMA, all CHs remained connected to intersection BSs. When DMA was used, only one uplink existed in every 300 m TR, which reduced the total number of uplink connections. With 100 vehicles at an intersection, the W-DMA method had five CHs, whereas the DMA system had one CH. Table 5 shows the average reduction percentage for 100 vehicles with DMA.

Table 5 shows that the number of sent messages depended on the number of times that vehicles stopped at the intersection. Therefore, the number of messages sent increased with increased stop time for both methods. However, DMA showed an average reduction percentage of 59.42% less than that of W-DMA. According to [30], an increase in N.O.V results in an increase in the number of uplink connections. Figure 4 shows the simulation results for 200 vehicles at an intersection.

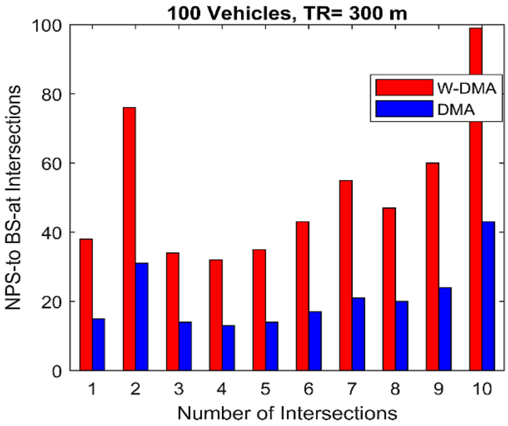

Figure 3. NPS-to BS-at intersections when TR=300 m and N.O. V= 100

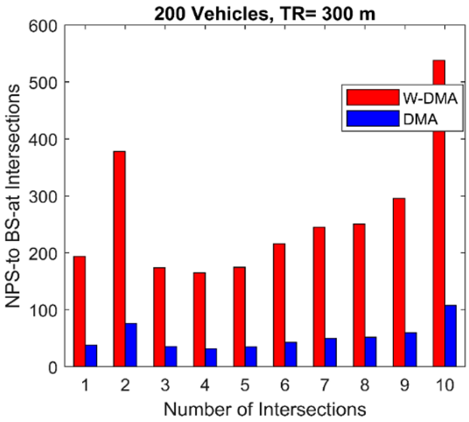

Figure 4. NPS-to BS-at intersections when TR=300 m and N.O. V= 200

Figure 4 shows that an increase in N.O.V to 200 at intersection resulted in an increase in the number of uplinks for W-DMA, because each cluster had the maximum number of CMs. Therefore, the N.O.CH with 200 vehicles was 10 for W-DMA. When using DMA, only one uplink connection existed, because the 10 CHs connected to 1 DMA vehicle that filtered messages sent to the BS. The number of sent messages in both methods increased, although DMA had fewer sent messages than W-DMA. Table 5 shows the average reduction percentage for 200 vehicles with DMA. Table 5 shows that the use of the DMA method reduced the messages sent to BSs by 80% compared with the W-DMA method. This result was caused by the 200 vehicles that were stopped at the intersection; these vehicles were divided into 10 clusters, and each cluster had 1 CH that was responsible for connecting to the BS. When using DMA, these 10 CHs connected to 1 DMA, and only this DMA connected to the BS. Therefore, using DMA reduced the number of uplinks from 10 to 1 at intersections in addition to removing duplicated vehicle information through filtering. Figure 5 shows the simulation results for 300 vehicles at an intersection for both methods.

In Figure 5, the increased N.O.V at an intersection led to an increased number of uplink connections, which resulted in an increased number of messages. However, DMA showed fewer uplink connections than the W-DMA method, because each cluster had the maximum number of CMs in the W-DMA method. Therefore, the N.O.CH within a 300 m TR was 15. The use of DMA reduced the number of uplink connections to 2, because each DMA had 11 CHs. One DMA had 11 CHs, whereas the other had 4 CHs. W-DMA did not control messages, which resulted in many messages being sent to the BS. The use of DMA reduced the number of the sent messages, because DMA filtered out duplicated messages from immobile vehicles. Table 5 shows the average reduction percentage for 300 vehicles with and without DMA.

Table 5 shows that the use of DMA reduced the messages being sent to the BS by 86% over W-DMA. When using DMA with 300 vehicles, only 2 DMAs sent information to BSs. By contrast, the W-DMA method resulted in 15 uplink connections sending necessary and unnecessary information to BSs. In crowded conditions, the N.O.V on the specific road covered by this study increased to 400 vehicles, which increased the N.O.V stopped at intersections. Therefore, this section focuses on the analysis of 400 vehicles at an intersection, as shown in Figure 6.

Figure 6 shows that the increase in N.O.V to 400 at an intersection resulted in an increase in the number of messages sent to BSs because of the increase in the number of uplinks. However, the number of increased messages for the W-DMA method was greater than that for the DMA; the W-DMA method had 20 uplink connections, whereas the DMA had 2. The messages sent by the W-DMA method contained necessary and unnecessary information. In DMA, only necessary information was sent to intersection BSs. Table 5 shows the average reduction percentage for 400 vehicles with and without DMA.

Table 5 shows that the use of DMA reduced the number of messages sent to BSs by 89% compared with W-DMA. When using DMA with 400 vehicles, only 2 DMAs sent information to the BSs. In the W-DMA method, 20 uplink connections sent necessary and unnecessary information. In crowded conditions, 575 vehicles existed at an intersection, which resulted in considerable uplink connections and messages being sent to BSs. Figure 7 shows the effect of 575 vehicles being present at intersections.

Figure 7 shows that the increased N.O.V at an intersection resulted in an increased number of uplinks and sent messages for both methods. The number of uplinks was 3 when using DMA, whereas it was 29 for W-DMA. Increased uplinks resulted in an increased number of messages being sent to intersection BSs. The increased stop time of vehicles (red light traffic) at the intersection also increased the number of messages being sent to BSs. Table 5 shows the average reduction percentage for 575 vehicles with and without DMA. Table 5 shows that the use of DMA reduced the amount of messages sent to BSs by 90% compared with W-DMA. Only 3 DMAs sent necessary information to BSs when using DMA with 575 vehicles, whereas 29 uplink connections sent necessary and unnecessary information in the W-DMA method.

Table 5. Reduction percentage in packets sent at intersections form 100 to 575 vehicles

No.	100 vehicles	200 vehicles	300 vehicles	400 vehicles	575 vehicles
1	60.53%	80.41%	85.93%	89.00%	90.05%
2	59.21%	79.89%	85.38%	89.06%	90.00%
3	58.82%	79.31%	85.77%	88.92%	89.98%
4	59.38%	80.61%	85.32%	88.98%	90.06%
5	60.00%	80.00%	85.54%	88.86%	89.98%
6	60.47%	80.09%	85.67%	88.91%	89.99%
7	61.82%	79.59%	85.79%	89.04%	89.92%
8	57.45%	79.28%	85.83%	89.03%	89.99%
9	60.00%	79.73%	85.86%	88.87%	89.92%
10	56.57%	79.93%	85.81%	88.98%	89.96%

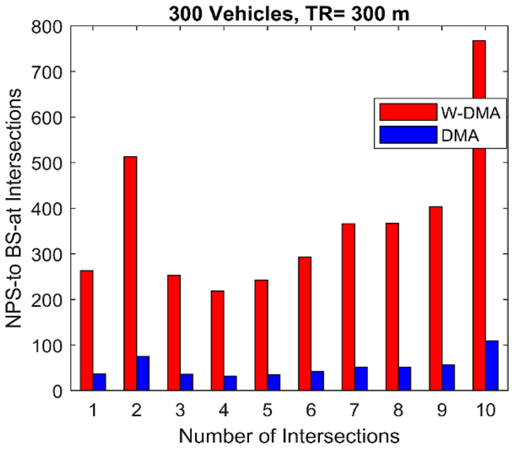

Figure 5. NPS-to BS-at intersections when TR=300 m and N.O. V=300

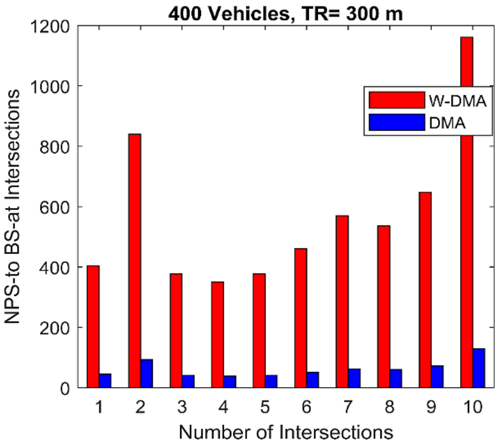

Figure 6. NPS-to BS-at intersections when TR=300 m and N.O. V=400

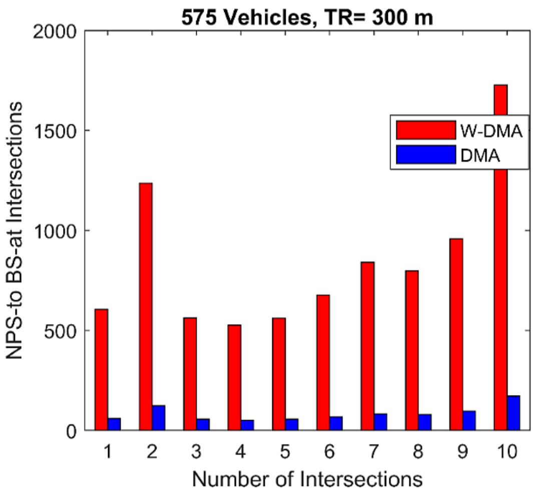

Figure 7. NPS-to BS-at intersections when TR=300 m and N.O. V=575

5. CONCLUSION AND FUTURE WORK

This study proposes the DMA method to avoid duplicated information from being sent to BSs at intersections to reduce unnecessary messages in VANETs. The DMA uses IAVs, which are vehicles that receive and store information from a large N.O.CH. The IAVs compare their stored information with the contents of new messages to eliminate duplicated information and ensure that only new information is sent to BSs. In this method, CHs continue to receive information from CMs, although they have stopped moving at an intersection to prevent network disconnections. BSs receive only new information from CHs. Evaluation was conducted using MATLAB software. The evaluation of this study investigated the use (DMA) and disuse (W-DMA) of the proposed method at intersections. The results show that the DMA method reduces the average amount of unnecessary messages by 81% compared with the W-DMA method. Future works can analyse and evaluate DMA's performance in scenarios in which vehicles move among intersections in reducing unnecessary information and under highway conditions.

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