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A New Method for Predicting Cluster Stability in VANET Based on the Birth-Death Process

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Abstract*: One of the main characteristics of a Vehicular Ad-hoc Networks (VANET) is high mobility. Therefore, the high overhead and end-to-end delay are natural results. The prediction of future movements for vehicles provides traffic observations to improve and enhance the network performance and to serve the VANET applications. The clustering approach is a popular technique used in most studies to deal with the network's dynamic topology. In most studies, the clustering algorithms are tested and evaluated according to the cluster head (CH) selection approach. Selecting a suitable CH will lead to the prolonging of the cluster lifetime. A long life time represents an indication for cluster stability, also known as cluster maintenance. Cluster maintenance has got less consideration by the previous VANET studies. The stability prediction represents a challenging task in the clustering approach. This paper highlights the stability prediction in the VANET's Highway scenario. It proposes a new approach to evaluate the vehicle's cluster stability prediction by utilizing the stochastic process. The modeling of joining and leaving takes place using the birth-death process as a stochastic process for evaluating the stability of the clustering algorithm. The main advantage of this approach is to predict and evaluate the vehicle cluster stability with time, using a new mathematical model.

Keywords: VANET, clustering, birth-death, stochastic process, stability, cluster maintenance, Markov.

I. Introduction

Vehicle Ad-hoc Networks (VANETs) are networks that can supply information on roads to the drivers in order to make driving safe and easier. It will become widespread in the very near future, creating a notable change to human lives [1]. The enormous safety, suitability, and trade possibilities of VANETs are the causes of VANET's spread. VANETs are simply multi-agent wireless networks that are constructed to solve traffic issues by allowing vehicles to communicate together [2]. It provides wireless communication among vehicles by using a dedicated short-range communication (DSRC), which is essentially improved by IEEE 802.11a, and Long Term Evolution (LTE) [3]. Each vehicle contains an on-board unit (OBU) sensor to connect with the nearby vehicles or Road Side Unit (RSU) if it is the CH according to its coverage area and function. There are many models built to implement, support, and improve VANET [4], [5].

However, there are many issues in VANET, such as efficient data dissemination, network scalability, and stable network topology. In order to study VANET's behavior and evaluate its performance, the clustering technique must be the first step to control its changeable topology and to build a meaningful group of vehicles, as shown in Figure 1. The clustering technique contains three phases: cluster creation, cluster head (CH) selection, and cluster maintenance. Most of the related studies have focused on the second phase (CH selection) of any clustering process, while very few studies considered the last phase (cluster maintenance). The stability of vehicle clusters has a high impact on VANET performance [3]. The motivations behind clusters stability prediction are related to the nature of VANET, such as dynamic changes in topology, high speed, and frequent disconnection in networks. In addition, the cluster head (CH) stability plays a crucial role in network scalability and robustness. The stable clusters refer to good performance metrics and QoS. Most of the researchers focused on CH selection methods to improve the stability of the clustering process. The researchers used the performance metrics to evaluate the cluster stability depending on CHs selection process, CHs duration, and CHs lifetime [4]. In this study, the cluster stability is measured and evaluated depending on the stochastic process (Birth-Death process), using the probability of losing or winning one vehicle in each cluster. The process is modeled using a proposed mathematical model to estimate the stability of clusters by means of a set of assumptions derived from probability [5].

In this new approach, the problem is modeled by estimating the joining and leaving vehicles to/from the clusters. Joining and leaving happen through the third phase (maintenance phase) of each clustering process. In a highway scenario, the frequent disparity among vehicles' speeds causes many vehicles to leave their clusters and/or join the new clusters [5]. For example, the slowest vehicle in the current cluster will leave its cluster and join the nearest suitable cluster according to coverage area, as shown in Figure 1. The vehicles in VANETs are supported by using DSRC to communicate with each other in the cluster range to achieve the low latency requirement. This includes safety and control messages among vehicles in each cluster, and LTE to communicate among CHs and RSUs. The communication types are either Vehicle to Vehicle (V2V), or with the infrastructure Vehicle to Infrastructure (V2I). Another case involves Infrastructure to Infrastructure (I2I), whereby RSU sends a message to another RSU [4].

This paper is organized as follows: Section II presents the related works, section III reviews theoretical background and its details, and section IV contains the methodology. Section V contains the results and discussions, and section VI refers to the conclusions and future works.

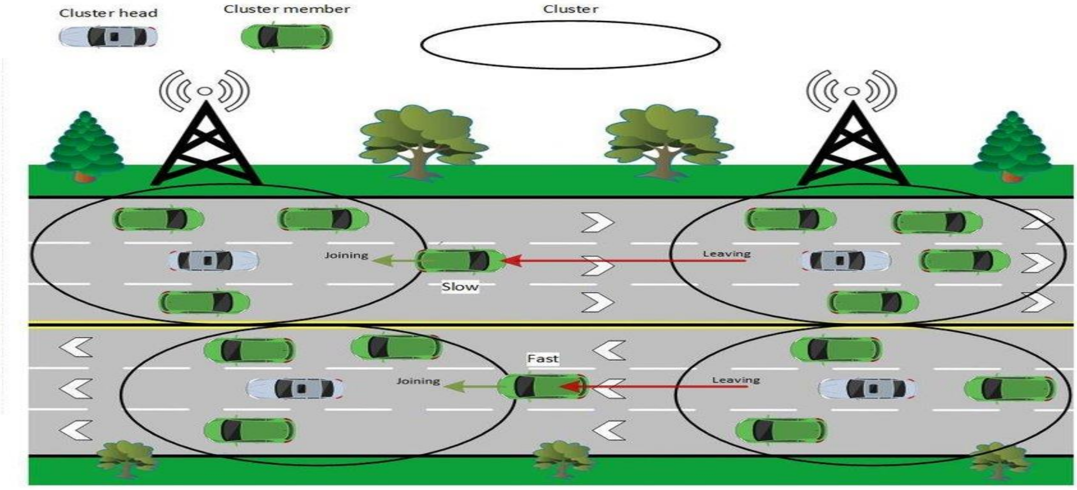

Figure 1. Leaving and Joining in VANET

II. Related works

In VANET, the clustering algorithms have been evaluated in many studies according to the cluster head efficiency, cluster member's efficiency, cluster head duration, cluster member duration, cluster head lifetime, cluster member's lifetimes, and the number of clusters. Table 1 presents the recent related works that evaluate cluster stability depending on many different performance metrics. This study systematically summarizes the most related works by referring to the clustering algorithm title, type of environment, performance metrics, and the used simulator.

Reference	Year	Scenario	Clustering algorithm	Performance metric	Simulator
[6]	2017	Highway	Chain-Branch-Leaf (CBL)	Number of Chains, Branch/Chain, Branch time, Leaf time, Leaf/VANET	Matlab
[7]	2019	Highway	passive multi-hop clustering algorithm (PMC)	cluster head duration time cluster members duration time cluster head changes Cluster overhead	NS2
[8]	2019	Highway	Novel Clustering algorithm	CH lifetime, CM lifetime, Number of changed states, Control Packet Overhead, CH Alienation, Vehicle Alienation Time, Cluster Formation Rate	NS3
[9]	2019	Highway	Connected Dominating Set and Set Cover (CDS-SC)	Cluster stability, number of members per cluster, Cluster head density, Cluster state distribution, Packet delivery ratio	Netsim
[10]	2020	Random	High Degree Clustering algorithm (HDCA)	PDF, Throughput, Lost packet number, Dead node number	Netlogo
[4]	2020	Random	QoS and monitoring of malicious vehicles (QMM)	Packet delivery ratio, Throughput, E2E delay, Packet lose	NS2
[11]	2020	Random	Multi-Agent	Cluster formation time, Cluster lifetime, cluster head	NS2

	based Stable Clustering (MASC)	selection time, Packet data lose, throughput

Table1. Summary of related works

III. Theoretical background

Prediction in VANET is important to suggest any clustering algorithms. It is also important in controlling and evaluating the VANETs behavior. Many tools can be utilized in this field such as probability, randomness, and stochastic processes [12]

A. Prediction in VANET

The nature of VANET such as its high mobility and large-scale network directly affects the dynamic change in deployment. This causes additional overhead and delay. The most important issue is to predict the future movement to build a reliable system and enhance both the communication in VANET and the Intelligent Transportation System (ITS). The movement in VANET is more regular than the Mobile Ad hoc Network (MANET), for example, a vehicle moves and saves its current speed with a certain time to reach the goal. In VANET, to predict the location, each vehicle is provided by a Global Position System (GPS) in order to provide continuous future information about location. However, the GPSs information is not accurate in all conditions, as in covered streets it may not be as effective. To predict the future deployment of VANET, it may depend on the vehicle speed, direction, and current location. The clustering approach is an important step to deal with VANET in order to control its behavior and predict it. Therefore, the proposed system is applied to the clustered network to predicate the stability of clusters, so as to predict the network stability. Using prediction in VANET is performed by several methods, like a linear regressing model, mathematical statistics, neural network, historical trend extrapolation, Kalman filter, and the time series method [13],[14].

As for the approach adopted in this paper, the birth-death process is used to predict the cluster stability in the future as one of the efficient tools in VANET prediction.

B. Stochastic Process

Mathematical models can be divided into probability models and deterministic models. Through this division, probabilistic models are more appropriate to represent most of the life phenomena. The use of probabilistic models is more used than their specific counterparts, as they are given in form of groups or families of random variables instead of a single value for the random variable. Random variables are grouped using a parameter such as time. These are known as stochastic processes (or random/chance processes). The theory of stochastic processes plays an important role in the investigation of the stochastic phenomenon depending on time. The first results were achieved in this field with the research on Brownian motion, telephone calls, and traffic accidents. The basis for the mathematical theory of stochastic processes was given by A. N. Kolmogorov (1931) and since then the theory and practice of stochastic processes in it have not undergone significant development. The birth-death process is a continuous Markov process in which only two ways are stated: birth, which increases the state variable by one, and death, which decreases the state by one. The name of the model is derived from a population representation where transitions are literal births and deaths. The process of birth and death can be used to observe the number of vehicles in a cluster. When birth occurs, the process goes from state n to state n+1. When a death occurs, the process goes from state n to state n-1 [15], [16], [17], .

IV. Network Model

In this paper, the proposed system is applied to the environment of [18]. In this section, the environment and clustering approach are clarified. The Highway scenario was selected to apply a developed clustering process. The road segment length is 4 Kilometer. Different network sizes are selected, namely (50, 80, and 100) vehicles. The clustering approach is performed as follows: the cluster formation is formed as center based clustering by grouping the vehicles which fall within a distance equal to or less than the Dedicate Short Range Communication (DSRC). There are many Road Side Units (RSUs) distributed along the road segment to manage the clustering process, each of which covers 1 Kilometer. The CH selection depends on the speed of nodes. The vehicle which has the nearest speed to the average speeds of vehicles in the current cluster was selected as a cluster head. The CHs stability, CHs duration, CMs stability, CMs duration, and CHs lifetime versus CMs lifetimes have been calculated as performance metrics. The clustering method was a non-overlapping clustering method. More details are found in [18].

V. Methodology

Regarding the scenario in this paper, after the clustering algorithm has been applied in VANET, each cluster is composed of many vehicles. For each cluster, after a short time interval called Δtm has been passed, there are three expected states: no changes, cluster increasing by one, or cluster decreasing by one only. As shown in Figure 2, the cluster increases one vehicle (Joining) in two cases, either from forward or from backward. The forward increment comes from a lagged slow vehicle joining the current cluster. The backward increment comes from a new hurried vehicle joining the cluster. The cluster decreases one vehicle (Leaving) in two cases, either from forward or from backward. The forward decrement comes from a fast vehicle in the current cluster leaving it. The backward decrement comes from a slow vehicle in the current cluster lagging.

When the consecutive time intervals are passed and the number of vehicles remains the same in their clusters, it reflects an indication of good stability. The previous three cases are modeled and studied in detail. Figure 3 represents the Markov chain approach for vehicle clustering. The hall state space for such a process shows only the possible states in a state-space case for vehicles in a cluster, only three cases can happen to each cluster after a very short time period. These states probabilities are: no changing (n), New vehicle joins to the cluster (n+1), and the cluster losing one vehicle (n-1). Each case has a probability according to the new event (E). The transition (A) means either joining from forwarding or backward, the transition (D) means leaving either forward or backward. The algorithm in Figure 3 summarizes the mathematical model and presents all the leaving and joining possibilities based on the birth-death process.

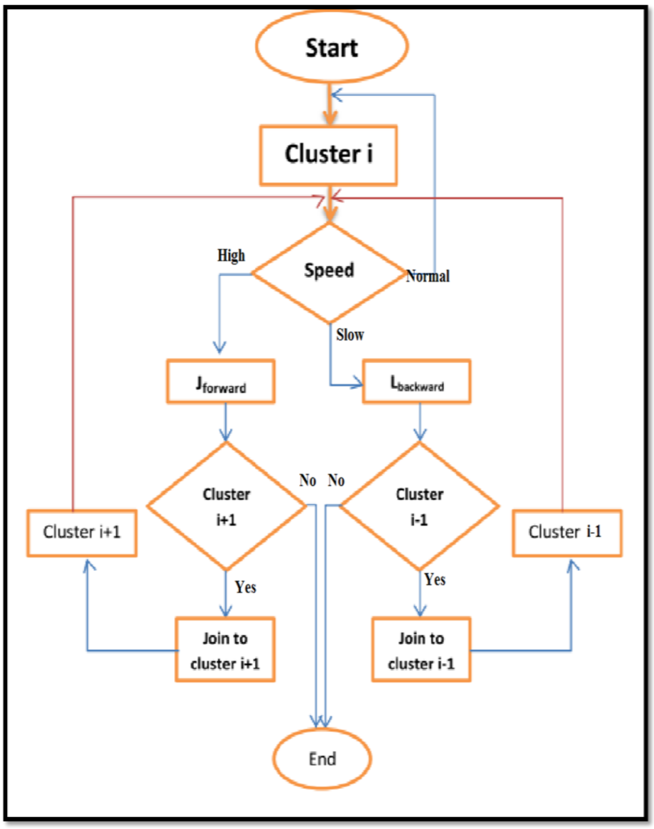

Figure 2. Proposed system flow chart

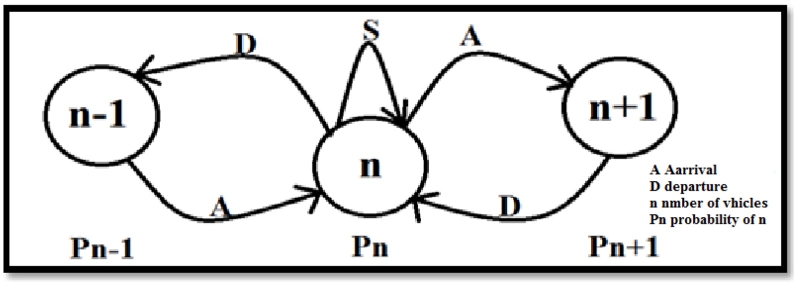

Figure 3. Vehicles State diagram in a cluster

Algorithm Leaving and Joining
Input: NUM_OF_CLU, speeds of vehicles.
Output: Updated clusters
Begin
1: set i=1
2: Repeat
3: For each (cluster$_i$)
3.1: Set MEMBERS= number of vehicles in (cluster$_i$)
3.2: Sort vehicles ascending order according to the speed and save in array SPEED_ARRAY[]
3.3: Set MIN_VE = ID(SPEED_ARRAY[0])
3.4: Set MAX_VE = ID(SPEED_ARRAY[MEMBERS])
3.5: Join MAX_VE to the cluster i+1
3.6: Leaving MIN_VE to the cluster i-1
3.7: Else go to 4
4: set i= i+1
5: Until i > NUM_OF_CLU
End

Figure 4. Leaving and Joining algorithm

Notation	***Description***
Δtm	Time interval

$L_{forward}$	Losing vehicle due to its high speed
$L_{backward}$	Losing vehicle due to its low speed
$J_{forward}$	Winning vehicle due to its low speed
$J_{backward}$	Winning vehicle due to its high speed
Tm	Current time
N	Number of vehicles at time tm
S	No change
E_n	System state (the event at certain time)
tm+Δtm	The next time
.	The probability of the cluster contains n
P_n (tm)	vehicles at time tm
O(Δtm)	Zero
P_n (tm,	The probability of the cluster contains n
tm+Δtm)	vehicles at time tm +Δtm
A	Arrival
OΔtm)	The error

Table 2. Abbreviation of symbols

The below assumptions must be taken with respect to abbreviations in table 2:

1: The joining probability at the interval time (tm + Δtm) in both cases from forward or backward can be modeled in (1) (2) as:

$$P_n (tm + \Delta tm) = J_{forward} \Delta tm + O(\Delta tm) \quad (1)$$

$$P_n (tm + \Delta tm) = J_{backward} \Delta tm + O(\Delta tm) \quad (2)$$

2: The leaving probability at the interval time (tm + Δ tm) in both cases forward and backward can be modeled in (3)(4) as:

$$P_n (tm + \Delta tm) = L_{forward} \Delta tm + O(\Delta tm) \quad (3)$$

$$P_n (tm + \Delta tm) = L_{backward} \Delta tm + O(\Delta tm) \quad (4)$$

3: The probability of more than one event occurrence in the same time is zero, as shown in (5).

$$P_{n+z\,,\,z>1} (tm + \Delta tm) = 0 + O(\Delta tm) \quad (5)$$

Initially, the $P_n(tm)$ is the probability of the event E_n at time tm. After passing a short period of time (tm + Δtm), the probability becomes P_n (tm + Δtm) with new event E_n, E_{n+1} or E_{n-1}. to model all the cases.

The final equation can be derived by cummulating all the possible probabilities as shown in (6). Eq. 6 can be used to find the stability of a cluster by predicting its number of vehicles in any time:

$$P_n(tm + \Delta tm) = P_n (1- J_{f.orward} \Delta tm) (1- J_{backward} \Delta tm) (1- L_{forward} \Delta tm) (1- L_{backward} \Delta tm) + P_{n+1} (J_{forward} \Delta tm) (1- L_{forward} \Delta tm) (1- L_{backward} \Delta tm) (1- J_{backward} \Delta tm) (J_{backward} \Delta tm) (1- L_{forward} \Delta tm) (1- L_{backward} \Delta tm) (1- J_{forward} \Delta tm) + P_{n-1} ((L_{forward} \Delta tm) (1- J_{forward} \Delta tm) (1- J_{backward} \Delta tm) (1- L_{backward} \Delta tm) (L_{backward} \Delta tm) (1- J_{forward} \Delta tm) (1- J_{backward} \Delta tm) (1- L_{forward} \Delta tm) + O(\Delta tm) \quad (6)$$

To show the expected value of eq. 6, the following example is suggested: Suppose $L_{forward} = 0.3$, $L_{backward} =0.7$, $J_{forward} = 0.4$, $J_{backward} = 0.6$, n= 5 (the number of vehicles in the current cluster), Δtm= 0.01 second and tm = 1second. Predict the stability of the current cluster after Δtm.

Solution: According to eq.6 :

$$P_n(tm, tm + \Delta tm) = p5(1) * (1- 0.004) * (1- 0.006) * (1 – 0.003) * (1 – 0.007) + p6 (1) * (0.004) * (1 – 0.003) * (1 – 0.007) * (1 – 0.006) + p6(1) * (0.006) * (1 -0.003) * (1 – 0.007) * (1 – 0.004) + p4(1) * (0.003) * (1 – 0.004) * (1 – 0.006) * (1 – 0.007) +p4(1) * (0.007) * (1 – 0.004) * (1 – 0.006) * (1 – 0.003)$$

$$Pn(1, 1 + 0.01) = 0.98014455 + 0.00393632 + 0.00591637 + 0.00294928 + 0.00690938$$

$$= \underline{0.9998559}$$

From the previous example, the value of the probability is very high (0.999) wich gives an indication about the stability of the created clusters in this study.

VI. Results and Discussions

In the previous paper [18], the highway clustering algorithm has been designed and applied in different environments. The proposed system is applied in the environment of [18]. There are three network sizes selected, namely 50, 80, and 100. Also, the range of clusters was set as a variable. The efficiency of the clustering algorithm depends on the mathematical approach called the stochastic process. The joining and leaving of vehicles to the clusters can be predicted mathematically using a Markov model based on the birth-death process. But in this study, practical implementation is applied to practically fit the mathematical approach of the Markov concept. The number of vehicles in each cluster was observed in different sequential times (i.e. at tm, tm+Δtm, tm+4Δtm, tm+8Δtm, tm+12Δtm, tm+16Δtm, tm+20Δtm), to observe the leaving and joining vehicles. Also, the average and standard deviation (STD) are calculated to indicate central tendency and the data spread. The stable cluster is the cluster that has the number of vehicles equal to or close to the average number of vehicles in each unit of time. The other results are taken from [18].

Figure 5 refers to the effects of changing clusters radius with the number of clusters in three traffic types, low, medium, and high, whereby the numbers of vehicles are 50, 80, and 100 respectively. The figure indicates the number of vehicles in clusters increases whenever the DSRC increases.

Many different experiments were implemented and analyzed to observe the number of created clusters in different simulation runs for different highway VANET environments. The number of vehicles in each cluster at different successive times was also observed and indicated. The variation in cluster vehicles number at successive times is used as an indication about the behavior of the clustering process, whether or not it can be modeled as the birth-death Markov process.

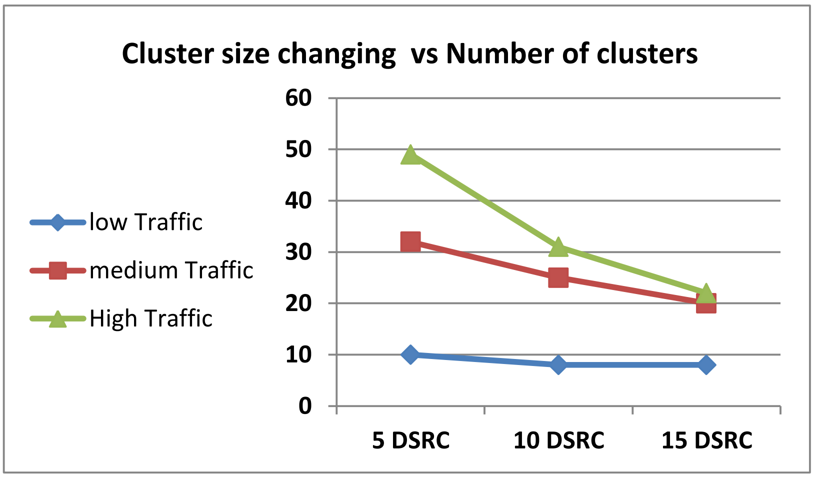

Figure 5. The average number of clusters with changing cluster size

Table 3 represents the collected data about the 12 created clusters for the case of a highway low traffic (50 vehicles) at different successive times (tm, tm+Δtm, tm+4Δtm, tm+8Δtm, tm+12Δtm, tm+16Δtm, tm+20Δtm). It is taken into consideration that Δtm is used as very small time periods equal to (4 millisecond) in this study. The observed change in the vehicle's number is either ±1 or 0. This concept is identical to the Markov process. The expected and standard deviation values for each cluster data indicate high stability with respect to the numbers in each cluster.

Random clusters	***tm***	***tm+Δtm***	***tm+4Δtm***	***tm+8Δtm***	***tm+12Δtm***	***tm+16Δtm***	***tm+20Δtm***	***Average***	***STD***
cluster 1	4	4	4	4	4	4	4	4	0
cluster 2	1	1	1	1	1	1	1	1	0
cluster 3	3	3	3	3	3	3	**2**	2.857142857	0.377964473
cluster 4	3	3	3	3	3	**2**	**2**	2.714285714	0.487950036
cluster 5	5	**6**	**6**	**7**	**7**	**7**	**8**	6.571428571	0.975900073
cluster 6	4	4	4	4	4	4	4	4	0
cluster 7	2	2	2	2	2	2	2	2	0
cluster 8	2	2	2	2	2	2	2	2	0
cluster 9	4	4	4	4	**3**	**3**	**3**	3.571428571	0.534522484
cluster 10	3	3	3	3	3	3	**2**	2.857142857	0.377964473
cluster 11	2	2	2	2	2	2	**1**	1.857142857	0.377964473
cluster 12	2	2	2	**1**	**1**	**1**	**2**	1.571428571	0.534522484

Table 3. Number of vehicles in 12 cluster when Δtm=4 and network size=50

Figure 6 represents the graphical representation of the created data from the case in Table 3. A clear indication is observed in cluster 5, as the increment in cluster members is due to the joining process. On the other hand, in clusters 3, 9, and 10, the decrement in cluster members happened due to leaving process. The others either remained stable (S) without change or contained consecutive leaving and joining with sequential times.

The other two cases, the medium traffic (80) with 12 clusters and the high traffic (100) with 12 clusters, are presented in Figure 7 from Table 4 and Figure 8 from Table 5, respectively.

Figure 7 represents a graphs of s 12 random samples of these clusters to evaluate the stability when the traffic is medium (80 nodes) with different consecutive times. A clear indication can be observed for clusters 3, 4, 6, and 8, the increment in cluster members is due to the joining process. On the other hand, in clusters 5, 7, and 12, the decrement in cluster members happened due to the leaving process. The others either remained stable (S) without change or contained consecutive leaving and joining with sequential times.

When the traffic is high, as shown in Figure 8, a clear indication is observed in cluster 5, as the increment in cluster members is due to the joining process. On the other hand, in clusters 2, 3 and 6, the decrement in cluster members happened due to the leaving process. The others either remained stable (S) without change or contained consecutive leaving and joining with sequential times.

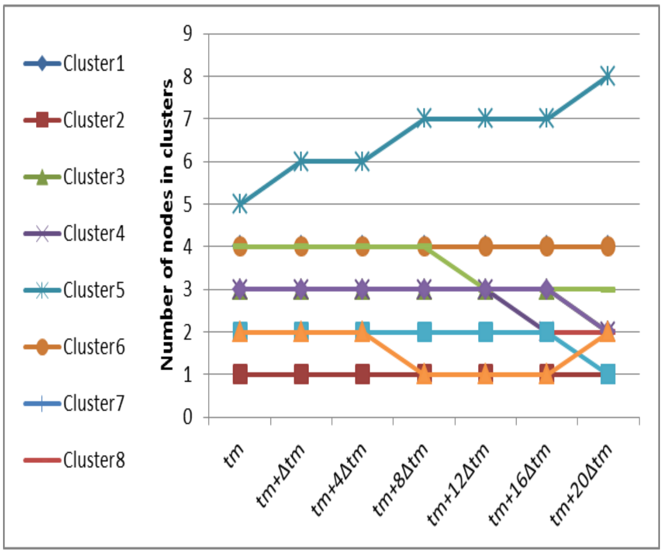

Figure 6. Number of vehicles in 12 cluster when Δtm=4 and network size=50

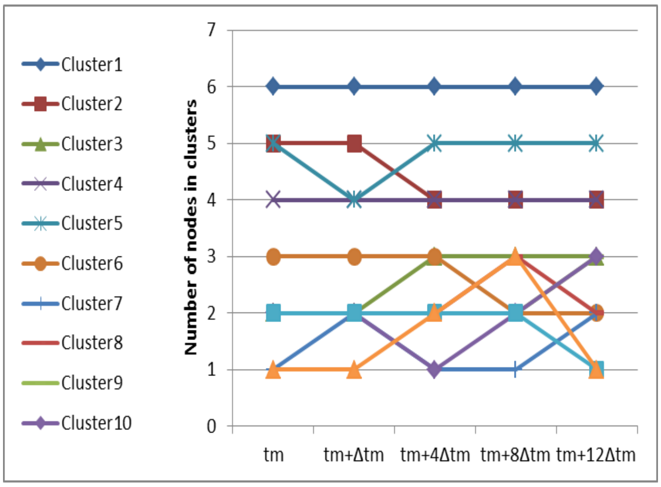

Figure 8. Number of vehicles in 12 cluster when Δtm=4 and network size=100

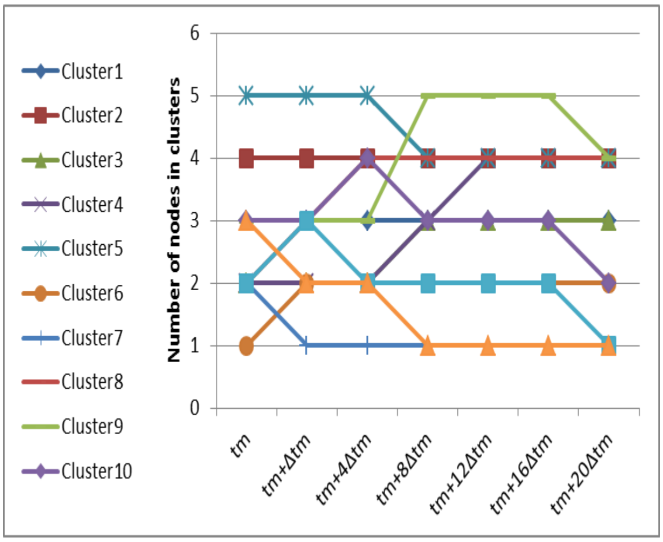

Figure 7. Number of vehicles in 12 cluster when Δtm=4 and network size=80

Random clusters	***tm***	***tm+Δtm***	***tm+4Δtm***	***tm+8Δtm***	***tm+12Δtm***	***tm+16Δtm***	***tm+20Δtm***	***Average***	***STD***
cluster 1	3	3	3	3	3	3	3	3	0
cluster 2	4	4	4	4	4	4	4	4	0
cluster 3	2	2	2	**3**	**3**	**3**	**3**	2.571428571	0.534522484
cluster 4	2	2	2	**3**	**4**	**4**	**4**	3	1
cluster 5	5	5	5	**4**	**4**	**4**	**4**	4.428571429	0.534522484
cluster 6	1	**2**	**2**	**2**	**2**	**2**	**2**	1.857142857	0.377964473
cluster 7	2	**1**	**1**	**1**	**1**	**1**	**1**	1.142857143	0.377964473
cluster 8	2	3	**4**	**4**	**4**	**4**	**4**	3.571428571	0.786795792
cluster 9	3	3	3	**5**	**5**	**5**	**4**	4	1
cluster 10	3	3	**4**	**3**	**3**	**3**	**2**	3	0.577350269
cluster 11	2	3	**2**	**2**	**2**	**2**	**1**	2	0.577350269
cluster 12	3	**2**	**2**	**1**	**1**	**1**	**1**	1.571428571	0.786795792

Table 4. Number of vehicles in 12 cluster when Δtm=4 and network size=80

Random clusters	***tm***	***tm+Δtm***	***tm+4Δtm***	***tm+8Δtm***	***tm+12Δtm***	***Average***	***STD***
cluster 1	6	6	6	6	6	6	0
cluster 2	5	5	**4**	**4**	**4**	4.4	0.547722558
cluster 3	2	2	**3**	**3**	**3**	2.6	0.547722558
cluster 4	4	4	4	4	4	4	0
cluster 5	5	**4**	**5**	**5**	**5**	4.8	0.447213595
cluster 6	3	3	3	**2**	**2**	2.6	0.547722558
cluster 7	1	**2**	**1**	**1**	**2**	1.4	0.547722558
cluster 8	2	2	2	3	2	2.2	0.447213595
cluster 9	2	2	2	2	3	2.2	0.447213595
cluster 10	2	2	**1**	**2**	**3**	2	0.707106781
cluster 11	2	2	2	2	**1**	1.8	0.447213595
cluster 12	1	1	**2**	**3**	**1**	1.6	0.894427191

Table 5. Number of vehicles in 12 cluster when Δtm=4 and network size=100

VII. Conclusions and Future works

The key challenge in VANET is its dynamic nature. The frequently changing topology requires accurate and significantly modified techniques to be valid for such environments. The most considerable technique in controlling and evaluating any VANET is the clustering approach. In this paper, a new modified method is proposed to predict the stability of VANET's clustering. Various experiments were designed and implemented in highway scenarios. The Markov model was utilized with the stochastic birth-death process to present, observe and model the joining and leaving vehicles from/to each cluster. These events are utilized to predict cluster stability. When the number of vehicles in each cluster remains unchanged or slightly changed during different successive times, the cluster can be considered as a stable cluster. The results showed that the number of vehicles in each of the created clusters in different environments are been either unchanged or slightly changed by one only. This indication can be used to represent the mathematical concept of Markov. The average number of vehicles and their standard deviation in each cluster at different successive times are also utilized as a statistical test with central tendency and dispersion for the stability of each cluster. As for future works, the stability can be predicted in two sides of a road segment. In addition, the method of center-based cluster formation can be replaced by the distributed method to reduce the cost of build and setup of the RSUs. As well, the system can be developed by using overlapped clustering method as used in [19].

References

[1] T. Yeferny and K. Arour, "Efficient routing method in p2p systems based upon training knowledge," in *2012 26th International Conference on Advanced Information Networking and Applications Workshops*, 2012, pp. 300–305.

[2] H.-W. Tseng, R.-Y. Wu, and C.-W. Lo, "A stable clustering algorithm using the traffic regularity of buses in urban VANET scenarios," *Wirel. Networks*, vol. 26, no. 4, pp. 2665–2679, 2020.

[3] G. F. Savari, V. Krishnasamy, J. Sathik, Z. M. Ali, and S. H. E. A. Aleem, "Internet of Things based real-time electric vehicle load forecasting and charging station recommendation," *ISA Trans.*, vol. 97, pp. 431–447, 2020.

[4] H. Fatemidokht and M. K. Rafsanjani, "QMM-VANET: An efficient clustering algorithm based on QoS and monitoring of malicious vehicles in vehicular ad hoc networks," *J. Syst. Softw.*, vol. 165, p. 110561, 2020.

[5] O. Senouci, S. Harous, and Z. Aliouat, "Survey on vehicular ad hoc networks clustering algorithms: Overview, taxonomy, challenges, and open research issues," *Int. J. Commun. Syst.*, vol. 33, no. 11, p. e4402, 2020.

[6] L. Rivoirard, M. Wahl, P. Sondi, M. Berbineau, and D. Gruyer, "CBL: A clustering scheme for VANETs," in *VEHICULAR 2017-The Sixth International Conference on Advances in Vehicular Systems, Technologies and Applications*, 2017, pp. 19–25.

[7] D. Zhang, H. Ge, T. Zhang, Y.-Y. Cui, X. Liu, and G. Mao, "New multi-hop clustering algorithm for vehicular ad hoc networks," *IEEE Trans. Intell. Transp. Syst.*, vol. 20, no. 4, pp. 1517–1530, 2018.

[8] Z. Y. Rawashdeh and S. M. Mahmud, "A novel algorithm to form stable clusters in vehicular ad hoc networks on highways," *EURASIP J. Wirel. Commun. Netw.*, vol. 2012, no. 1, p. 15, 2012, doi: 10.1186/1687-1499-2012-15.

[9] S. Kamakshi and V. S. Shankar Sriram, "Plummeting Broadcast Storm Problem in Highways by Clustering Vehicles Using Dominating Set and Set Cover," *Sensors* , vol. 19, no. 9. 2019, doi: 10.3390/s19092191.

[10] A. A. M. A.-N. Haitham Shiaibth Chasib, "Performance Evaluation of Highest Degree Clustering Algorithm in Mobile ad-hoc Networks," *Int. J. Adv. Sci. Technol.*, vol. 29, no. 10s SE-Articles, pp. 3667–3675, Jun. 2020.

[11] N. P. S. Rathore, A. Yadav, and A. Chauhan, "Multi-Agent based Stable Clustering and Collision

Detection In VANET," in *2020 4th International Conference on Intelligent Computing and Control Systems (ICICCS)*, 2020, pp. 1147–1150.

[12] T. Yeferny and S. Hamad, "Vehicular Ad-hoc Networks: Architecture, Applications and Challenges," *arXiv Prepr. arXiv2101.04539*, 2021.

[13] Z. Zhang, A. Boukerche, and R. Pazzi, *A novel multi-hop clustering scheme for vehicular ad-hoc networks*. 2011.

[14] I. Ahmad *et al.*, "VANET–LTE based heterogeneous vehicular clustering for driving assistance and route planning applications," *Comput. Networks*, vol. 145, pp. 128–140, 2018, doi: https://doi.org/10.1016/j.comnet.2018.08.018.

[15] X. Ge, Q. Gao, and X. Quan, "A novel clustering algorithm based on mobility for VANET," in *2018 IEEE 18th International Conference on Communication Technology (ICCT)*, 2018, pp. 473–477.

[16] N. D. Vvedenskaya, A. V. Logachov, Y. M. Suhov, and A. A. Yambartsev, "A Local Large Deviation Principle for Inhomogeneous Birth–Death Processes," *Probl. Inf. Transm.*, vol. 54, no. 3, pp. 263–280, 2018.

[17] A. Rasheed, S. Gillani, S. Ajmal, and A. Qayyum, "Vehicular ad hoc network (VANET): A survey, challenges, and applications," in *Vehicular Ad-Hoc Networks for Smart Cities*, Springer, 2017, pp. 39–51.

[18] S. J. Mohammed and S. T. Hasson, "A developed Clustering Approach to Model the Data Dissemination Types in a Highway," in *2021 1st Babylon International Conference on Information Technology and Science (BICITS)*, 2021, pp. 332–336, doi: 10.1109/BICITS51482.2021.9509917.

[19] Nabil, M., Hajami, A. and Haqiq, A., 2018. Predicting the longest route lifetime as the most stable route between two vehicles in VANET. International Journal of Computer Information Systems and Industrial Management Applications, pp.125-133.

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