Clustering Based Affinity Propagation in VANETs: Taxonomy and Opportunity of Research

Mohammed Saad Talib, Aslinda Hassan, ZuraidaAbal Abas, Ali Abdul-hussian Hassan, MohanadFaeq Ali, Z.J AL-Araji

Abstract: Vehicular communication networks received good consideration and focusing on diverse researchers in the latest years. Vehicular Adhoc Networks (VANETs) represents a developed type of an effective communication technology to facilitate the process of information dissemination among vehicles. VANETs established the cornerstone to develop the Intelligent Transport Systems (ITS). The great challenging task in routing the messages in VANETs is related to the different velocities of the moving vehicles on the streets in addition to their sparse distribution. Clustering approach is broadly used to report this challenge. It represents the mechanism of the alliance the vehicles based on certain metrics such as velocity, location, density, direction and lane position. This paper is to investigate and analyze several challenges and their present solutions which based on different developed clustering approaches based on the affinity propagation algorithm. This paper isaim to present a complete taxonomy on vehicles clustering and analyzing the existing submitted proposals in literature based on affinity propagation. Presenting and analyzing the submitted proposals will provide these domain researchers with a good flexibility to select or apply the suitable approach to their future application or research activities. To prepare this paper in a systematic manner, a total of 1444 articles concerning the Affinity Propagation in clustering** published in the era of 2008 to 2019 were collected from the reliable publishing sources namely (ScienceDirect, IEEE Xplore, and SCOPUS). Due to their relevance, applicability, generality level and comprehensiveness, **only nineteen articles among the collected articles were assigned and eventually analyzed in a systematic review method.A considerable success has been achieved in revealing the essential challenges and necessities for clustering based affinity Propagation in VANETs to guide the researchers in their upcoming investigations. This paper also contributes in dealing with open problems issues, challenges and guidelines for the upcoming investigations.

Index terms: Vehicular Adhoc Networks; Clustering; Affinity propagation.

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I. INTRODUCTION

Many researchers have been focusing their studies to develop the Intelligent Transportation System (ITS). VANET applications can contribute to improving the roads safer and passengers comfort applications[1]. ITS with VANETs can assist the process of providing sudden information to the drivers about their surroundings vehicles and road users to facilitate the driving conditions[2]. These techniques are continuing to develop and utilize the ultimate use of their possibilities. VANETs technologies and their applications are emerging and highly expanding in this era [3]. Progress in technology and innovations assist the VANET principles and make it the suitable technology that enables diverse transportation capabilities. Data dissemination approach represents the backbone process in vehicular networks. Efficient and appropriate spreads of data among vehicles and/or infrastructures are indispensable to succeed the network capabilities [4][1]. The useful information is distributed to other vehicles as proactive data diffusion method. A broadcast mode is usually used to transmit the safety information in VANETs [5][2]. VANET represents a rich research area in this era due to their exciting topographies such as its frequent dynamic topology, dynamic connectivity, no centralized organization and self-organizing [6].

A. Overview of VANETs

The vehicular network represents one of the most significant emerging technologies to assist vehicles communication in different applications such as vehicles traffic, support drivers, entertain passengers and pedestrians [7]. Vehicles can communicate with each other using vehicle to vehicle communication technology or with the road side units through vehicle to infrastructure technology. Vehicles communication can be achieved through standard promising technology known as wireless access for vehicular environment. This technology is utilized in VANET to transmit information to the drivers and passengers about safety or entertainment applications to improve road safety[8]. VANET is a capable addition to support various safety and infotainment applications in ITS. Usually Urban and highway roads are greatly affected by traffic jams due to a large number of passing vehicles [9].

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Most of the recently produced vehicles comprise the possibility of utilizing "Intra-Vehicular Network" in which the communication among vehicles and/or the fixed infrastructures is being conceivable. Different wireless communication tools (gadgets) can be utilized in this fashion, such as Global Positioning System (GPS), On-board units (OBU), Smartphone, Media Players and Bluetooth [10][1]. Figure 1 shows the Vehicular Communication categories in vehicular networks.

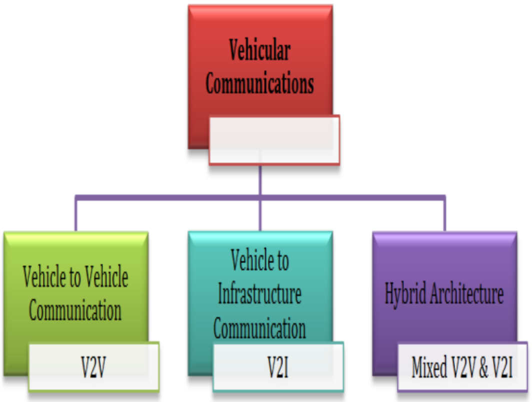

Figure 1: Vehicular Communication in VANETs

B. Overview of Clustering in VANETs

The process of grouping the vehicles in one virtual set according to specific rules is called vehicles clustering and these groups or sets are denoted by clusters. Different grouping rules (instructions) are proposed and analyzed. These instructions are heavily reliant on the clustering objectives and suggested to ensure the process of creating stable clusters [11][12]. Clustering approaches in VANET represent a complex problem due to its high movement (velocities) and frequent channel fails due to this dynamic environment. Each vehicle must get an indication about its adjacent vehicles in order to identify its position in a cluster and identify the cluster head (CH). Various criteria are used in selecting the suitable vehicle to play the role of the CH. Some of these criteria are; velocity, lane, destination, and vehicle location [13][14]. Clustering in VANET aims to achieve different facilities, such as quality-of-service(QoS) and information spreading in dense networks[15]. In order to decrease the flooding produced by the network ineffective dissemination, numerous clustering procedures are considered[16].

Cluster stability is a significant objective that clustering procedures attempt to attain and at the same time can be considered as one of the major clustering performance measures. Stability is essential for communication layers (either upper or lower) in which performances can be developed unusually with the support of clusters.

It permits spatial reprocess of the properties that abridge the routing process in order to create a stable network which can be noticed by each cluster node(CN). There are different ways to define the stability, the most regularly used is thechanging number of CH and the number of CMs changing their CH. If the CH is carefully selected and achieve the cluster formation process by collecting the feasible vehicles then such cluster stability can be developed[11].

Vehicle clustering represents a management scheme in which the adjacent vehicles are gathered into a group known as a cluster. Each cluster has one active node plays the role of a CH. CH is selected to control and manage the cluster activities. All the other nodes in each cluster are entitled cluster members. These members are usually belonging to one cluster or in some cases it belonged to multiple clusters [9][17]. Figure 2 shows the vehicles clustering.

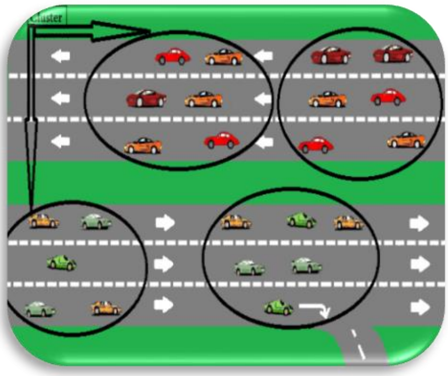

Figure 2: Clustering of Vehicles in VANETs.

C. Overview of Affinity Propagation

Clustering is a collection process used to align the set of things into groups. It used to collect the ad hoc networks nodes; it used also in scientific data analysis to process and detects the data patterns. The purpose of data clustering is to reduce the distance between each data point and its allocated paradigm. This distance can be considered as Euclidean distance or others. The Affinity Propagation (AP) procedure is an innovative technique for data clustering [18]. It can be used to create clusters in a short time with very small error than the old techniques (such as the K-means approach [19]). Clustering error in this context indicates the application-specific distance between the assigned paradigm and each related data point. In AP, the data point can exchange messages. These messages define the present affinity for the certain data point to choose specific data point as its paradigm. This procedure is utilizing the similarity function s(i, j), where s(i, j) represents the possibility of a data point j to be the paradigm (exemplary) of data point i [20]. The essential aim of AP is to maximize the similarity s(i, j) for each data point i and its exemplar j. A minimization application (such as Euclidean distance) must have a negative similarity function. The self-similarity, s(i, i) for each node i is influencing the number of the identified exemplars.

In more likely, initializing the individual data points with a specific self-similarity is appropriate to convert these data points into exemplars. The number of created clusters is proportional to the common self- similarity input value [21]. An extraordinary technique for clustering is proposed by Frey and Duek in their

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Affinity Propagation (AP) study which presented in [18]. AP facilitates in creating clusters with reduced time and error. Comparing with other clustering techniques, the AP approach does not require a fixed number of vehicles to compose a cluster. AP makes use of the similarity measures between the data points in its input to perform the exchange of realvalued messages between datapoints in creating the clusters and then select the exemplary as a CH [22].Measuring the similarity between two data-points i and j denoted by s(i,j) can be appraised to indicate the emerge exemplary. In such process, messages are exchanging with other exemplars until a set of high quality exemplars appear. Two styles of messages can be replaced between vehicle i and j to perform this process.

A responsibility message denoted by r(i,j) is sent from vehicle i to j in the first style as a potential exemplary. It represents the adequate way in which vehicle j as an exemplary considers other conflicting exemplars. While in the second style, an availability message denoted by a(i,j) indicating the suitability of j be an exemplar is replied from j to vehicle i [23].

II.PAPER SELECTION PROCESS

The adopted selection process in this study is aimed to focus on the articles concerning clustering with Affinity Propagation.This process is implemented in the sequential stages. Firstly, three search engines (namelyScienceDirect, IEEEXplore and SCOPUS) are searchedbased on certain keywords to assign and collect the relatedpublished papers.Figure 3 presents the total of 1444 papers published between 2008 to 2019 in these three search engines.

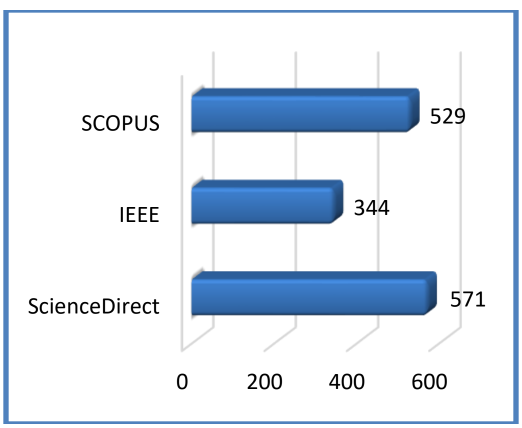

Figure 3: The number of publications in ScienceDirect, IEEEXplore and SCOPUS from 2008 to 2019.

The results show that the ScienceDirect has superiority in a number of related published papers while the IEEEXplore is published the lowest among these three engines. Figure 4summaries the number of publications for each search engine in each year of the study years period.

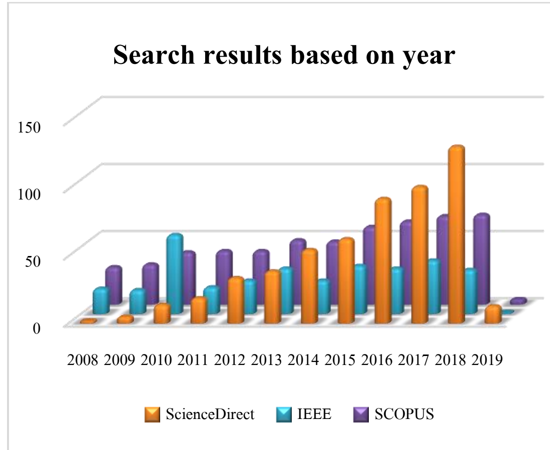

Figure 4: The number of publications for each search engine each year.

An online electronic searching process is conducted on the following three scientific databases.

- Elsevier (https://www.sciencedirect.com),
- IEEE Xplore (https://ieeexplore.ieee.org) and
- SCOPUS (https://www.scopus.com).
- In addition this paper used (https://www.mendeley.com)to managing and citing research papers.

Figure5 represents a developed framework to represent the selection criteria, the followed collection, and the evaluation steps and the resulted informationin this study.

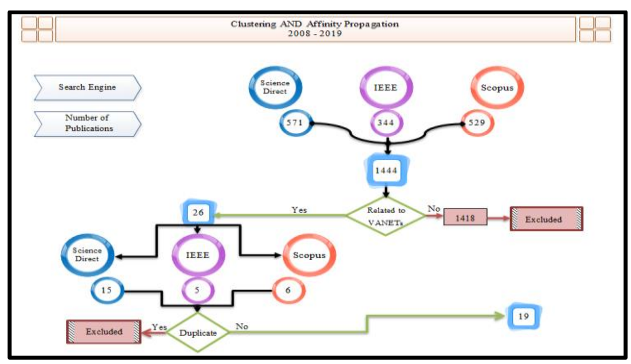

Figure 5: Selection criteria and evaluation framework.

Focusing on these 1444 articles and peer reviewing resulted in assigning only 26 articles which are closely related. Due to the detailed and specific peer reviewing process, all the papers which are not deeply contributed to vehicular adhoc networksclustering based on affinity propagation are indicated as unrelated papers and then excluded.The remaining closely related papers which are compatible with this study interests are found to be only 15 in Science Direct, 5 in IEEE Xplore and 6 in SCOPUS.

An additional duplication checking process is implemented on these 26 selected papers. Only19 significant related papers have been adopted to be related to the clustering in VANETs based on affinity propagation. Among these, only sevenpapers are contributed in affinity propagation while the other twelve papers are only mentioned the affinity propagation as related works.

Table 1 describesthe details of the closely related articles which are being selected in this study.

Table 1: Details of the selectedarticles

Publisher	No	Publish in	Authors	Title	Year
IEEE	1	IEEE "GLOBECOM 2009 proceedings"	Shea, Christine Hassanabadi, Behnam Valaee, Shahrokh	"Mobility-Based Clustering in VANETs using Affinity Propagation"	2009
ELSEVIER	2	"Procedia Engineering"	Bhaumik, Madhuja DasGupta, Suparna Saha, Soumyabrata	"Affinity based clustering routing protocol for vehicular ad hoc networks"	2012
ELSEVIER	3	"Ad Hoc Networks"	B. Hassanabadi C. Shea L. Zhang S. Valaee	"Clustering in Vehicular Ad Hoc Networks using Affinity Propagation"	2014
IEEE	4	"AsiaPacific Network Operations and Management Symposium"	Wang Chengyuan Li Xin Li Fan Lu Huimei	"A mobility clustering-based roadside units deployment for VANET"	2014
IEEE	5	"International Conference on Advanced Communication Technology"	ShahwaniHamayoun Bui ToanDuc JeongJaehoon (Paul) Shin Jitae	"A stable clustering algorithm based on Affinity Propagation for VANETs"	2017
ELSEVIER	6	"Computers and Electrical Engineering"	Nabar, Kaustubh Kadambi, Govind	"Affinity Propagation-driven Distributed clustering approach to tackle greedy heuristics in Mobile Ad-hoc Networks"	2018
IEEE	7	"IEEE Wireless Communications and Networking Conference" WCNC	Koshimizu Takashi Wang Huan Pan Zhenni Liu Jiang Shimamoto Shigeru	"Normalized multi-dimensional parameter based affinity propagation clustering for cellular V2X"	2018

In table 1, specific information about the selected articles publishers (i.e. where the article is published), articles authors, articlestitles and their publication years are presented.

III.CLUSTERING CLASSIFICATION

Clustering approaches in VANET's represent a complex and challenging problem due to theirhigh mobility and frequent fail channels. Each vehicle requires gettinginformation about its neighboring vehicles, its position in a cluster and its cluster head. Various criteria are used in selecting the suitable vehicle to be the CH. The main objective of clustering is how to create stable clusters for the vehicles.Most of the used criteria are; the vehicle velocity, lane, destination, and vehicle location in addition to the Affinity Propagation[13][24][14].

Figure 6 presents the essential issues and parameters used in VANETs clustering.

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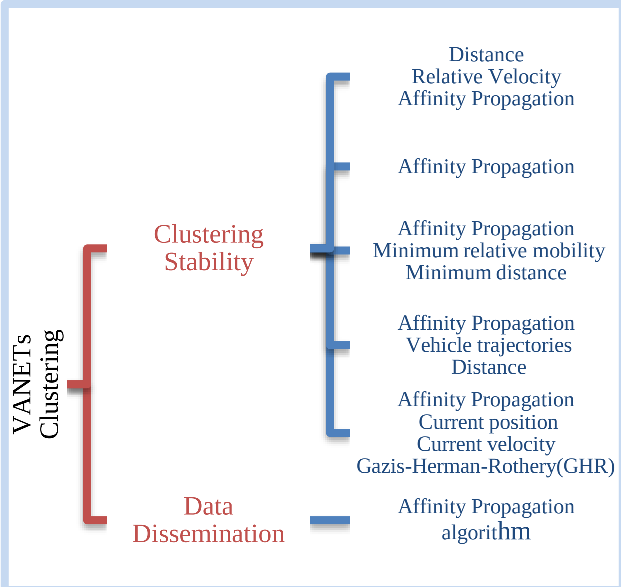

Figure 6: Taxonomy of clustering based on Affinity propagation in VANETs

Figure4 shows that the literature is focusing on two considered clustering approachesin VANET'sbased on affinity propagation. In the first and most important approach is to create clusters depending on the affinity propagation algorithm and otherparameters to improve the stability of the VANET's clusters. In the second approach, the focusing is on the data communication process (i.e. V2V and V2I).Table 2 summaries the other related parameters, scenarios, and issues. It also discusses the main strong points in each of these designated articles.

Table 2: Classification of Affinity Propagation articles

Issue	Parameter	Scenario	Strength	Simulation	Ref
Stability	Minimum distance Minimum relative velocity Affinity Propagation algorithm	Highway	Increase average CM duration Increase average CH duration Lessaverage rate of CH change	Ns2	[20]
Stability	Affinity Propagation	-----	Reduce routing overhead Save the bandwidth of the network Reduce the time delay	-----	[25]
Stability	Affinity Propagation Minimum relative mobility Minimum distance	Highway	Increase average CM duration Increase average CH duration Less average rate of CH change Strong to channel error Exhibitions reasonable overhead	Ns2 SUM O	[21]
Data delivery	Affinity Propagation algorithm	Urban	Message Delivery Ratio Average Delay Hop Count	Vanet Mobi Sim	[26]
Stability	Affinity Propagation Vehicle trajectories Distance	-----	Increase cluster lifetime	MAT LAB	[22]
Stability	Position Velocity Affinity Propagation Gazis-Herman-Rothery	Highway	Less number of clustering iterations Clustering control	-----	[23]

Table 2 analyzes the details of the related articles in vehicular ad-hoc networks. Table 3 presents additional details about these mentioned articles.

Table 3 Classification of non-Affinity Propagation articles

No	Type of Article	Issue	Challenge	Strength	Reference
1	"Research-article"	Stability	Cluster formation	Cluster formation time CM selection time CH selection time Control overheads	[27]
2	"Research-article"	Stability	Quality of service in case of link failures	Network stability Decrease endtoend delay Increase packet delivery ratio Decrease communications overhead	[28]
3	"Research Article"	Traffic information	Traffic management	More stable dynamic clusters Increase accuracy	[29]
4	"Research-article"	security	revocation of misbehaving vehicles	Decreases the complexity of certificate management Increase efficiency and scalability Significantly reduce the revocation cost	[30]
5	"Research-article"	Delay content	Data Exchange	Increase the performance	[31]
6	"Review-article"	Comprehensive survey	Comprehensive survey	A comprehensive survey on Clustering approaches in VANETs	[32]
7	"Research-article"	Overhead of re-clustering Network management	Stability	Increase the cluster stability Increase CH lifetime Increase cluster lifetime Decrease the overhead Decrease the communication cost	[33]
8	"Review-article"	Comprehensive survey	Comprehensive survey	Survey article on clustering techniques	[34]
9	"Research-article"	Establish a stable cluster Maintain a stable cluster	Stability	Improving the stability based on CH duration CM duration Clusters Number CH changing rate Number of state changes	[35]
10	"Research-article"	Data sharing	stable connection	Reduces the frequency of link failures Improving cluster network life	[36]
11	"Research-article"	security and reliability	stability and trusting	Increase the security Increase the cluster stability Increase reliable data sharing Decrease the overhead	[37]
12	"Research-article"	data dissemination	stable and reliable communication	Improve packet delivery ratio Improve information coverage Improve averagedelay of message transmission	[38]

IV.SUMMARY AND DISCUSSION

Among the other research issues that can be considered for the upcoming development of this work are as follows:

(1) Consider the congestion detection and observing the queue conditions.
(2) Focus on the process of vehicles communication in light traffic situations and its challenges.
(3) Analyze and estimate the effects of memory limitations, communication and computational overheads on network performance.
(4) Developing significant scenarios to improve the conditions of the noisy environment such as urban with heavy traffic lights and intersections.
(5) Develop accuracy methods to improve the traffic flows predictions.
(6) Consider other related factors in creating vehicles stable clusters.

Based on the previous literature on affinity propagation as a state of the art in clustering and used to get more stability to solve the clustering issues which are cluster creating and cluster head selection. So, Can conclude thatit's lacked and limited use with the mobility parameters, and need to use more mobility parameters such as relative-velocity, relative-distance, position and relative-mobility to get high clustering stability in vehicular ad hoc networks.

V.CONCLUSION

VANET's have been considered as an exciting and extreme developing research field in networking and wireless communications.Establishing VANETs can be attempted by forming the vehicles as graph nodes. These nodes have the ability to create wireless communication with others as a self-structured open communication network. VANETs have found various applications contributes to decreasing traveling time, expanding road capacity, making the travel more saver, efficient and reducing road congestions.This paper presented the possible survey on the published articles between 2008 and 2019 which are related to clustering in VANETs and the main focus is making on the affinity propagation. Others mechanisms, communication styles, clustering approaches, and applications are also briefly discussed. An indication of the VANETs research challenges and future trends is also stated.This article survey is motivated by detectingthe essentialweaknesses of current clustering algorithms such as: vehicle mobility,less strong to link-failures, dynamic topology and vehicle direction consideration.

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