IOP Conference Series: Materials Science and Engineering

PAPER • **OPEN ACCESS**

A New Deployment Schema Using Dynamic Relay Vehicle to Improve VANETs Connectivity in Urban Environment

To cite this article: K D Ibrahem *et al* 2021 *IOP Conf. Ser.: Mater. Sci. Eng.* **1076** 012035

A New Deployment Schema Using Dynamic Relay Vehicle to Improve VANETs Connectivity in Urban Environment

K D Ibrahem[1], A N Rashid[1] and F S Mubark [1]

[1] College of Computer Science and Information Technology, University of Anbar, Iraq

E-mail: Krmeald.ibrahem@gmail.com

Abstract. Vehicular ad-hoc network (VANETs) have emerged as promising technology to support traffic safety applications of intelligent transportation system (ITS). One of the most important challenges facing VANET is the connectivity, due to obstacles, high mobility, dynamic topology which leads to disconnection problem. Deploying road Sid unite (RSU) to improves VANET connectivity is considered as a highly cost solution. Previous researches suggested diverse RSU deployment schemes and algorithms to solve the RSU deployment issue in order to achieve better network connectivity with minimum number of RSU. In this paper we propose dynamic relay node as replacement to RSU with zero infrastructure. It's Using key metrics of interest (such as connection duration, re-healing time, receiving time) we provide thorough visualization for network connectivity of urban VANETs with dynamic relay node. It is not only a low-cost solution, but it is practical solution since it does not require RSU installation or maintenance. Simulations are carried out in ns2 to evaluate the performance of dynamic relay node in urban environment. The proposed scheme proves its efficiency through increasing the vehicle density in the road and by increasing relay vehicle velocity. The result shows that the proposed scheme improve the network connectivity as the number of relays increased up to four dynamic relay nodes.

Keywords: relay node, dynamic connectivity, network connectivity, connection duration, re-healing time, VANET, RSU, Network.

1. Introduction

Network connectivity is an important aspect of VANET technologies. An advantage in VANETs is that all the nodes can act as sender, receiver and routers to forward the safety message without any additional infrastructure. Recently, there are a lot of significant VANET applications. For instance, a number of applications are ranging from the dangerous medical services to the comfort activities. VANETs must have the ability for fulfilling all requirements of the constantly changing requirements of users and must be complying with architectures and standards of available technologies [1] The main aim of using VANETs have been reducing accidents level. This is because the high impact on the safety of passengers and for driving smoothly via drivers in urban area. With the increase in vehicles population, there will be also increase in accidents rate, thus there is necessity for communications between vehicles [2]. The intelligent transportation system (ITS) can help drivers on the road to react in a hazard situation. ITS provides a solution to alleviate traffic congestion and improves public safety objectives such as collision avoidance. The allocation of 75MHz in the 5.2GHz band for licensed dedicated short range

communication (DSRC) delivers high media contents to (v2v) communications [3] V2V communication avoid costly RSU installations and take advantage of the VANET for the delivery of traffic information, but it should carefully control the additional transmission overhead caused from multi-hop communications by improving bandwidth usage and by possibly involving the lowest number of hops [4]. By the V2V communication, the vehicle's driver can receive a warning message from another vehicle when there is any hazard situation or risk of accident portability in the surrounding region to take emergency braking or any reaction to prevent and avoid the accident [5].
Generally, drivers are having inadequate information related to the conditions of roads, locations, and speeds of vehicles around them. They are also urged for making certain decisions such as lane changing and breaking with no awareness regarding the nearby environment areas. Communications between the vehicles or between the vehicles as well as the roadside infrastructure might be updating this information rapidly and improving the safety of traffic. For instance, if a vehicle identifies accidents in advance, it is going to be broadcasting warning messages to surrounding vehicles. Furthermore, the vehicles behind them are therefore warned prior to entering accident zone, also it is going to be helping drivers for acting in fast way and choosing alternative routes as well as avoiding traffic congestions [6].

2. Related work

In this section, the related work discussed either suggest improving connectivity through using vehicles as RSU or suggesting RSU deployment strategies. In W. Viriyasitavat et al. [7] suggested solutions which can be migrating bad effect of gradual and partial penetrations problem regarding the DSRC technologies. The suggested solution was on the basis of self-organizing network paradigms which draw the inspirations from the biological systems, like the social insect colonies through developing local rules as well as distributed algorithm required for performing such function, it has been indicated that the cars equipped with DSRC might be serving as RSUs. In D. Ou et al. [8] a connectivity-oriented maximum coverage RSU deployment scheme(CMCS). The proposed scheme aims to maximize V2I communication performance in urban areas. The results show that the CMCS is able to cover the majority of vehicles on the roads and increase communication performance with fewer RSUs.
M. Fogue et al. [9] suggests a genetic algorithm for roadside unit deployment (GARSUD), that applies the genetic algorithm as the ability of automatically offering RSU deployments adequate for certain road map layouts. The study's results of simulation showed that GARSUD has showed the ability of reducing warning notification time (which is considered as the time needed for informing emergency powers that be regarding the dangerous situations of traffic) as well as for improving vehicular communication abilities in various density cases as well as complexity layouts.

A. B. Reis et al. [10] present a methods for parked cars to self-organize and act as a support network to the existing urban vehicular network. Such method enabling the parked cars in creating coverage maps on the basis of received signal strength, also making significant decisions, like in the case when parked cars serving as RSUs. The result shows that even a small number of parked cars can bring considerable improvements to the network, and that our proposed methods for self-organization create support networks of parked cars that can cover the urban area with an optimal number of vehicles.

C. Sommer et al. [11] combined between simulation and experiment in real life to extended the connectivity through using the parked vehicle, and this is done by covering the disconnectivity network problem. The paper assure that the cooperative awareness increased by 40% by using parked vehicles as a relayer.

in J. Barrachina et al. [12] the author presents a Density-based Road Side Unit deployment policy (D-RSU), particularly developed for obtaining effective system with minimum costs for alerting the emergency services when accidents occur. Their method has been on the basis of using RSUs with inverse proportions to vehicle's expected density. The results are showing that D-RSU has the ability for reducing needed number regarding RSUs, in addition to the notifications time for the accidents.

IOP Conf. Series: Materials Science and Engineering 1076 (2021) 012035 doi:10.1088/1757-899X/1076/1/012035

In Y. Liu et al. [13] a new RSUs deployment strategy for the VANET's content downloading. encounters between RSU and vehicles were modeled as time continuous homogeneous Markov chain. also, the deployment algorithm of RUS has been developed on the basis of the algorithm of depth-first traversal with regard to the graph's edges. The results of simulations showing that the suggested deployment algorithm of RSU might be satisfying file downloading service necessities with minimum deployment costs of RSU

3. Problem statement

According to the U.S. Department of Transportation, the nationwide deployment of RSU is expected to be completed in 2008. However, until now this goal has not been achieved and there are a number of obstacles that were a reason preventing the success of the plan can be summarized as follows:

3.1. The constraint of RSU deployment

There are several difficulties to determine advantages of using RSU. Because of innovative nature related to the technology of DSRC, general adoptions through market has required so that entire advantages related to technology might be achieved. Also, it must be indicated that these economic justifications are extra difficult in the case when certain roadside infrastructures to display the traffic information like Dynamic Message Sign (DMS) [14]. The continuous cooperation and the coalitions regarding public (city authority, federal agencies, and so on), also private (manufacturers of cars and certain other companies) sectors have been required. Like indicated till recently, such cooperation was unconsummated [15]. Suitable financial investments are considered the main issues in general deployments regarding the roadside infrastructures since investments billions of dollars are needed to install 200*;* 000 – 250*;* 000 RSUs [16]. A lot of RSUs have been required and costly: Communication ranges regarding the DSRC has been restricted to 100-300m that indicate a lot of RSU have been required for establishing comfortable communication in nodes. To implement more RSUs have been very costly.

Link disconnections: which is other disadvantage regarding RSU communication models has been the link's disconnections among nodes. All nodes must be connected with DSRC signal for disseminating messages efficiently among nodes. Due to the fact of mobility patterns related to VANETs nodes have been elevated, nodes are going to be often disconnected from DSRC signal range.

RSU Failure: Message transmissions in nodes has been potential just via RSUs. A case must be considered, in the case when anyone of RSU getting failure whole network is going to be collapsed. All nodes under specific RSUs won't be under coverages, also such nodes will not get information like warning alert messages, emerging messages from other nodes. RSUs are going to be slowing down with the multiple service request. With regard to such communication architectures, RSUs acts as servers in the responding back to nodes. Regarding the high density of network topologies, a single RSU receives multiple requests from nodes simultaneously. With regard to such condition, working process that is related to RSU will not be slowing down that is going to degrade communication performances in nodes. With simultaneous multiple requests, RSUs won't be having the ability for responding back to all nodes as well as service requests might be dropped.

3.2. Funding constraints

VANETs were created for a lot of applications, like entertainment, transport efficiency, traffic safety warnings, as well as information [17]. Based on certain report, specified (V2I) safety applications might be addressing about 2.3 million crashes, which correspond to $202 billion in the costs; the systems of V2I might be addressing 25% regarding all the light-vehicle crashes as well as 14% regarding all the heavy-vehicle crashes [18]. RSUs enabling the drivers not just being informed about surrounding real-time traffic conditions, yet for accessing infotainment services or internet in vehicles [19, 20].
U.S. Department of Transportation (DoT) expected a general deployment regarding RSUs supporting infrastructures with regard to vehicular networks to be occurred in 2008[21]. Such anticipation was not seen by the light due to problems in justifying RSU advantages, no cooperation between private as well

as public sectors, yet majorly, no funding with regard to infrastructure that the widespread deployments have estimated for costing billions of dollars [22]. Industry survey in 2012 through Michigan's DoT as well as Center for Automotive Research reiterated that "a major challenge seen by respondents to broad adoptions regarding connected vehicle technologies has been funding with regard to the roadside infrastructures." [23]. The cost to add various types related to infrastructure has been very variable. For instance, install wired base stations which have been connected to Internet might be lowering delays; yet they are requiring expensive power installations as well as wired network connectivity such costs might be 5,000$ for each one of the base stations [24].

4. The proposed solution: dynamic vehicle as RSUs

In this paper We proposed a solution of normal vehicles are used as temporary RSU. a number of vehicles is selected to work as temporary roadside unit relaying safety messages to nearby vehicles and acting as a communication bridge for other vehicles in the network. In the VANETs environment each vehicle plays a sender, receiver, and router role to forward the messages to nearby vehicles. In the proposed system. It assumes that all vehicles are equipped with on board unit (OBU) that enables vehicles to communicate with each other. in addition, each vehicle is installed with the Global Positioning System (GPS) which enables the vehicle to announce their location in the environments. When a vehicle automatic system detects any dangerous situation, a message will be generated.

This message will be broadcasted to all neighbor vehicles up to 250m transmission range. There are many applications of the VANETs and each one requires a different solution. For the case study of the research, this work adopted a specific problem to find the solution by proposing a practical and cheap explanation for it. Post-Crash Notification (PCN) considers as a case study where the vehicle with an accident should notify all the neighbor vehicles for avoidance congestion. The target of the PCN system is disseminating the safety message (information about the location of the accident and its time occurring and others) to all vehicles within the Region of Interest (ROI). This dissemination of the message should be short and does not take long time.

4.1. Dynamic Relay node selection algorithm

When the source vehicle generates a safety message to send, it firstly searches to the vehicles who will temporarily take the role of RSU. Then, it will disseminate the safety message to all neighbor vehicles with rebroadcasting order to the selected relay vehicles. When selection program starts, it will search all directions to select one relay vehicle, based on vehicles coordinates, the position of the vehicles will be identified. Then the program will calculate the distance between the source vehicle and destination vehicles, by using the Euclidian distance equation the distance that will be calculated. The program will search for the vehicle with less distance rather than Radius which represent source transmission range and then choose the farthest one as relay vehicle. This selection process will be repeated four times, one time in each direction of the source vehicle.

Algorithm 1: Relay Node selection
Input: X axis , Y axis, number of node ,transmission range
Output: 4 relay nodes

Begin
- Distributed random node
- Select the position of center node
- Get informations (neighbor)
- fgGet_ Position (neighbor)
//From GPS get information about the neighbor nodes within a transmission range

- Identify node direction in each side of source node with respect to its coordinate X, Y of_nodes axis
- Calculate Euclidian distance between nodes in this side and surce nodes:
  - *Ecludain = sqrt((X_of_nodes - xcenternode).^2+ (Y_of_nodes - ycenternode).^2*
- Choose the nodes less than Radius
  - *Select_Node=find (distance <radius)*
- Choose farthest node and assume as relay node in this side
  - *Index_Ecludain =max (distance (select_node))*

END

We demonstrate the relay node selection using Matlab as simulator. The main aim is to evaluate the efficiency of proposed system in term of selecting four normal nodes to works as relay node based on each node position and movement direction. The scenario, were implemented in the simulation, are a network with one static node in reed color as the source node in the top center of the network and 250 dynamic nodes in black color. Shown in Figure 1 the simulation area is 1000x1000 with 250m as transmission range. The objective of this scenario is to test the capability of the source node to select four relay nodes, each one in different direction. In our work, we only consider v2v communication between the source node and distention nodes. After the simulation begin four nodes in green color are selected as relay node with 90 angle between them with respect to the source node.

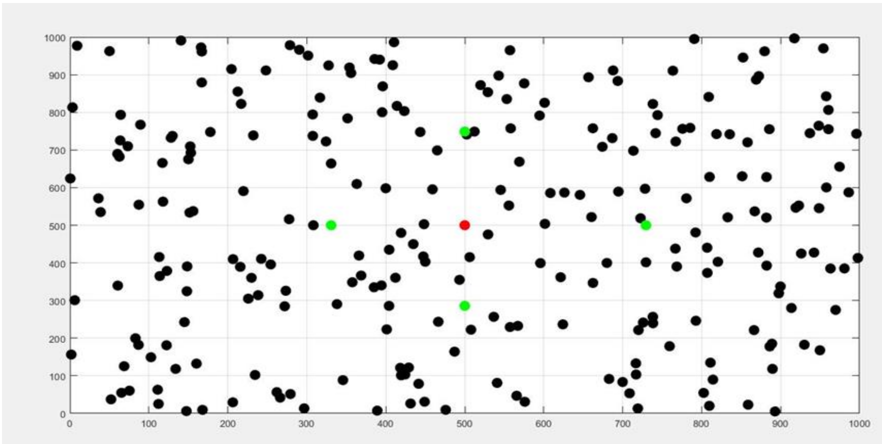

Figure 1. The source node with four selected relay nodes.

5. Simulation Sitting and Results

The process operates by exchanging the safety message with relay vehicle in order to rebroadcast it to the neighbor vehicles moving toward scene of accident in the road. To evaluate the performance of the proposed solution three metrics are chosen each one of them are considered as an important metrics in dynamic connectivity.

Table 1. The parameter used in our system.

PARAMETERS	Simulation Value
SIMULATION ENVIRONMENT	Ubuntu 14.04
SIMULATOR	NS-2.35
SIMULATION TIME	300 Second
ANTENNA MODEL	Omni directional antenna
TRANSMISSION RANGE	250 m
MAC TYPE	IEEE 802.11p
INTERFACE QUEUE TYPE	Drop tail
NETWORK INTERFACE TYPE	Wireless Phy
RADIO PROPAGATION MODEL	Two Ray Ground
SIMULATION AREA(TOPOLOGIES)	1000 X1000 m
PACKET SIZE	1500KByte
NO. RELAY NODES	
FOR VARYING VEHICLE DENSITY	1, 2, 3, 4
NO. OF VEHICLES	20, 40, 60, 80, 100
MOBILITY OF VEHICLES	Random real time urban
RELAY VEHICLE VELOCITY	topology velocity
	10, 20, 30, 40, 50 km/h

5.1. Average connection duration verses network density

Connection duration depicts the continuous duration of time in which two vehicles are connected over a single- or multi-hop route. It is an important metric since it is determining how long current communication paths last between pairs of vehicles and thus determines the applications that can be supported by VANET.

The simulation result in Figure 2 shows that for extremely low network density (20 vehicle), the vehicles are usually disconnected; therefore, the number of connection periods is small. As the network density increases to 60 vehicles, the network begins to be connected. As well as the number of relay node increased the connection duration improved this is because more relay node means more vehicle connected in the network. The connection between two vehicles last for longer time. These results show that unless the vehicle density is above a certain number (60-80veh in this case), vehicular ad hoc networks can support a very limited number of applications.

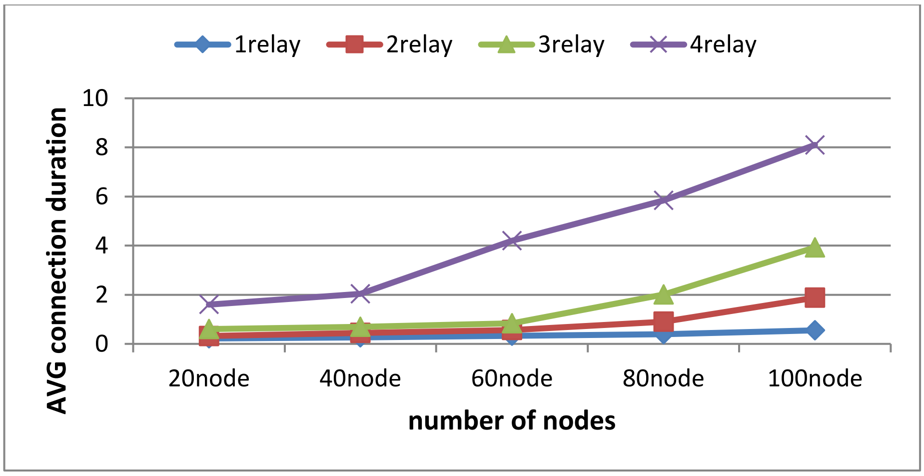

Figure 2. Impact change on number of vehicles respect to connection duration.

5.2. Average connection duration verses relay vehicles velocity

The performance of relay node with regard of connection duration is improved as the velocity of relay increases. Simulation result for the effect of relay node velocity varying on connection duration is shown in Figure 3. The proposed system keeps its efficiency as increased the number of relay nodes. It's clear that increasing relay node velocity does not decrease connection duration as we can see in Figure 3.

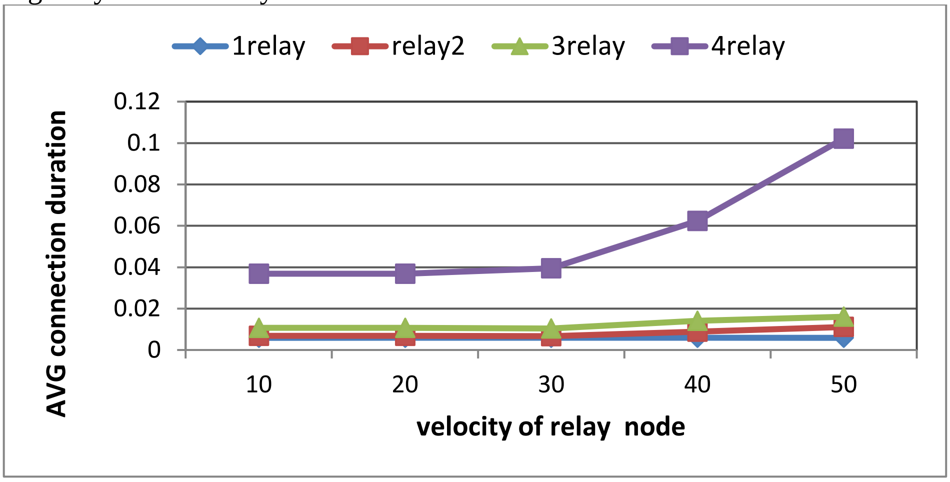

Figure 3. Impact change on velocity of relay vehicles respect to connection duration.

5.3. Effect of network density on re-haling time

Time period between two connection established between pair of vehicles that is called re-healing time. It is fundamental to analyze for how long these periods are separated,
or how long the connectivity will take to re-heal.

We tested the re-healing time by measuring the time between two connected period. The result of increasing network density to the re-healing time is showed in Figure 4. we see in the graph re-healing time in one relay node significantly drops as the density increases. In one relay the re-healing time is the largest because the number of relays is low this will decrease network connectivity and increase time between every two connection. This is essentially due to the fact that when network density increases, there are a higher number of potential connected vehicles. Thus, once a sender and a receiver in such a network are disconnected, these two vehicles take very small amount of time to re-heal and become connected again. When network density and number of relay nodes increase from 20 to 100 and from 1 to 4, network connectivity improved which decrease re-healing time.

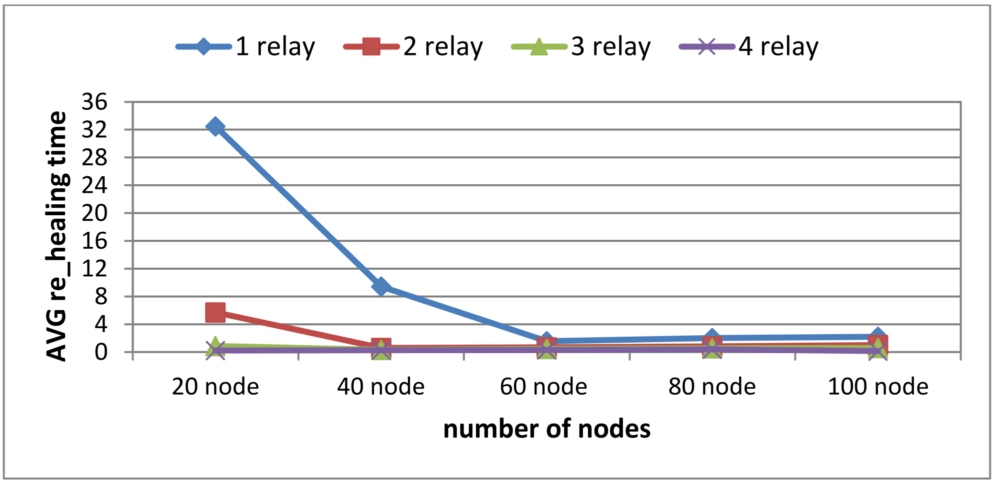

Figure 4. Impact change on number of vehicles respect to re-healing time.

5.4. Effect of relay vehicle velocity on re-healing time

The speed of vehicles and the re-healing time increased in parallel with one and two relay node in the network when relay speed increases over (30km/h in this case), Figure 5 shows that increasing relay velocity has no effect in the four and three relay node scenario while there is a negative impact in one and two relay node case. increasing relay velocity with disconnected network decrease the chance to find destination node which make re-healing time increased.

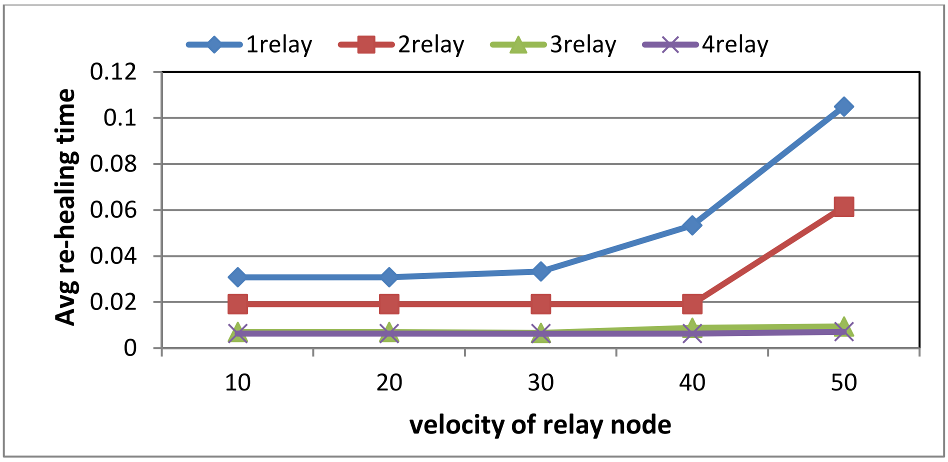

Figure 5. Impact change on velocity of relay vehicles respect to re-healing time.

5.5 Effect of network density on receiving time

Receiving time represent the average of set of all receiving time. This metric shows the efficiency of using relay node in avoiding latency. One of the essential goals of this work is to enhance network connectivity through decrease time at which message received. Improving receiving time decrease latency enhance the overall network performance. From the Figure 6, it is clear the performance of relay node with regrading receiving time in high density is better. Relay node keeps its efficiency as increased the size of the network. With one relay node receiving time is high, this is because it's hard to find destination node in disconnected network. The receiving time keeps lowering as relay node number increased, As well as network density. Four relay nodes have the lowest average of receiving time than other number of relay.

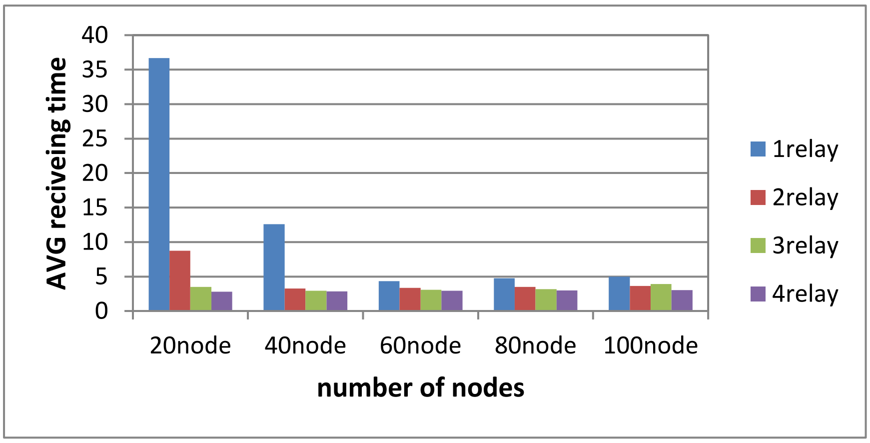

Figure 6. Effect of Network Size on receiving time.

5.6. Effect of velocity on receiving time

It is highly prone to connection breakages and take longer time to connect when the network topology becomes more dynamic. Figure 7 shows that increasing velocity has a higher effect on receiving time with disconnected network scenario. For one relay network with four relay nodes responds better to the changes of the network topology and keeps a lower rate of receiving time, we can see the average receiving time decrease as the velocity of relay increase.

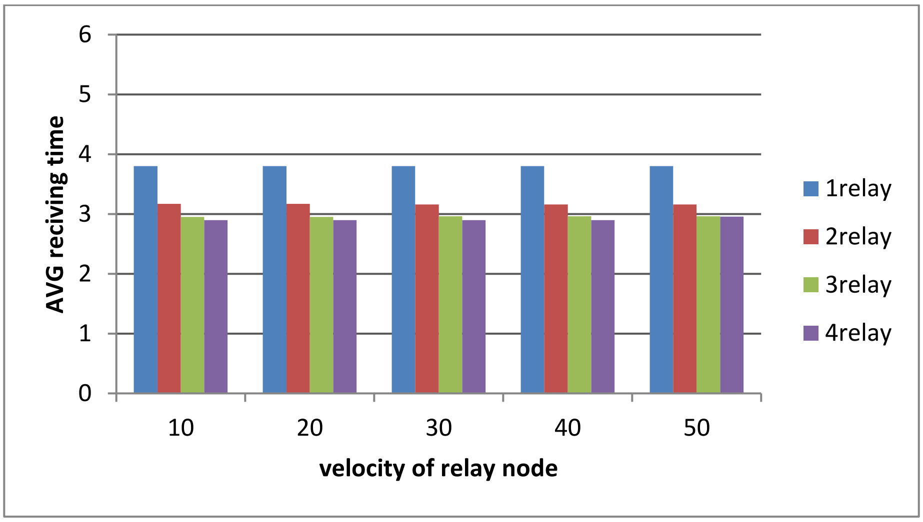

Figure 7. Effect of relay velocity on receiving time**.**

6. Discussion the results and conclusion

The proposed system considered Promising solution for RSU limitation in the road and High cost related to RSU installation and maintenance. As such, the main idea behind the proposed solution is to exploit normal dynamic vehicle to work as temporary RSU without additional equipment or infrastructure. In order to increase VANET connectivity 4 relay node selected based on their positions and movement direction, our proposed system proves the ability to increase network connectivity every time the relay number increase. And this is because each relay node works as a router to deliver the safety message to the destination node, the whole network nodes considered as participating nodes. While the network density is an essential factor affecting connectivity of VANET, connectivity between relay node and distention node significantly change with network density increases. Another interesting finding is that connection duration improves in conjunction with relay speed increases.

When we compared our results with the paper published by W, Viriyasitavat et al [7] the paper discussed the effect of using normal vehicle as a replacement to RSU in the urban environment, the study used only one relay node in a random direction. The main drawback of this studying is the limited area covered by relay node, which is only one direction of the accident site. In addition, the study used only one relay node which could reach a small number of vehicles.

Finally, dynamic relay node proves its good performance due to have lower financial cost as it depends on normal dynamic vehicle only. There is still room to improve VANET connectivity through implementation With more relay node, increased simulation area and testing on larger network density It will expand the size of the covered area.

References

[1] S. Ur Rehman, M. A. Khan, T. A. Zia, and L. Zheng, "Vehicular Ad-Hoc Networks (VANETs) - An Overview and Challenges," *J. Wirel. Netw. Commun.*, vol. 3, no. 3, pp. 29–38, 2013.
[2] S. K. B. and P. M. Khilar, "'Vehicular communication: a survey,'" *IET Networks, vol. 3, no. 3, pp. 204-217,* 2014.
[3] F. Hoque and S. Kwon, "An Emergency Packet Forwarding Scheme for V2V Communication Networks," vol. 2014, 2014.
[4] G. Martuscelli, A. Boukerche, L. Foschini, and P. Bellavista, "V2V protocols for traf fi c congestion discovery along routes of interest in VANETs : a quantitative study," no. September, pp. 2907–2923, 2016.
[5] R. Baker, Stephen, Cole, "Brilliant Project Management," p. 200, 2015.
[6] F. Barbir, "Chapter 1 - 1. Introduction," *PEM Fuel Cells*, pp. 1–16, 2005.
[7] W. Viriyasitavat, W. Viriyasitavat, and O. K. Tonguz, "Cars as Roadside Units : A Cooperative Solution Cars as Roadside Units : A Cooperative Solution," pp. 1–5, 2012.
[8] D. Ou, Y. Yang, L. Xue, and D. Dong, "Optimal Connectivity-Based Deployment of Roadside Units for Vehicular Networks in Urban Areas," no. 2559, pp. 46–56, 2016.
[9] M. Fogue, J. Sanguesa, F. Martinez, and J. Marquez-Barja, "Improving Roadside Unit Deployment in Vehicular Networks by Exploiting Genetic Algorithms," *Appl. Sci.*, vol. 8, no. 1, p. 86, 2018.
[10] A. B. Reis and S. Sargento, "Leveraging {Parked} {Cars} as {Urban} {Self}-{Organizing} {Road}-{Side} {Units} - {IEEE} {Conference} {Publication}," 2015.
[11] C. Sommer, D. Eckhoff, and F. Dressler, "IVC in cities: Signal attenuation by buildings and how parked cars can improve the situation," *IEEE Trans. Mob. Comput.*, vol. 13, no. 8, pp. 1733–1745, 2014.
[12] J. Barrachina *et al.*, "Road side unit deployment: A density-based approach," *IEEE Intell. Transp. Syst. Mag.*, vol. 5, no. 3, pp. 30–39, 2013.
[13] Y. Liu, J. Ma, J. Niu, Y. Zhang, and W. Wang, "Roadside units deployment for content downloading in vehicular networks," *IEEE Int. Conf. Commun.*, pp. 6365–6370, 2013.
[14] Xiangheng Liu, A. Goldsmith, S. S. Mahal, and J. K. Hedrick, "Effects of communication delay on string stability in vehicle platoons," pp. 625–630, 2002.
[15] R. J. Weiland, G. Farber, W. Harris, C. Johnson, R. Mudge, and D. Robertson, "The Roadway INFOstructure Providing for The Roadway INFOstructure," no. November, 2003.
[16] P. M. Khilar and S. K. Bhoi, "Vehicular communication: a survey," *IET Networks*, vol. 3, no. 3, pp. 204–217, 2014.
[17] Q. Xu, T. Mak, J. Ko, and R. Sengupta, "Vehicle-to-vehicle safety messaging in DSRC," p. 19, 2004.
[18] Federal Highway Administration, "Crash Data Analyses for Vehicle-to- Infrastructure Communications for Safety Applications," no. november, p. 84, 2012.
[19] J. Ott, D. Kutscher, I. Informatik, and T. Z. I. Universitat, "Drive-thru Internet : IEEE 802 . 1 1 b for ' Automobile ' Users," pp. 362–373.
[20] H. T. Cheng, H. Shan, and W. Zhuang, "Infotainment and road safety service support in vehicular networking: From a communication perspective," *Mech. Syst. Signal Process.*, vol. 25, no. 6, pp. 2020–2038, 2011.
[21] US Department of Transportation, "VEHICLE INFRASTRUCTURE INTEGRATION (VII) VII Architecture and Functional Requirements Version 1.1," *Integr. Vlsi J.*, no. Vii, p. 88, 2005.
[22] A. B. Reis, S. Sargento, and O. K. Tonguz, "Parked Cars are Excellent Roadside Units," *IEEE Trans. Intell. Transp. Syst.*, vol. 18, no. 9, pp. 2490–2502, 2017.
[23] Center for Automotive Research, "Connected Vehicle Technology Industry Delphi Study," p. 30, 2012.
[24] N. Banerjee, M. D. Corner, D. Towsley, and B. N. Levine, "Relays , Base Stations , and Meshes : Enhancing Mobile Networks with Infrastructure Categories and Subject Descriptors."2008