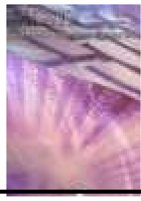
DSR Design for Scientific RENAISSANCE



Vehicular Ad Hoc Network Clustering

Wurood Hallem Jawad.
Department of Computer Science College of Science for Women

University of Babylon Babylon Iraq

Wurood.jawad@student.uobabylon.edu.iq

ISSN (Printed): 2314-7350
ISSN (Online): 2231-8852

Abstract VANET is modern and effective networks to manage the communication between cars and city infrastructure. It's used to increase the efficiency of self-driven cars in transforming data, and hence to improve their ability. In this study, clustering is considered as a method to group the cars to improve data sharing speed in order to gain high efficient network. Clustering is the creation of a more reliable and scalable vehicle network by combining vehicles moving on a specific street or area. There are multiple criteria for clustering. We will address two criteria: First: - extent of communication between cars we mean by extent of communication the distance through which the car can communicate with another car. The second: - the direction in which the car is traveling. For this purpose, a simulation is established by using NetLogo to represent a virtual city and mobilized cars, to observe the important variables effecting the process. And get a better understanding on how to shape the optimal clustering operation for different circumstances.

Keywords: **Vehicle ad hoc network, Mobile ad hoc network, Vehicles-to-Vehicles, Vehicles-to-Infrastructure.**

1. Introduction

Vehicle ad hoc network (VANET) is essentially a specific form of ad hoc mobile network (MANET) used in modern transportation systems, serving as communication between adjacent vehicles and nearby fixed roadside equipment. VANET provides two approaches to connectivity, Vehicles-to-Vehicles (V2V), and Vehicles-to-Infrastructure (V2I). Several of VANET's applications concentrate on enhancing road safety by reminding drivers of avoiding dangerous transport incidents, such as traffic accidents, severe weather and so on. Notice that through this research; sometimes the cars in VANET network, are referred to as nodes. VANET's key characteristics can be set to [1]:

- High mobility: the nodes (i.e. cars) travel frequently and fairly quickly.
- Patterned mobility: nodes usually move along predefined paths such as roads and streets.
- No energy constraints: typically, VANET nodes are linked to continuous power suppliers such as vehicle engines.
- Frequent changes in network topology: nodes movements cause topology changes repeatedly due to changes in high-rate connections.
- Unbounded network size: VANET usually has wide, dense, and unbounded deployments.
- Frequent communications: the nodes relay on network traffic regularly to deal with changes in network topology, routing, and communications.
- Time-critical for data delivery: network traffic needs to be transmitted within time limit, because VANET nodes need to take real-time action or decisions.

VANET clustering aims to turn the network structure from flat to hierarchical representation by splitting the network into virtual vehicle classes called clusters. Every cluster has a leader, normally donated by the head of the cluster (CH), and several members of the cluster (CMs). The CH serves as the cluster’s center for communication, or entry point. Then instead of dealing with a mere ad hoc network, a virtual channel introduced in a structure-based network without the need to install costly physical infrastructure. Additionally, when the clustering takes into account the vehicle mobility information, the topology within the cluster becomes relatively static. Therefore, the highly dynamic problem of topology is becoming less serious.

That sort of clustering is generally called (clustering based on versatility). To achieve their goals, a wide variety of protocols and applications depend on the VANET clustering. Many security applications, for example, exploit clustering to address certain security threats and detect intrusion. In addition, several VANET routing protocols are proposed based on clustering to mitigate scalability problems As clustering makes efficient use of network resources and scheduling of medium access, different MAC protocols use the CH of each cluster to organize the medium access between cluster members .In addition to many other applications, such as topology discovery and QoS assurance, VANET safety applications benefit from clustering to disseminate safety messages[2].

2. Mobile Ad hoc Network

Ad hoc networks emerge as the latest network age And defined as a temporary set of mobile nodes (MNs) Without the assistance of any centralized management or
standard help Services. services. In Latin, ad hoc simply means "for this," meaning "furthermore" Generally temporary intent only.

A Network Ad Hoc Usually considered as a network with relatively mobile nodes Compared with that of a wired network. Therefore the topology of the network is a lot More dynamic and the changes are often unforeseeable against the Internet What a wired network.

That produces a lot of difficult research issues, Because it is often unclear how the routing should take place Due to the various resources, such as bandwidth, battery power and Asking for latency. The routing protocols widely used in wired networks Is not well suited for a complex environment of this kind. In contrast to wireless networks based on an infrastructure, in ad hoc Networks of all nodes are mobile and dynamically connectable in a Even arbitrarily.

This can be achieved, either because it might not be To have the requisite financially realistic or physically feasible Infrastructure or condition does not require installation thereof.

A Reference Examples of these cases will be acquaintances or business partners At an airport terminal and want to exchange business cards, or to swap business cards Emergency response, a group of rescue workers may need to deploy quickly In such instances Situations, a set of wireless network interfaces mobile hosts can Form a temporary network, without any infrastructure established or Centralized Government. This form of wireless network is known as a publicity Hoc networking. In case only two hosts are within the range of the transmission

Ad-hoc network presence, no specific routing protocol or routing decisions are necessary In many realistic ad hoc networks, however, two hosts wishing to Communicating might not be close enough to wireless transmission range To one another.

These hosts could only interact if there were other hosts in between They, who also participate in an ad hoc network, are prepared to forward packets To them.

Consider Figure 1 as shown below, as an example. Handy host C Is not within the wireless transmitter range of host A (specified by the circle About A) and host A is not within wireless transmitter range of host C Now, if A and C wish to interact with each other, in this case, they might Provide host B services to forward packets to them, because host B Lies within both the

A and C transmission ranges. A true Network ad hoc Could be more complicated than this example given the inherent Non-uniform wireless transmission propagation characteristics, and Possibility of any or all of the hosts concerned moving at any time.

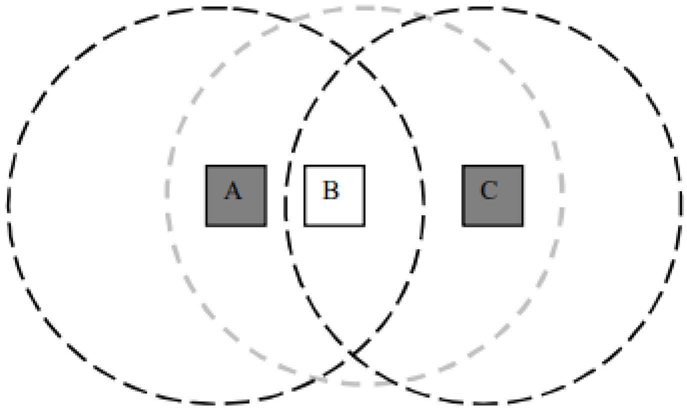


Figure 1 an example of mobile ad hoc network

3. Vehicular Ad hoc Network

Vehicular ad hoc networks (VANETs) are created by applying the principles of mobile ad hoc networks (MANETs) – the spontaneous creation of a wireless network of mobile devices – to the domain of vehicles. [11] VANETs were first mentioned and introduced [12] in 2001 under "car-to-car ad-hoc mobile communication and networking" applications, where networks can be formed and information can be relayed among cars. It was shown that vehicle-to-vehicle and vehicle-to-roadside communications architectures will co-exist in VANETs to provide road safety, navigation, and other roadside services. VANETs are a key part of the intelligent transportation systems (ITS) framework. Sometimes, VANETs are referred as Intelligent Transportation Networks [13]

While, in the early 2000s, VANETs were seen as a mere one-to-one application of MANET principles, they have since then developed into a field of research in their own right. By 2015, [14](p3) the term VANET became mostly synonymous with the more generic term inter-vehicle communication (IVC), although the focus remains on the aspect of spontaneous networking, much less on the use of infrastructure like Road Side Units (RSUs) or cellular networks.

VANET is a distributed mobile self-organized network. It is also less infrastructure network comparing with Wi-max, Wi-Fi or GSM technology [11]. As each mobile network has number of mobile nodes. Vehicles, mobile nodes in VANET, must have some features to participate in a VANET. Transceiver device to communicate with others is essential to have for each vehicle. A VANET has been used to sense or monitor environment conditions of the network. For this purpose, vehicles should be supplied with sensor devices to sense traffic conditions, hazards, road conditions etc. furthermore, vehicles may have reasons for intelligence such as CPU and memory to make decisions [12]. On the other hand, the VANET needs to special nodes, usually stationary, to provide a variety of services as well as they sometimes service as gateways to the Internet. These stationary

nodes are usually deployed on the road sides, thus they called Road Side Units (RSUs). There are three scenarios to utilize the VANET's services; these are
urban, rural and highway scenarios. Each scenario has own specific characteristics, for example in urban scenario, as this dissertation focuses on, there are high density of vehicles and low speed average whereas in highway or rural scenarios the story is different [13].

4. Results

First the result of observing the model simulation by following the default values of the system variables are shown. Next the changing in the values of the variables and how they effect the simulation results will be discussed.

Notice the criteria used to compare between the different simulations is the number of links over time in each simulation (the pattern of it). This could be observed and compared by using of the plotting of the number of links between the cars over the ticks (time) in the simulation. Moreover, the maximum number of links in each simulation will be observed.

Notice that the clustering rules are:

- There are predefined maximum limit distance between two cars in each cluster. Which means that the user of the system inputs the maximum value between two cars in order to consider them as in the same cluster. Which could be input by the slider named *grouping-distance*. This slider have a minimum value of 1. And a maximum value of a 10. Notice that this value doesn't represent the size of the cluster. Since the size of the cluster will heavily depend on the number of cars in it, and the distance between the cars.
- Each cluster is composed of cars in the same direction. So if there are two cars on the same street, with close distance that less than the *grouping-distance* variable value. But they are heading to different directions, no connection will be joined between these two cars. And thus they will not be in the same cluster.

1-Default values: Default values are the values where the initial setup of the system is configured to. These values are:

- Grouping distance: 5
- Number of cars: 100
- Light interval: 10
- Acceleration: 0.185
- Deceleration: 0.057
- Speed limit: 70
- Probability of turning: 40
- Time to crossing: 1000

- Basic politeness: 50
- Turning left?: Off

The general pattern could be observed when the default values of the simulation are set on are as following:

- The number of links starts to jump very high at the beginning, when the traffic for up and down roads are green. This is because new links are made for the first time (approximately from tick 1 to tick 560).
- Afterward, it keeps the number of links steady when all the traffics are red. Meaning no new clusters are created. This is because most of cars are stopped now, therefore the number of links are fixed (approximately from tick 560 to tick 750).
- When the left and right roads traffics are green, and cars starts to move, the number of links starts to go down in general, this is because some cars are turning and disconnect from their previous clusters (approximately from tick 780 to tick 860).
- The drop down of number of links is followed by a simple increase and decrease pattern of links over time. And this is because some cars are turning and disconnect from their cluster. And after turning they find new cluster to join in. especially when they turn and move forward, they face a red light traffics, with some cars stopped and available to join them (approximately from tick 880 to tick 1300).
- When most cars turn and stops in the red traffics, the number of links start to be simply increasing until almost all cars are stopped now (approximately from tick 1300 to tick 1800).
- After the up and down roads traffic are green, the links number is decreased because with the movement of cars many connections are lost because some cars are moving away from their clusters (approximately from tick 1800 to tick 2000).
- Afterward when some cars are turning we can notice a simple decrease and increase in the number of the links due to the turning of some cars and disconnecting from their clusters and joining the clusters of stooped cars. However, this general pattern shows an increase in this step. Until it hit its peak when all the traffics light are red (approximately from tick 2000 to tick 2800).

And the same pattern is repeated again and again after the second step, resulting in pattern for the number of links over time like it showed in Figure 4.3.

This group of steps will be the initial cycle that the different variables will be observed upon it. It starts with the traffic lights of vertical roads are green. Then they are set to red, and the traffic lights of horizontal roads are green. Afterward the traffic lights of horizontal roads are red, and the traffic lights of vertical roads are green. And finally the cycle ends when both of them are red now.

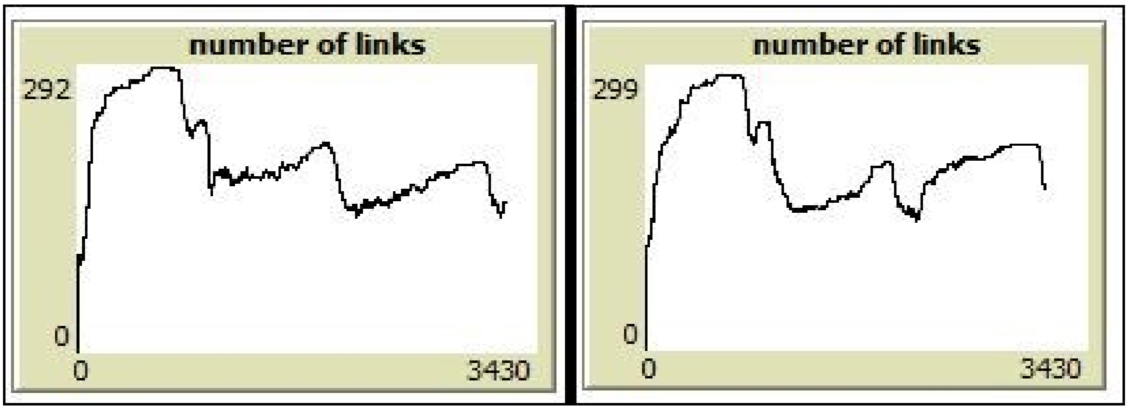


Figure 2 two pattern of two simulations with the same default values of variables, showing the number of links over time

2-Variables impact: here the variables, which are effecting clusters creating (number of links), are discussed. By both showing, which variables are effecting the number of links and the maximum size of links approachable, and to how much extent they do.

- Turning left variable: the default value of it is *off*. However, when turning its value to *on*, we can observe generally a similar pattern to the default pattern showed in Figure 4.3. However, some differences in the speed of changing in the shape of pattern is observed as showed in Figure 4.4. Where we can notice that the peaks are higher and stretched on longer time line than the default pattern. This is because turning left gives the cars extra field to join stopped cars in their clusters. And create new connection to the stopped cars.
  Moreover, the same reason made the increase of links after the cars movement is going up more rapidly.

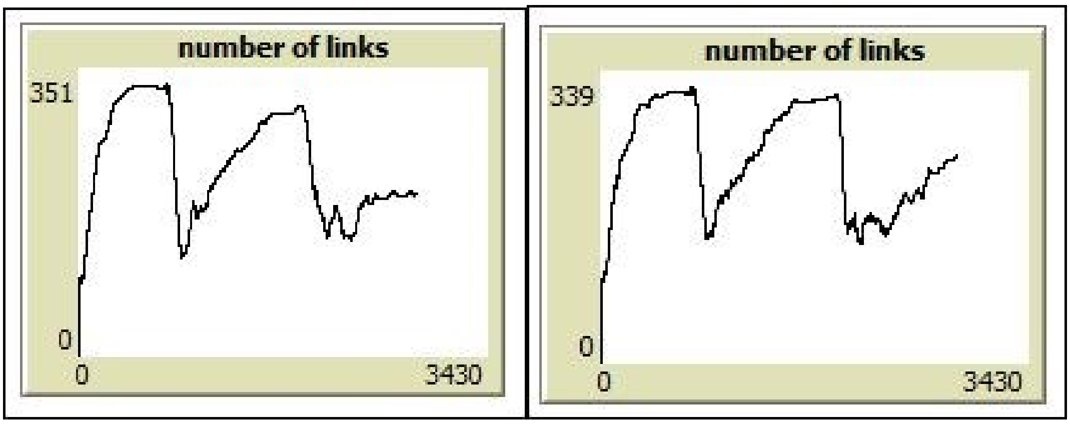


Figure 3 two pattern of two simulations with *turning left* variable is set to on, showing the number of links over time

- <u>Grouping distance variable:</u> although the minimum value for this variable is one, but we cannot really see the links connecting between the cars until the value of grouping distance variable reaches the value of three.
  So to test the impact of this variable, its value is reduced from five to three. And it showed that approximately the maximum number of links during a whole cycle is drop down to about 149 links comparing to 290 links with the default values. This is because shorter the link between cars, less connections are made.
  However, the pattern of number of links over time is still similar to the pattern with the default values as shown in Figure 4.5.
  But when the grouping distance value is set to eight, we can notice that the maximum number of the links is up to about 410 links. Which is normal since each car have more cars to connect to when the grouping distance is high. However no dramatic change was observed in the pattern of the number of links over time comparing to the default values pattern, neither the pattern when the grouping distance value was three as shown in Figure 4.6.

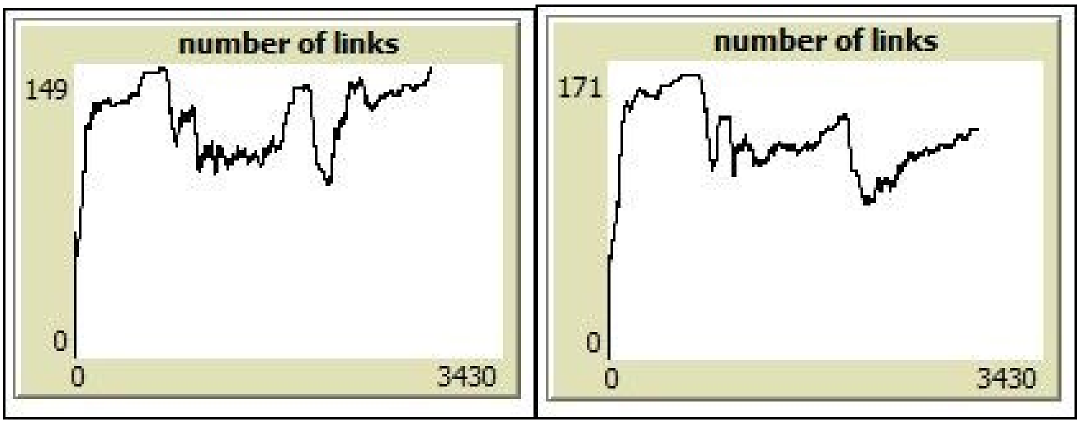


Figure 4 two pattern of two simulations with *grouping distance* variable is set to three, showing the number of links over time

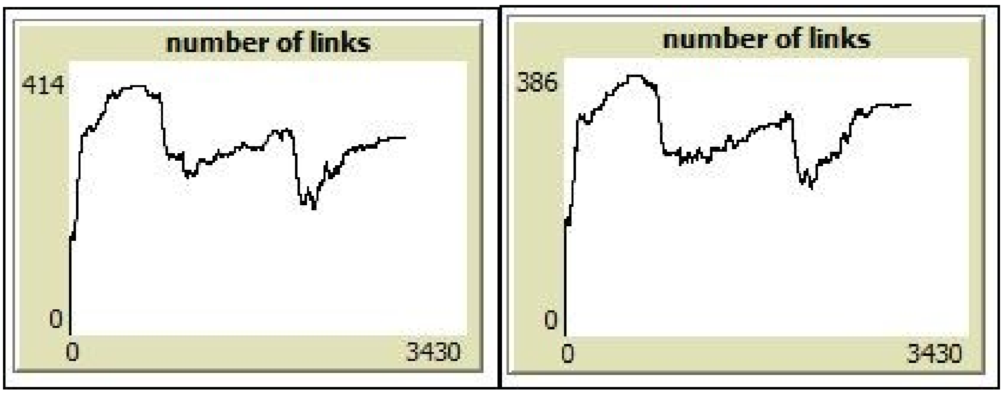


Figure 5 two pattern of two simulations with *grouping distance* variable is set to eight, showing the number of links over time

- Probability of turning variable: when decreasing the initial value of this variable from 40% to 20%, or when increasing it to 70%, there is no real change in the maximum number of links. Moreover, when decreasing the value into 20% the pattern of the number of links during time is not dramatically changing as shown in Figure 4.7. However, when increasing the value to 70%, we can notice that the curves of the graph are more linear than others as shown in Figure 4.8. And the falling down in the number of links after the traffic lights are green are up faster than other observations. Which indicate that the number of links are created faster after the movement of the cars. And this is because the cars are more likely to turn and join the stopped cars cluster on the opposite street.

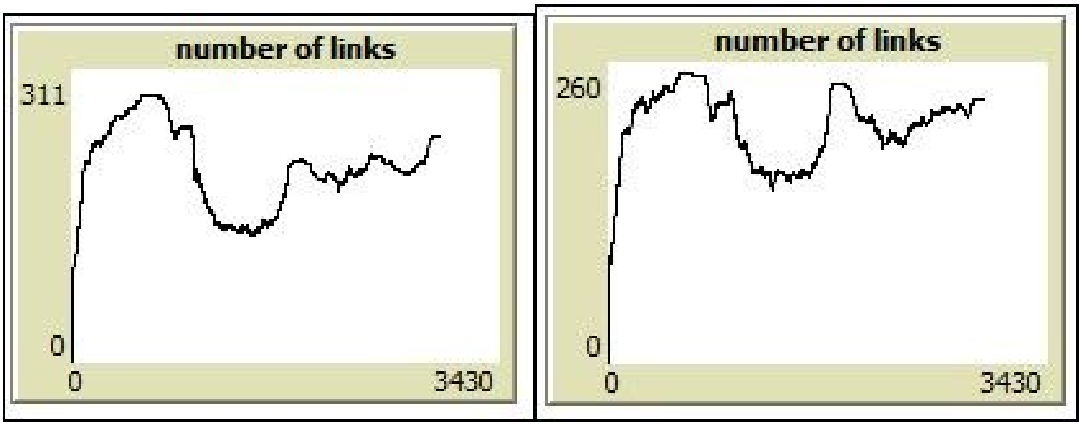


Figure 6: two pattern of two simulations with *probability of turning* variable is set to 20%, showing the number of links over time

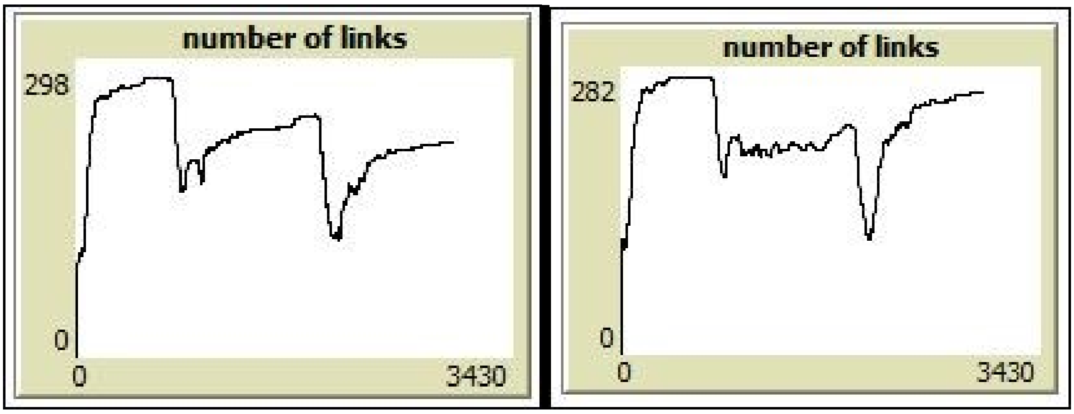


Figure 7: two pattern of two simulations with *probability of turning* variable is set to 70%, showing the number of links over time

- Number of cars variable: when decreasing the initial value of this variable from 100 to 50, the number of connections are decreased, which is expected since there are less cars to connect. Nevertheless, the patter is relatively still the same as showed in Figure 4.9.
  However, when the number of cars is increased to 200, we can see a jump in the number of links to maximum number of 700, which is expected too. But the pattern is different now. Since we can't notice the falling down edge shape of link numbers anymore after the car

movement. And the number of links is going down smoothly and keeps a relatively increasing curve, as

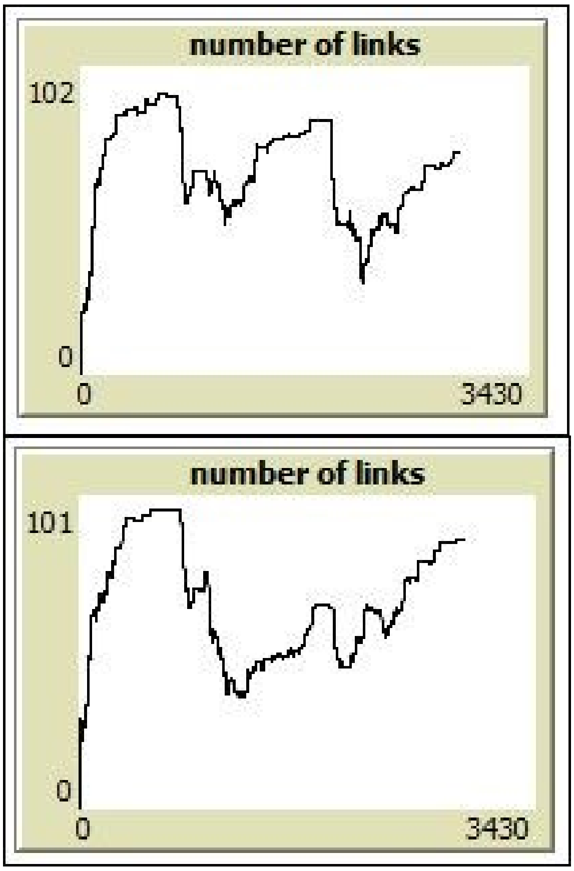


Figure 8: two pattern of two simulations with *number of cars* variable is set to 50, showing the number of links over time

shown in Figure 4.10. This is because the large number of cars make many cars available to connect nearby. So when the car disconnect from its previous cluster, it finds a new cluster quickly to join since there are many cars around.

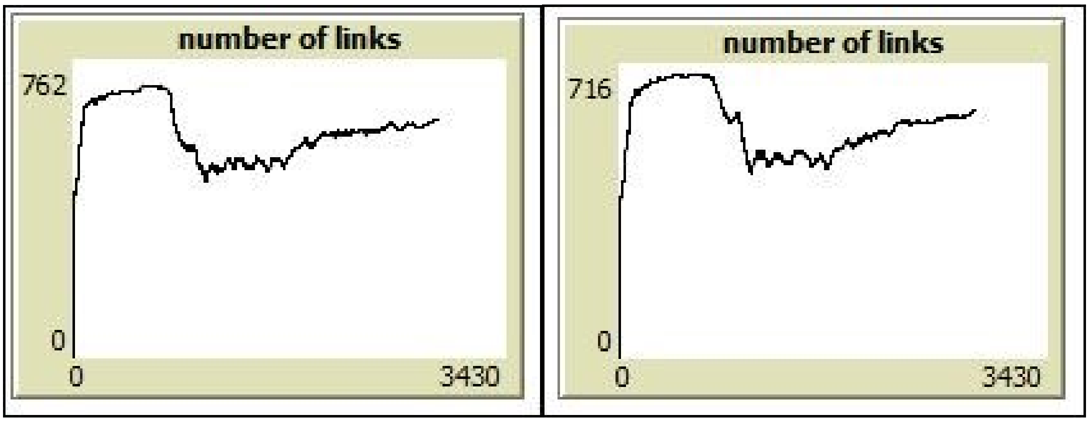


Figure 9: two pattern of two simulations with *number of cars* variable is set to 200, showing the number of links over time

- Speed limit variable: when the maximum speed of the cars are set up to 125, or set down to 30, no change in the maximum number of links are observed.
  However, we can notice smother curves in the peaks and the increasing number of links after the movement of cars when setting the maximum value to 125 as shown in Figure 4.11. This is because the cars can find new cars to connect with faster.
  On the other hand, when setting the maximum speed to 30, we notice a less stable and steady peaks and curves as shown in Figure 4.12. This is because some cars keeps moving for a longer time until they find a nearby cars to connect to.

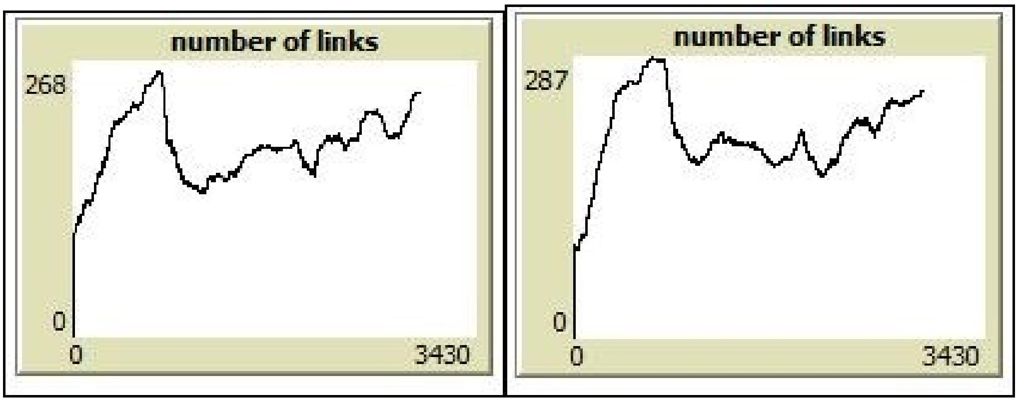


Figure 10: two pattern of two simulations with *speed limit* variable is set to 30, showing the number of links over time

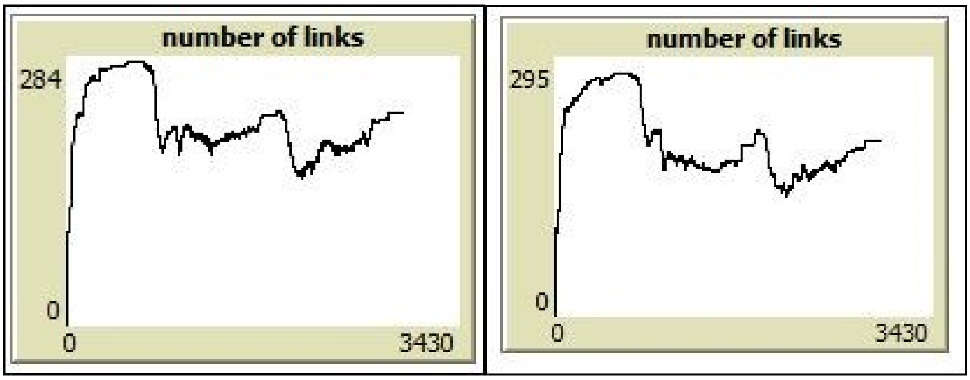


Figure 11: two pattern of two simulations with *speed limit* variable is set to 125, showing the number of links over time

- Time interval variable: the same number of ticks is considered here with other simulations, when the value of it is decreased from 10 to 5 (since we can't select the cycle period, in order to compare it fairly to the other graphs we have), we notice that the maximum number of links is approximately similar to other simulations. However, we can notice the previous default pattern is repeated during the same length of ticks, as showed in Figure 4.13. This is because the cars now spend less time in each traffic light.
  Similarly when the light intervals is increased to 20, more ticks are required to observe one cycle time period. And that led to similar pattern but on longer time, as showed in Figure 4.14.

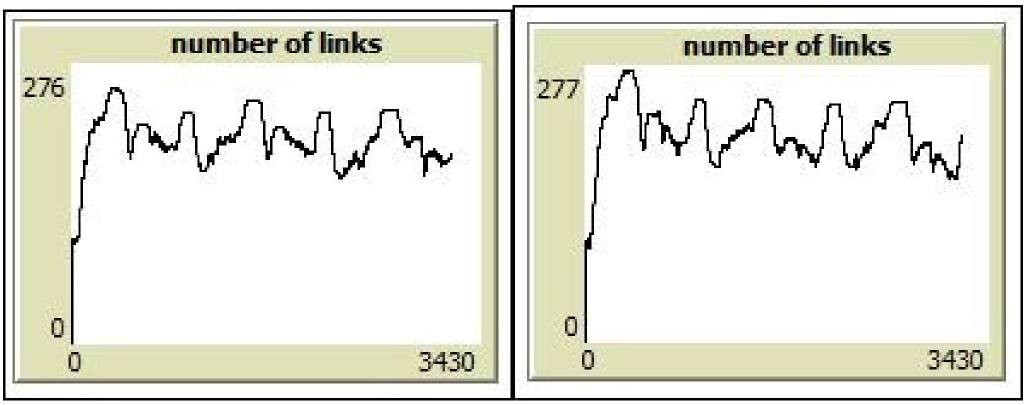


Figure 12: two pattern of two simulations with *light interval* variable is set to 5, showing the number of links over time

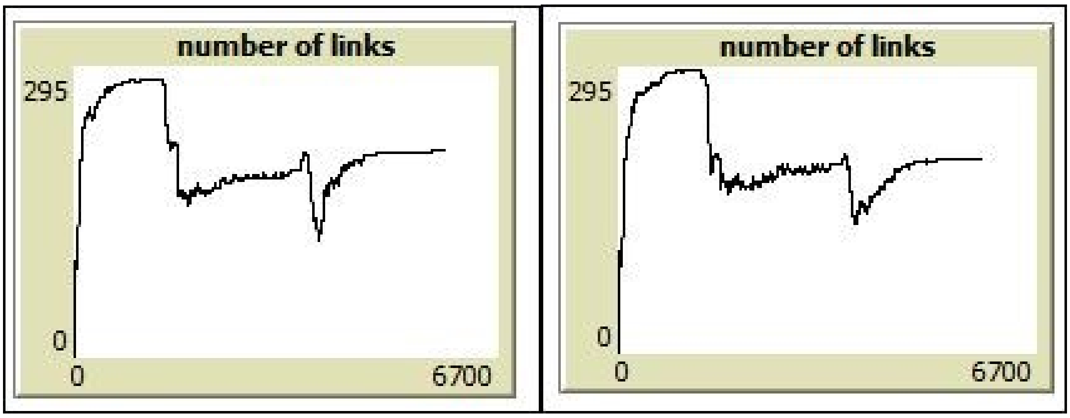


Figure 13: two pattern of two simulations with *light interval* variable is set to 20, showing the number of links over time

1-Number of groups: here we will try to associate the pattern of number of links with the pattern of number of groups. Number of groups is the number of clusters where each group (cluster) contain connected cars. This will give a better understanding of how the movement of cars under different circumstances is effecting the car clustering.

- Default settings: when the default settings are set, some similarity in patterns are observed as showed in Figure 4.15. Which illustrate the similarity areas between the pattern of number of links and number of groups in default setting. Which shows that the number of groups get to its peak when the number of links at its lowest points.
- Turning probability variable: in order to ensure that the correlation between the number of links and number of groups is valid, a further test is conducted. Which a new setting of variables are set and to compare their pattern. The variable of *turning probability* is set to 20%. And compare the pattern of number of links with the pattern of number of groups as showed in Figure 4.16. Similar observation is found to the previous results, showing that there is reverse correlation between number of links and number of groups.

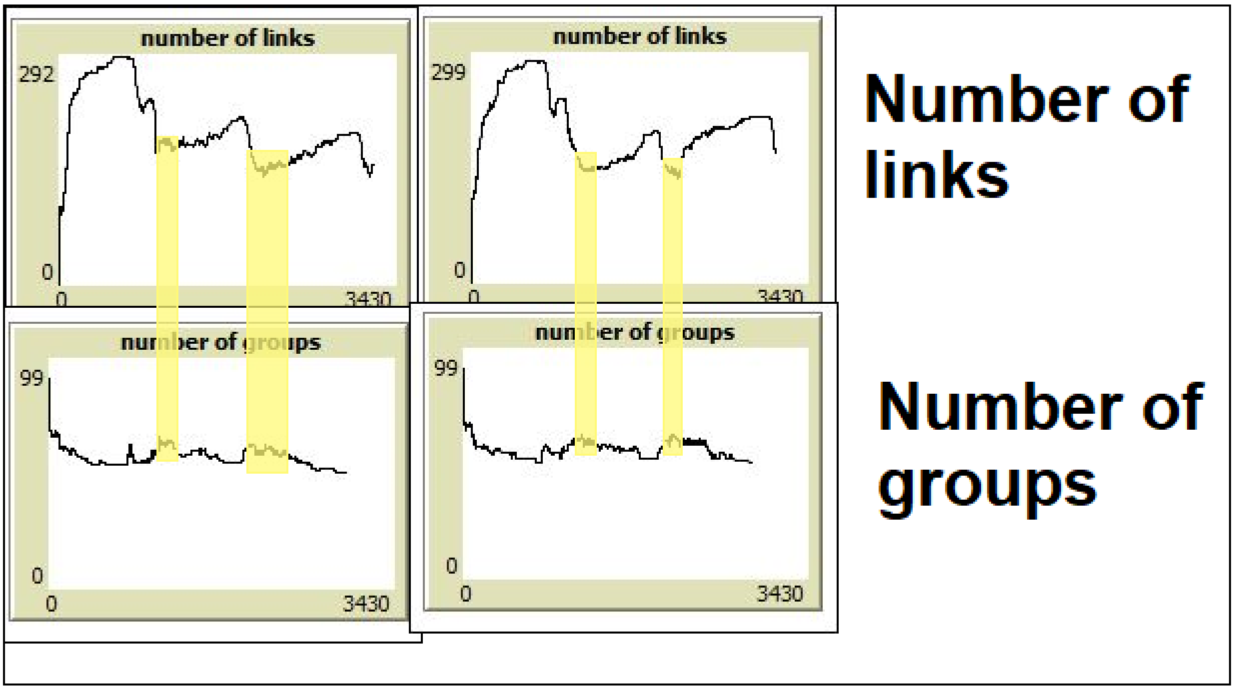


Figure 14: comparing between the patterns of number of links and number of groups, with default settings

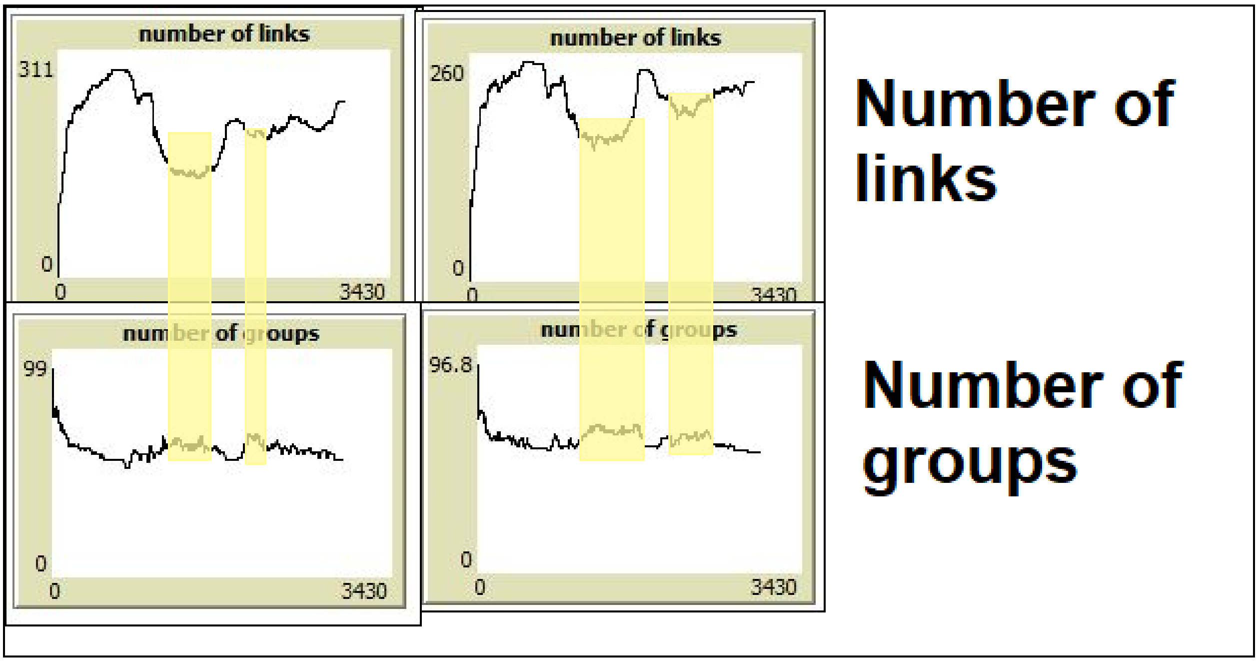


Figure 15: comparing between the patterns of number of links and number of groups, with variable *turning probability* is set to 20%

- Interpretation: as discussed previously, the lower the number of the links, the higher number of groups. Therefore, we can conclude there is a reverse relationship between the two numbers. This is because the lower the number of links means there are lower connection between the cars. Which indicate more groups of cars (clusters). Since if more cars are coming together in the same group (higher number of links) will lead to lower number of clusters.

The results will be discussed. Mainly how the different values of combination of variables effecting the clustering of cars in city environment.

Notice that creating the clusters in NetLogo will be done by drawing links (red lines) between the cars in the environment. So the cluster shape will not be circular as usually used in other works.

5. Conclusions:

In this project, a theoretical background about VANET is conducted. And identified the limitations and challenges of it. Moreover what could improve its performance. One important key in improving the VANET performance is clustering the cars in close distance so it will decrease the communication cost, and increase data transformation speed.

To test the best configurations to create the optimal clusters, a simulation of a city and its moving cars is created by using NetLogo. And many tests and simulations are carried out and observed. This led to highlighting the importance of each variable and how they affect the clustering process.

References

[1] D. Marinescu, "Cloud Access and Cloud Interconnection Networks", in *Cloud Computing*, 1st ed., Science Direct, 2018, pp. 153 - 194.

[2] A. Singh and S. Kad, "A secure clustering based approach in vehicular adhoc network", *2016 International Conference on Signal Processing, Communication, Power and Embedded System (SCOPES)*, 2016. Available: 10.1109/scopes.2016.7955617 [Accessed 11 July 2020].

[3] R. Brendha and V. Prakash, "A survey on routing protocols for vehicular Ad Hoc networks", *2017 4th International Conference on Advanced Computing and Communication Systems (ICACCS)*, 2017. Available: 10.1109/icaccs.2017.8014615 [Accessed 3 July 2020].

[4] V. Estivill-Castro, "Why so many clustering algorithms", *ACM SIGKDD Explorations Newsletter*, vol. 4, no. 1, pp. 65-75, 2002. Available: 10.1145/568574.568575 [Accessed 7 July 2020].

[5] R. Bali, N. Kumar and J. Rodrigues, "Clustering in vehicular ad hoc networks: Taxonomy, challenges and solutions", *Vehicular Communications*, vol. 1, no. 3, pp. 134-152, 2014. Available: 10.1016/j.vehcom.2014.05.004 [Accessed 8 July 2020].

[6] X. Ji, H. Yu, G. Fan, H. Sun and L. Chen, "Efficient and Reliable Cluster-Based Data Transmission for Vehicular Ad Hoc Networks", *Mobile Information Systems*, vol. 2018, pp. 1-15, 2018. Available: 10.1155/2018/9826782 [Accessed 8 July 2020].

[7] G. Alsuhli, A. Khattab and Y. Fahmy, "Double-Head Clustering for Resilient VANETs", *Wireless Communications and Mobile Computing*, vol. 2019, pp. 1-17, 2019. Available: 10.1155/2019/2917238 [Accessed 5 July 2020].

[8] M. Zanjireh and H. Larijani, "A Survey on Centralised and Distributed Clustering Routing Algorithms for WSNs", *2015 IEEE 81st Vehicular Technology Conference (VTC Spring)*, 2015. Available: 10.1109/vtcspring.2015.7145650 [Accessed 5 July 2020].

[9] M. Abdelhafez, G. Riley, R. Cole and N. Phamdo, "Modeling and Simulations of TCP MANET Worms", *21st International Workshop on Principles of Advanced and Distributed Simulation (PADS'07)*, 2007. Available: 10.1109/pads.2007.25 [Accessed 8 June 2020].

[10] Xu Jinyong, Zhao Hangsheng and Sun Yun, "Analyzing and simulation on MANET system on satellite communication constellation", *2008 International Conference on Microwave and Millimeter Wave Technology*, 2008. Available: 10.1109/icmmt.2008.4540868 [Accessed 8 June 2020].

[11] D. Bhattacharyya and M. A. Bhattacharyya, "Architecture of vehicular ad hoc network," *Advances in Vehicular Ad-Hoc Networks: Developments and Challenges,* pp. 19-36, 2010.

[12] A. Botta, W. de Donato, V. Persico, and A. Pescapé, "Integration of Cloud computing and Internet of Things: A survey," *Future Generation Computer Systems,* vol. 56, pp. 684-700, 3// 2016.

[13] Avinash Devare, Archana Hande, Anandmohan Jha, Sandhya Sanap, and S. Gawade, "A Survey on Internet of Things for Smart Vehicles," *IJRSET,* vol. 5, no. 2, 2016.

[14] S. More, K. Ravi, and M. M. Arab, "Data sharing in vehicular ad hoc network (VANET) using DES," in *Applied and Theoretical Computing and Communication Technology (iCATccT), 2015 International Conference on*, 2015, pp. 882-885: IEEE.

[15] D. B. Rawat and G. Yan, "Infrastructures in vehicular communications: Status, challenges and perspectives," *IGI Global,* 2010.

[16] S. Rehman, M. A. Khan, T. A. Zia, and L. Zheng, "Vehicular Ad-Hoc Networks (VANETs)- An Overview and Challenges," *Journal of Wireless Networking and Communications,* vol. 3, no. 3, pp. 29-38, 2013.

[17] Y. Qian and N. Moayeri, "Design of secure and application-oriented VANETs," in *Vehicular Technology Conference, 2008. VTC Spring 2008. IEEE*, 2008, pp. 2794-2799: IEEE.

[18] Q. Yang, L. Wang, W. Xia, Y. Wu, and L. Shen, "Development of on-board unit in vehicular ad-hoc network for highways," in *Connected Vehicles and Expo (ICCVE), 2014 International Conference on*, 2014, pp. 457-462: IEEE.

[19] M. Aissa, A. Belghith, and B. Bouhdid, "Cluster connectivity assurance metrics in vehicular ad hoc networks," *Procedia Computer Science,* vol. 52, pp. 294-301, 2015.

[20] M. Fathian, G. R. Shiran, and A. R. Jafarian-Moghaddam, "Two New Clustering Algorithms for Vehicular Ad-Hoc Network Based on Ant Colony System," *Wireless Personal Communications,* vol. 83, no. 1, pp. 473-491, 2015.

[21] V. Vèque, F. Kaisser, C. Johnen, and A. Busson, "CONVOY: A New Cluster-Based Routing Protocol for Vehicular Networks," *Vehicular Networks,* pp. 91-129, 2013.

[22] C. Cooper, D. Franklin, M. Ros, F. Safaei, and M. Abolhasan, "A comparative survey of VANET clustering techniques," *IEEE Communications Surveys & Tutorials,* vol. 19, no. 1, pp. 657-681, 2017.

[23] R. S. Bali, N. Kumar, and J. J. Rodrigues, "Clustering in vehicular ad hoc networks: taxonomy, challenges and solutions," *Vehicular communications,* vol. 1, no. 3, pp. 134-152, 2014.

[24] R. Goonewardene, F. Ali, and E. Stipidis, "Robust mobility adaptive clustering scheme with support for geographic routing for vehicular ad hoc networks," *IET Intelligent Transport Systems,* vol. 3, no. 2, pp. 148-158, 2009.

[25] L. Bononi and M. Di Felice, "A cross layered mac and clustering scheme for efficient broadcast in vanets," in *Mobile Adhoc and Sensor Systems, 2007. MASS 2007. IEEE International Conference on*, 2007, pp. 1-8: IEEE.

[26] R. Aquino and A. Edwards, "A reactive location routing algorithm with cluster-based flooding for inter-vehicle communication," *Computación y Sistemas,* vol. 9, no. 4, pp. 297-313, 2006.

[27] C. Perkins, E. Belding-Royer, and S. Das, "Ad hoc on-demand distance vector (AODV) routing," 2070-1721, 2003.

[28] M. S. Almalag, S. Olariu, and M. C. Weigle, "Tdma cluster-based mac for vanets (tc-mac)," in *World of Wireless, Mobile and Multimedia Networks (WoWMoM), 2012 IEEE International Symposium on a*, 2012, pp. 1-6: IEEE.

[29] J. J. Blum, A. Eskandarian, and L. J. Hoffman, "Challenges of intervehicle ad hoc networks," *IEEE transactions on intelligent transportation systems,* vol. 5, no. 4, pp. 347-351, 2004.

[30] Z. Nayyar, M. A. K. Khattak, N. A. Saqib, and N. Rafique, "Secure clustering in vehicular ad hoc networks," *International Journal of Advanced Computer Science and Applications,* vol. 6, no. 9, pp. 285-291, 2015.

[31] A. Singh and S. Kad, "A secure clustering based approach in vehicular adhoc network," in *Signal Processing, Communication, Power and Embedded System (SCOPES), 2016 International Conference on*, 2016, pp. 1127-1133: IEEE.

[32] R. S. Hande and A. Muddana, "Comprehensive survey on clustering-based efficient data dissemination algorithms for VANET," in *Signal Processing, Communication, Power and Embedded System (SCOPES), 2016 International Conference on*, 2016, pp. 629-632: IEEE.

[33] B. Chaima, F. K. Mohame, and B. H. Sofiane, "Cluster based key management in VANET networks," in *Programming and Systems (ISPS), 2015 12th International Symposium on*, 2015, pp. 1-6: IEEE.

[34] S. A. Mohammad and C. W. Michele, "Using traffic flow for cluster formation in vehicular ad-hoc networks," in *Local Computer Networks (LCN), 2010 IEEE 35th Conference on*, 2010, pp. 631-636: IEEE.

[35] B. Ducourthial, Y. Khaled, and M. Shawky, "Conditional transmissions: Performance study of a new communication strategy in VANET," *IEEE Transactions on Vehicular Technology,* vol. 56, no. 6, pp. 3348-3357, 2007.

[36] B. Everitt, Cluster Analysis, 5th ed. Hoboken: Wiley, 2011, pp. 1 - 7.

[37] S. Hanson and J. Huff, "Classification issues in the analysis of complex travel behavior", *Transportation*, vol. 13, no. 3, pp. 271-293, 1986. Available: 10.1007/bf00148620