International Journal of Emerging Trends & Technology in Computer Science (IJETTCS)
Web Site: www.ijettcs.org Email: editor@ijettcs.org
Volume 6, Issue 1, January - February 2017 ISSN 2278-6856

A COMPARATIVE STUDY OF CLUSTERING PROTOCOLS IN VANET

A. Malathi[1] , Dr. N. Sreenath[2]

[1] Research Scholar, Department of Computer Science, Pondicherry Engineering College, Puducherry, India

[2]Professor, Department of Computer Science, Pondicherry Engineering College, Puducherry, India

Abstract
Vehicular ad hoc network (VANET) is the one of the interesting area of research. In a highly dynamic environment the communication is a challenging task. For providing a secured communication among vehicles in the VANET many researchers prefer clustering algorithm. Clustering is a technique used to group the nodes in geographical vicinity for efficient VANET formation and to enhance the services for which they are exploited. In this paper we survey different clustering techniques proposed in VANET. We highlight different categories of clustering algorithm, the significance of various approaches with their objectives, techniques used with their efficiency. A comparative study is presented in this paper.

Keywords: VANET, Clustering, classifications of clustering, IEEE

1. INTRODUCTION
Over last few years VANET has been emerged as a challenging research area. The objective of the VANET is to enable group of vehicles to form and maintain network to communicate among themselves and with other nodes. The VANET has been exploited for many applications which range from safety to non-safety applications. Every vehicle in the network has a responsibility to communicate with other vehicles and nodes in the network to provide a efficient services for which the network has been formed. Therefore we study the architecture of VANET and present in the section2. In Section3 we present about cluster formation and in section4 we present various clustering techniques. In section 5 the comparative performance analysis of various clustering techniques is presented.

2. ARCHITECHTURE OF VANET
The spontaneous creation of a wireless network among the vehicles which are equipped with Onboard Unit and provided with the systems like Global Positioning System (GPS) forms a Vehicular ad hoc Network. In these networks vehicles are connected with the communication backbone through the Road side unit and enable Inter-Vehicle Communication, Vehicle-to-Roadside Communication, The architecture of VANET is illustrated in Fig.1.

Any wireless networking technology can be used as the base in the VANET.. The technologies like WLAN , cellular technologies or LTE (Long term evolution) can be used for VANETs. The VANET protocol stacks are being standardized in the U.S., in Europe, and in Japan, corresponding to their automotive industry.

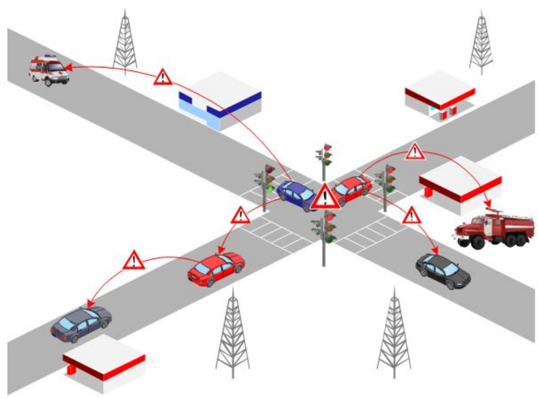

Fig. 1: VANET Architecture

In the U.S., the IEEE 1609 WAVE (Wireless Access in Vehicular Environments) protocol stack builds on IEEE 802.11p WLAN operating on seven reserved channels in the 5.9 GHz frequency band is used in VANET. The WAVE protocol stack is designed to provide multi-channel operation. The Technical Subcommittee on Vehicular Networks & Telematics Applications (VNTA) in IEEE actively promote technical activities in the field of vehicular networks, V2V, V2R and V2I communications, standards, communications-enabled road and vehicle safety, real-time traffic monitoring, intersection management technologies, future telematics applications, and ITS-based services.

The ETSI ITS G5 builds the same radio technology with some adaptations in Europe to operate up to five reserved channels in the 5.9 GHz frequency band. The protocol stack is also designed by the ETSI ITS G5 to provide multi-radio multi-channel operation, security, and a complex hierarchy of higher layer protocols integrating a broad range of basic services.

In the case of Japan, ARIB STD-T109 builds the same radio technology operating on a single frequency in the 700 MHz band. The TDMA operation is used to split use between road side services and pure vehicle to vehicle communication in the protocol stack.

3. CLUSTERING

In the process of Clustering nodes like mobile devices, sensors, vehicles etc. are grouped together in their geographical vicinity according to some rules. Clusters are a virtual groups. Each cluster has at least one cluster head (CH) that is selected by other cluster nodes (CN)[1]. Usually each CN has a chance to become a CH but depending on the preposition used in the algorithms one become CH. For example network connectivity, the types of nodes, (cluster relay) are used for CH selection. The size of the cluster varies from one cluster to another depending on the transmission range of the wireless communication device that a node uses. In some algorithms filters are used to prevent the nodes to join a cluster. The most frequently used filter is direction filter in which a node cannot become CN in a cluster whose CH moves in its opposite direction. An ideal cluster is represented as a circle with CH in the center and CN around it as shown in Fig. 2. Any CN can communicate directly with its CH and can communicate with other CN either directly or via their CH (either in 1-hop or n-hop). The important goal of the clustering algorithm is to achieve cluster stability. It is used as a measure of performance by the clustering algorithm. Cluster stability can be measured by frequency of CH changes or number of a CN changing its CH. The stability of clusters can be improved by selecting the CH and cluster nodes.

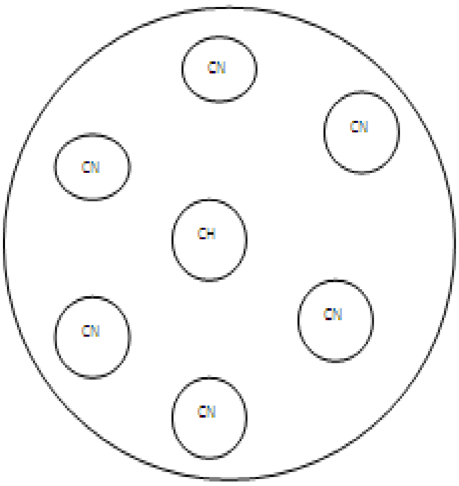

Fig. 2 Cluster with Cluster Head and Cluster Node

There are certain important considerations in the design process of cluster that should be followed in the clustering algorithms. They are Cluster formation, Application Dependency, Secure communication, Synchronization, Data aggregation. The best possible clusters are generated by the CH selection and cluster formation procedures. The message overhead should be reduced. Application robustness must be given high priority. The VANET clustering scheme has to preserve secure communication. Synchronization mechanisms and the effectiveness of these mechanisms must be considered. Data aggregation process makes energy optimization possible it remains a fundamental design challenge in VANET nowadays.

These clustering protocols are very scalable for medium to large size networks. However in dynamic networks like VANETs cluster management in terms of delay and overhead involved is very difficult task.

4.CLASSIFICATION OF CLUSTERING ALGORITHM

Stability is the most important factor for efficient communication between the vehicles in the VANET. To form a stable clusters many researches has provided various clustering techniques. The detailed classification of clustering algorithm is described in Fig.3.

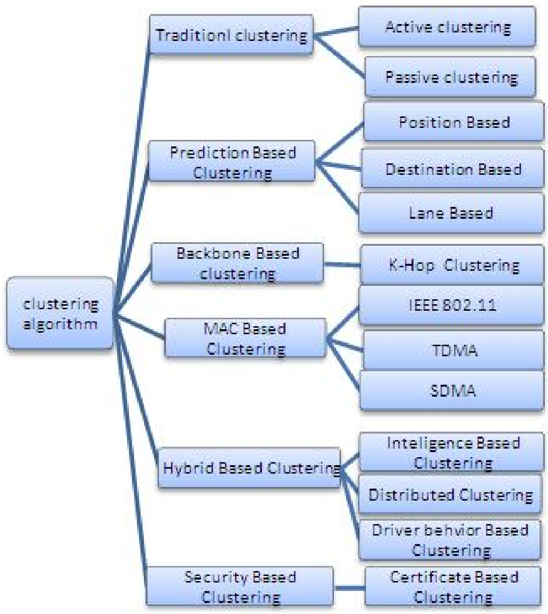

Fig. 3. Classifications of clustering algorithm

4.1. Traditional Clustering

The Traditional Clustering techniques used in VANETs are subdivided in to active and passive clustering based upon the function of nodes in VANET. Fig. 4 shows the subcategories of this technique in VANETs.

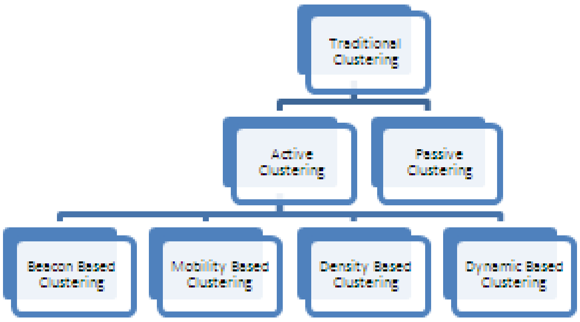

Fig. 4 Traditional clustering Techniques

A periodic updating of the clustering information and routing table are made in active clustering protocols. The clustering processes are initiated through flooding. The various active clustering protocols are Beacon based clustering, Mobility based clustering, Density based clustering and dynamic clustering. In Beacon based clustering, clusters are formed based on some vehicular or network parameters detected by beacons or hello messages by the receiving vehicle. Mobility based clustering protocols minimize relative mobility as well as distance of each CH to its cluster members and thereby attempts to improve the cluster convergence and cluster dynamics. Density based clustering protocols allow strong connections between CNs and low variation in number of CH changes results in improved cluster stability. Dynamic clustering technique forms cluster structure based on node dynamics like mobility patterns, velocity and density.

A cluster structure is constructed passively by the Passive clustering mechanism [2] [3]. At any instant, a node in a cluster possesses an external or internal state. The control overhead is reduced in passive clustering while constructing and maintaining the clusters. That is cluster state information is piggybacked with on-going data packets. This reduces control overhead packets.

4.2. Predictive Clustering

The cluster structure is formed by current geographic position of vehicles and its future behavior in Predictive clustering. The traffic information, future position and the intended destinations of vehicles are used in the cluster formation. The priorities are given to the vehicles with this information. Thus a prediction based clustering can be sub classified into position based , destination based clustering and Lane based clustering

.

4.2.1Position based Clustering

Position based clustering is a technique of forming clusters on the basis of geographic position of the vehicle and CH. Salhi et al. [4] proposed a position based clustering algorithm called as New Aggregate Local Mobility (NEW-ALM) algorithm, which is an improvement to the existing Aggregate Local Mobility (ALM) algorithm. The geographic position of the vehicle is used in forming the cluster structure and based on the priorities associated with each vehicle the CH is selected. The cluster stability is improved by electing the vehicles having a trip as the CHs.

Wang et al. [5] proposed another position based clustering algorithm. It is a cross layer algorithm based on hierarchical and geographical data collection and dissemination mechanism. Based on the division of road segments the cluster is formed. Control overheads are more in V2V and V2I communication. The performance is also influenced by the availability of roadside infrastructure.

Maslekar etal. [6] Proposed a new CH election policy for direction based clustering algorithm called as Modified Clustering based on Direction in Vehicular Environment (MC-DRIVE). The primary functioning of MC-DRIVE is based on the parameter THdistance. This value yields an optimal value of the cluster and is dependent on the speed and the radio range of the vehicles approaching the intersection. The cluster stability is maintained in term of the number of node within a cluster by this algorithm.

Wolny[7] optimized existing Distributed and Mobility-Adaptive Clustering (DMAC) algorithm presented in [8] by estimating road traffic mobility more efficiently. The cluster stability was increased by avoiding re-clustering when groups of vehicles move in different directions. The algorithm is based on periodical transmission of status message. It forms k-cluster so that nodes can be k-hops away from CH. This was achieved by introducing Time-To-Live (TTL) parameter in messages sent by the nodes. Modified-DMAC also introduced a freshness parameter for estimating the connection time. This was used for avoiding re-clustering. Although Modified-DMAC increases the algorithm overhead but it reduces the number of cluster changes thereby increasing the stability of cluster formation. Its performance has also not been evaluated in jammed traffic conditions which are very frequent in dense urban traffic scenarios.

A utility based cluster formation technique is used by Fan et al. [9] proposed a clustering scheme (DCA). The concept of spatial dependency which was initially proposed in [10] is extended in this algorithm. The position and velocity of the vehicle is defined as a utility function. The threshold value is computed based on the previous traffic statistics. All vehicles send a periodical status message. After receiving this information, The CH is chosen by the vehicles based on the utility function. This scheme fails to adapt to dynamic environment and is also not effective for frequent cluster re-organization.

Wang et al. [11] proposed a Cluster Establishment algorithm, which uses the Relative Angle (CERA) to obtain the distance from a potential CH to its neighbor cluster associate nodes. The relative angle between the movement direction of the current vehicle and its closest neighbor is measured to minimize the number of CHs. The algorithm also restricts the number of vehicles in each cluster by selecting cluster associate node. This position information is then used to establish the clusters and their cluster members.

Hassanabadi et al. [12] proposed Affinity Propagation based Algorithm (APA) for clustering in VANETs in a distributed manner. The clusters are formed based upon minimum relative velocity and minimum distance between a CH and its members. Using affinity propagation the CHs are elected periodically. The responsibility and availability messages to its neighbors are transmitted by every node and an independent decision made by the every node in clustering. The suitability of the vehicles for clustering is done by maximizing similarities. The similarity function of any vehicle pair is determined based upon Euclidean distance between the current position and the future position of the vehicular node and the CH is selected based on the minimum similarity.

4.2.2. Destination based Clustering

Destination based clustering techniques forms the cluster based on the current location, speed, relative and final destination of vehicle for cluster formation. The navigation systems are used to know destination. Farhan et al. [13] proposed an algorithm for improving the accuracy of GPS devices called Location Improvement with Cluster Analysis (LICA). Vehicles collect real-time data and relay the information to other vehicles, guiding the drivers to reach the destination safely and efficiently. An accurate distance measurement in LICA reduces the location error and achieves higher performance.

Tian et al. [14] presented a clustering method based on a vehicles position and moving direction. The clustering method is based on Euclidean distance. Vehicles broadcasts beacon message .The receiving vehicle first checks the beacons hop count value and it discards this beacon when the hop count exceeds maximum value. Then sender vehicle updates its topology table by calculating the distance between the vehicles. The vehicle with minimum distance is selected as the CH. The remaining vehicles are then divided into clusters.

The Adaptable Mobility-Aware Clustering Algorithm based on Destination (AMACAD) [15] enhances the clustering stability. It operates in a distributed way and calculate a metric called $F_{v,,2}$. This algorithm improves the lifetime of the cluster and thus decreases the number of CH changes. It avoids global re-clustering. The algorithm is based on certain assumptions like the destination of each vehicle is known and the routing is geographic based. The selection criterion used by a vehicle to join a cluster is minimum value of $F_{v,2}$. This algorithm works well when average speed of vehicles is almost constant which makes this scheme more efficient in urban areas.

Santos et al. [17] proposed Cluster Based Location Routing (CBLR) algorithm to choose CHs in VANETs. In this algorithm beacons are used to distribute the state of the vehicles. The nearby vehicles choose the appropriate state. Each node maintains about the nodes with which it can exchange information in a neighbor table and update the table when it receives the beacon messages.

4.2.3 Lane based Clustering

Lane based clustering creates cluster structures based on estimation of the lanes on which the vehicles are moving. Fan et al. [18] proposed Broadcasting based Distributed Algorithm (BDA) aimed at the existing clusters stability. This scheme requires the vehicles to have only single hop neighbor knowledge. This approach attempts to improve the performance of classical clustering algorithms. BDA gives maximum priority to leadership duration for cluster formation and lead to overhead increase during cluster formation.

Almalag et al. [19] presented a lane-based clustering algorithm based on the traffic flow of vehicles. Each vehicle computes Cluster Head Level (CHL), speed and other parameters and broadcast them. The CH is selected based on the highest CHL.

4.3.Backbone Clustering

Backbone based clustering technique is based on forming a backbone for cluster communication. The backbone then manages the network and performs function such as communication and assists in CH election.

4.3.1 K-hop clustering

In multi hop or k-hop clustering, the hop distance is used The distances between a CH and the members of a cluster are in predetermined maximum number of hops. Zhang et al. [20] proposed a multi-hop for representing N-hop mobility. A vehicle broadcast beacon message periodically and the relative mobility is calculated based upon two consecutive beacon messages received from the same node in N hop distance. Each vehicle node then calculates the aggregate mobility value and broadcast it. The vehicle with smallest aggregate mobility value is selected as the CH. The vehicles join a cluster when they receive the beacons from the CH. When a vehicle node receives multiple beacon messages, then it selects the CH which is closest one in terms of number of hops. If several CHs have the same hops, then the lowest relative mobility is considered.

Zhang et al. [21] proposed a novel K-hop clustering approach that takes into account the highest connectivity, vehicle mobility and host ID to select CH. The proposed clustering approach modifies max-min K-hop heuristic approach defined in [22] for cluster formation by considering highest connectivity in terms of signal strength and vehicle mobility. By dynamically adjusting the period of broadcasting location information transmission overheads are suppressed. This scheme improves network stability and reduces the overhead and the latency caused by route path recovery.

Wei et al. [23] proposed Criticality-based Clustering Algorithm (CCA) for VANETs that employed the metric called as `Network Criticality' to perform the process of building clusters. In a multi-hop VANETs the CCA algorithm improves the lifetime of clusters, and it provides a more stable structure. Dror et al. [24] proposed a distributed randomized two-hop Hierarchical Clustering Algorithm (HCA). HCA forms Time-Division MultipleAccess (TDMA) like synchronized clusters. The algorithm handles the channel access and does not assume any lower layer connectivity. The mobility pattern influences the cluster stability. The inter cluster interferences causes redundant cluster changes and message loss.

4.4. MAC based Clustering

Several Medium Access Control (MAC) based clustering techniques have been proposed for cluster formation in VANETs. These techniques use IEEE 802.11 MAC protocol to generate clusters. The popular MAC based protocols are classified as IEEE 802.11 MAC based Clustering, TDMA based Clustering and SDMA based Clustering.

4.4.1 IEEE 802.11 MAC based Clustering

Su et al. [26] proposed a cluster based Multichannel communication scheme that integrates Clustering with MAC protocols (CB-MMAC). The proposed scheme consists of three core protocols Cluster Configuration Protocol, the Inter-cluster Communication and the Intra-cluster Coordination and Communication Protocol. In the proposed scheme two transceivers are used one for delay sensitive communication within the cluster and other for inter-cluster data transfer.

Bononi et al. [27] proposed a cross-layered clustering scheme for fast propagation of broadcast messages which is called as Dynamic Backbone Assisted MAC (DBA-MAC) scheme that may be considered an extension of the MAC scheme described in [28]. A dynamic virtual backbone infrastructure is established through a distributed proactive technique. Distributed Co-ordination Function (DCF) systems and its performance is comparable in terms of reliability and overhead reduction as compared to simple 802.11 MAC flooding scheme and fast broadcast protocol proposed [26] protocol.

4.4.2. TDMA based Clustering

The process of assigning time slots using TDMA technique can be done using clustering where slots are assigned to CMS for data transmission.

Biswas et al. [29] proposed Vehicular Self-Organized MAC (VeSOMAC) protocol based on a self-configuring TDMA slot reservation protocol which enables inter-vehicle message delivery with short and deterministic delay bounds. The shortest delay is achieved by determining their TDMA time slot based on their location and movement on the road. The TDMA slot is assigned based on the sequential order of physical location of the vehicles. However, the assumption about forwarding messages without processing time or propagation delay is unrealistic. Omar et al. [30] proposed a Multichannel MAC protocol for VANETs (VeMAC) that aims to reduce interference between vehicles and reduce transmission collisions caused by vehicle mobility. The same TDMA time frame is assigned to all the vehicles moving in both directions and RSUs. VeMAC assumes that there are two transceivers on each vehicle and that all vehicles are time synchronized using GPS. The first transceiver is assigned to the control channel, while the second transceiver is assigned to the service channels.

Gunter et al. [31] proposed Cluster Based Medium Access Control Protocol (CBMAC), where the CH manage and facilitates intra-cluster communication. The CBMAC protocol uses an adoption of CBLR protocol proposed in [15] for cluster formation. The frequency of sending status messages in CBMAC depends on the state of node. In this scheme the CH improves QOS by taking the responsibility of assigning bandwidth to the member of the cluster. It minimizes the hidden station problem and provides better scalability. CBMAC also verified that the probability of a node for becoming CH for a short period of time is higher than the probability when the period is long.

Almalag et al. [32] proposed a new TDMA Cluster-based Medium Access Control (TC-MAC) that can be used for intra-cluster communications in VANETs. The centralized approach of cluster management and TDMA slot reservation scheme are integrated in this scheme. TC-MAC decreases collisions and packet drops in the channel,. It also provides fairness in sharing the wireless medium and minimize the effect of hidden terminals. A reliable non-safety messages are delivered by TC-MAC.

4.4.3 SDMA based Clustering

In Space Division Multiple Access (SDMA) based protocols, the road is divided into fixed length segments, and a segment is subdivided into a fixed number of blocks. A timeslot is assigned to each block enable the vehicles to transmit data. In SDMA the performance decreases proportionally with the density and leads to poor performance in sparse.

Salhi et al. [33] proposed a protocol for hybrid vehicular architecture, called Clustered Gathering Protocol (CGP). The protocol is designed to provide real-time data irrespective to the vehicle speed, its location etc. There is a increased delay in message propagation in this scheme. Another drawback is absence of retransmission mechanism to deal with the reception of erroneous data.

Chang et al. [34] [35] proposed different dynamic cluster based vehicle to vehicle protocols using SDMA. The protocol was called Traffic Gather. The main drawback of the channel allocation while using a static medium access technique in wireless networks is inherited. The broadcast storm problem prevails without using a mechanism of retransmission.

Brik et al. [36] proposed a new data collection protocol for vehicular environments called Clustered Data Gathering Protocol (CDGP). The key characteristic of CDGP is the Dynamic Clustering technique. It avoids collision problems by implementing a centralized, dynamic medium access technique, and enhancing the reliability by the integration of retransmission mechanism.

4.5.Hybrid Clustering

Hybrid clustering techniques combine two or more existing techniques such as use of artificial intelligence, fuzzy logic etc. This scheme is categorized into Intelligence based Clustering, Cooperative De-Centralized Clustering and Driver behaviour based Hybrid Clustering.

4.5.1 Intelligence based Clustering

A distributed and dynamic CH selection criteria to organize the network into clusters is proposed by Hafeez et al. [37]. CH is elected based on the relative movement between adjacent vehicles. The vehicle speed and position in future is predicted based on vehicle's acceleration. The proposed scheme achieves stable cluster. However the distributed processing overhead results in decreased message transmission efficiency.

Kumar et al. [38] proposed an Agent Learning-based Clustering Algorithm (ALCA). Agents are able to learn from the environment in which they are operating and perform the task of CH selection. Learning rate is also defined for the agents to take adaptive decisions. For each action performed by the agents, the corresponding action is rewarded or penalized, and value of the learning parameter is incremented or decremented. This process continues until the maximum value is reached.

Wang et al. [39] proposed an Analytical Model for Clustering (AMC) design for VANET. This approach forms the cluster based on modeling an unsaturated VANET cluster with a Markov chain through introduction of an idle state. A vehicle which maintains an active connection with RSU is elected as CH. The elected CH broadcasts a beacon message to vehicles within its communication range. The intended vehicles reply with a request to join message along with their identification information. This proposed model provides design and management of clustering the vehicles for maintaining acceptable communication performance.

4.5.2 Cooperative De-Centralized Clustering

Cooperative vehicular systems are being investigated to design innovative ITS solutions for road traffic management and safety. Through various wireless technologies, cooperative systems can support novel decentralized strategies for ubiquitous and cost effective traffic monitoring system [40]. QuickSilver [41] is a light weight distributed clustering. It is a system architecture that provides efficient use of available resources to guarantee that no harmful competition takes place for the channel bandwidth. QuickSilver utilizes two radio interfaces that allow vehicles to maintain their intra cluster connectivity and inter cluster contact opportunities simultaneously.

4.5.3 Driver behaviour based Hybrid Clustering

Vehicles nowadays are provided with a variety of sensors capable of gathering information from their surroundings. In near future, these vehicles will also be capable of sharing all the gathered information, with the surrounding environment and among nearby vehicles over smart wireless links. They will also be able to connect with emergency services in case of accidents [42].

Blum et al. [43] proposed a Clustering for Open Inter vehicle communication Networks (COIN) algorithm. CH selection is based on vehicular dynamics and driver intentions in COIN. Further COIN attempts to preserve CH for a longer duration and uses mobility information for clustering. Cheng et al. [44] proposed an innovative car-society clustered network based on salient classification scheme. The aim of the proposed approach is to increase the lifetime of the interest group, and to increase throughput in V2V environments.

4.6 Secure Clustering

VANETs can support applications and services for safety and comfort for the on board passengers and assist in improving the efficiency of the road transportation network. However, several serious challenges remain to be solved before efficient and secure VANET technology becomes available. One of these challenges is an efficient authentication of messages using cryptographic techniques [45]. Solutions for secure clustering in VANETs require efficient clustering algorithms in terms of complexity, scalability, availability and reach ability. Several algorithms have been proposed in the literature based on Public Key Infrastructure check for enabling communications security in vehicular environments. These are based on trusted third party certification authorities which is responsible for certifying the public keys of vehicles. Several research schemes have been proposed for distributing the responsibility of the CA's among a set of nodes in the network, using mobility as metric to elect the vehicles that will assume the role of CA.

Blum et al. [46] used a PKI with virtual infrastructure where a set of elected CHs are responsible for disseminating messages after digitally signing them. This scheme is valid only for the attack called intelligent collisions. Raya et al. [47] proposed a distributed PKI for VANETs managed by many CA, each corresponding to a particular region. The different CAs has to be cross-certified so that vehicles from different regions can authenticate each other's CA. It requires that each vehicle store the public keys of all CAs whose certificates were needed to be verified. A location-based approach to form a cluster was used where the area was divided into small zones or cells that form clusters. Vehicles automatically know to which group it belongs by comparing its GPS position to a preloaded dissection of the area map into cells. But its CH is dynamically determined as the vehicle closest to the center of the cell. The disadvantage of this proposal was the non-availability of the CA in case of a break in the connectivity.

Sivagurunathan et al. [48] proposed a self-organized key management system based on clustering. In this model, the network was divided into number of clusters based on the concept that any user can sign any other public key. The set of signatures formed a network of trusted relationships. However, the drawback of this self-organized approach stemmed from the assumption that trust is transitive and therefore the system became more vulnerable to the intrusion of malicious vehicles. Gazdar et al. [49] proposed an efficient dynamic architecture of PKI for VANETs based on a trust model. Each elected vehicle was the CA in its cluster. The proposed clustering algorithm was based on a Trust Metric (Tm) which defined the trust level of a vehicle. Each node, with a high trust level Tm, monitored its neighbors with lower trust levels. Whenever a vehicle became a member in a given cluster, it auto generates a short term pair of keys. The authors also used a new approach called the VANET Dynamic Demilitarized Zone (VDDZ) to shield CAs from malicious nodes.

5. Comparitive Analysis

The existing clustering schemes have large and varied nature of clustering parameters and therefore it is difficult to consider a single parameter for evaluating their performance. To accommodate this diversity, various the parameters are analyzed and then synthesized into six standard categories. These six categories are classified based on parameters that primarily impact vehicular movement, characterize efficiency of the clustering technique and constrain the network performance. Vehicular movement is affected by two categories that are `vehicle density' and `vehicle speed' whereas next three categories named as `cluster stability', `cluster convergence' and `cluster connect time' define efficiency of the clustering technique. The last category, called `transmission efficiency' impresses the network performance.

These categories are defined as follows,

(i) Vehicle density: It designates the average number of vehicles defined in the terms of Vehicles per kilometer (km) or vehicles per lane [51]. For urban scenarios, vehicle density has a higher value as compared to highways.

(ii) Vehicle speed: It is the range of speeds considered for simulation by a particular protocol in terms of m/sec or km/hr. A speed range that varies realistically indicates better adaptability.

(iii) Cluster stability: It is the average life time of a cluster. A high value of cluster stability indicates a better clustering protocol. Cluster connect time refers to percentage time duration that a vehicle stays connected to a single cluster. A high value of cluster connect time indicates the higher suitability of a protocol for clustering.

(iv) Cluster Convergence: It refers to the duration required for all the nodes to join a cluster at the initiation of a clustering scheme. The suitability of a clustering scheme for VANETs is more when it exhibits low clustering convergence.

(v) Transmission efficiency is described as the average number of messages or packets that are transmitted or received by a cluster member during time duration. High transmission efficiency shows that a clustering scheme is more effective in data dissemination.

The relative comparison of various clustering protocols are listed in the following table

Table 1 the relative comparison of various clustering protocols

PROTOCOL	VD	CS	VS	E	CG	CCT
Beacon Based Clustering						
DPP	L	M	L	L	M	L
ER-AC	H	L	L	M	M	L
LORA-CBF	L	L	L	L	M	M
Mobility Based Clustering						
SP-CL	L	H	M	L	L	H
SBCA	M	M	M	L	L	H
APROVE	L	H	M	M	L	M
MDJCS	M	M	L	H	M	M
D-CUT	L	L	L	L	M	L
DBC	H	H	L	L	M	M
Dynamic Clustering						
MULTIAGENTCLUSTER	L	M	L	M	L	L
VWCA	M	L	L	M	L	L
DCSV	L	M	M	L	M	M
AODV-CV	M	L	M	M	M	M
Passive Clustering						
PASSCAR	M	L	H	M	L	L
Position Based Clustering						
NEW-ALM	H	H	H	H	L	H
PPC	L	H	L	L	L	H
MC-DRIVE	L	M	L	L	L	H
DCA	L	M	H	L	L	H
CERA	L	H	L	M	L	M
APA	L	H	L	M	M	M
Destination Based Clustering						
LICA	M	M	M	M	M	H
EUCLIDEAN DISTANCE	H	H	M	H	M	H
AMACAD	L	H	M	M	M	H
CBLR	L	M	M	M	M	H
Lane Based Clustering						
BDA	M	H	M	M	L	H
LANE BASED CLUSTERING	L	H	L	M	L	H
Backbone Based clustering						
N-HOP USING REL.MOB	M	M	L	L	M	H
K-HOP	M	M	L	M	M	H
CCA	L	H	L	L	H	H
HCA	L	M	M	M	H	H
MAC Based Clustering						
CB-MMAC	M	H	H	L	L	H
DBA-MAC	M	L	L	L	L	H
TC-MAC	L	L	M	H	M	H
TRAFFIC GATHER	H	L	L	M	M	L
CDGP	M	L	L	L	M	H
Hybrid Clustering						
FUZZY BASED CH-ALGO	M	H	L	M	L	H
ALCA	H	H	L	M	L	M
AMC	M	H	M	M	L	M
QUICK SILVER	L	L	H	M	H	M
CELLULAR AUTOMATA CLUSTERING	L	H	L	H	L	L
COIN	L	M	L	M	L	L
ESA	L	M	M	M	M	M
SAV	L	M	L	M	M	M

VD-Vehicle Density CS- Cluster stability VS – Vehicle Speed E- Transmission Efficiency CG- Cluster Convergence CCT- Cluster Connection Time.

6. Conclusion

Vehicular Ad Hoc Networks are being used in wide areas of applications. The various Clustering schemes in VANET have been investigated by the research community from different perspectives. But, it has been a challenging task to perform clustering due to the dynamic nature of nodes in VANETs. This paper provides a complete taxonomy with challenges, constraints and solutions on clustering in VANETs based upon various parameters. Also, a detailed discussion is provided for each category of clustering which includes various challenges, existing solutions and future directions.

REFERENCES

[1]. S.Vodopivec, J.Besiter, A Kos, A survey on clustering alogariithms for vehicular adhoc networks, Telecommunications and signal Processing (TSP), 2012 35th International conference on IEEE 2012.

[2]. Weiwei Li, Ali Tizghadam, and Alberto Leon-Garcia. Robust clustering for connected vehicles using local network criticality. In Communications (ICC), 2012 IEEE International Conference on, pages 7157-7161. IEEE, 2012.

[3]. Taek Jin Kwon, Mario Gerla, Vijay K Varma, Melbourne Barton, and T Russell Hsing. Efficient flooding with passive clustering-an overhead-free selective forward mechanism for ad hoc/sensor networks. Proceedings of the IEEE, 91(8):1210-1220, 2003.

[4]. Ismail Salhi, Mohamed Cherif, and S Senouci. Data collection in vehicular networks. In Proc. ASN symposium, 2007.

[5]. Zhigang Wang, Lichuan Liu, MengChu Zhou, and Nirwan Ansari. A position-based clustering technique for ad hoc intervehicle communication. Systems, Man, and Cybernetics, Part C: Applications and Reviews, IEEE Transactions on, 38(2):201- 208, 2008.

[6]. Nitin Maslekar, Mounir Boussedjra, Joseph Mouzna, and Houda Labiod. A stable clustering algorithm for efficiency applications in vanets. In Wireless Communications and Mobile Computing Conference (IWCMC), 2011 7th International, pages 1188-1193. IEEE, 2011.

[7]. GrzegorzWolny. Modified dmac clustering algorithm for vanets. In Systems and Networks Communications, 2008. ICSNC'08. 3rd International Conference on, pages 268-273. IEEE, 2008

[8]. Stefano Basagni. Distributed clustering for ad hoc networks. In Parallel Architectures, Algorithms, and Networks, 1999.(I-SPAN'99) Proceedings. Fourth InternationalSymposium on, pages 310-315. IEEE, 1999.

[9]. Wei Fan, Yan Shi, Shanzhi Chen, and Longhao Zou. A mobility metrics based dynamic clustering algorithm for vanets. In Communication Technology and Application (ICCTA 2011), IET International Conference on, pages 752-756. IET, 2011.

[10]. Nitin Maslekar, Joseph Mouzna, Houda Labiod, Manoj Devisetty, and Ming-Chyi Pai. Modified c-drive: Clustering based on direction in vehicular environment. In Intelligent Vehicles Symposium (IV), 2011 IEEE, pages 845-850. IEEE, 2011.

[11]. Wang Xiaonan and Qian Huanyan. Constructing a vanet based on cluster chains. International Journal of Communication Systems, 27(11):2497-2517, 2014.

[12]. Behnam Hassanabadi, Christine Shea, L Zhang, and Shahrokh Valaee. Clustering in vehicular ad hoc networks using affinity propagation. Ad Hoc Networks, 13:535-548, 2014.

[13]. Antonio Fonseca and Teresa Vazao. Applicability of position-based routing for vanet in highways and urban environment. Journal of Network and Computer Applications,36(3):961-973, 2013.

[14]. Farhan Ahammed, Javid Taheri, and Albert Zomaya. Lica: robust localization using cluster analysis to improve gps coordinates. In Proceedings of the first ACM international symposium on Design and analysis of intelligent vehicular networks and applications, pages 39-46. ACM, 2011.

[15]. Daxin Tian, Yunpeng Wang, Guangquan Lu, and Guizhen Yu. A vanets routing algorithm based on euclidean distance clustering. In Future Computer and Communication(ICFCC), 2010 2nd International Conference on, volume 1, pages V1-183.IEEE, 2010.

[16]. Mildred M Caballeros Morales, Choong Seon Hong, and Young-Cheol Bang. An adaptable mobility-aware clustering algorithm in vehicular networks. In Network Operations and Management Symposium (APNOMS), 2011 13th Asia-Pacific, pages 1-6. IEEE, 2011.

[17]. Yan Zhang, Jim Mee Ng, and Chor Ping Low. A distributed group mobility adaptive clustering algorithm for mobile ad hoc networks. Computer Communications, 32 (1):189-202, 2009.

[18]. RA Santos, RM Edwards, and NL Seed. Inter vehicular data exchange between fast moving road traffic using an ad-hoc cluster-based location routing algorithm and 802.11 b direct sequence spread spectrum radio. In PostGraduate Networking Conference, 2003.

[19]. Peng Fan. Improving broadcasting performance by clustering with stability for inter-vehicle communication. In Vehicular Technology Conference, 2007. VTC2007- Spring. IEEE 65th, pages 2491-2495. IEEE, 2007.

[20]. Mohammad S Almalag and Michele CWeigle. Using traffic flow for cluster formation in vehicular ad-hoc networks. In Local Computer Networks (LCN), 2010 IEEE 35th Conference on, pages 631-636. IEEE, 2010.

[21]. Zhenxia Zhang, Azzedine Boukerche, and Richard Pazzi. A novel multi-hop clustering scheme for vehicular ad-hoc networks. In Proceedings of the 9th ACM international symposium on Mobility management and wireless access, pages 19-26. ACM, 2011.

[22]. Liren Zhang and Hesham El-Sayed. A novel cluster-based protocol for topology discovery in vehicular ad hoc network. Procedia Computer Science, 10:525-534, 2012.

[23]. Tracy Camp, Je_ Boleng, and Lucas Wilcox. Location information services in mobile ad hoc networks. In Communications, 2002. ICC 2002. IEEE International Conference on, volume 5, pages 3318-3324. IEEE, 2002.

[24]. Weiwei Li, Ali Tizghadam, and Alberto Leon-Garcia. Robust clustering for connected vehicles using local network criticality. In Communications (ICC), 2012 IEEE International Conference on, pages 7157-7161. IEEE, 2012.

[25]. Effi Dror, Chen Avin, and Zvi Lotker. Fast randomized algorithm for hierarchical clustering in vehicular ad-hoc networks. In Ad Hoc Networking Workshop (Med- Hoc-Net), 2011 The 10th IFIP Annual Mediterranean, pages 1-8. IEEE, 2011.

[26]. Peng Fan, James G Haran, John Dillenburg, and Peter C Nelson. Cluster-based framework in vehicular ad-hoc networks. In Ad-hoc, mobile, and wireless networks, pages 32-42. Springer, 2005.

[27]. Hang Su and Xi Zhang. Clustering-based multichannel mac protocols for qos provisioning over vehicular ad hoc networks. Vehicular Technology, IEEE Transactions on, 56(6):3309-3323, 2007.

[28]. Luciano Bononi and Marco 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, pages 1-8. IEEE, 2007.

[29]. Luciano Bononi, Marco Di Felice, Lorenzo Donatiello, Danilo Blasi, Vincenzo Cacace,Luca Casone, and Salvatore Rotolo. Design and performance evaluation of cross layered mac and clustering solutions for wireless ad hoc networks. Performance Evaluation, 63(11):1051-1073, 2006.

[30]. Subir Biswas, Jelena Misic, and Vojislav Misic. Id-based safety message authentication for security and trust in vehicular networks. In Distributed Computing Systems Workshops (ICDCSW), 2011 31st

International Conference On, pages 323-331. IEEE, 2011.
[31]. Hassan Omar, Weihua Zhuang, and Li Li. Vemac: A tdma-based mac protocol for reliable broadcast in vanets. Mobile Computing, IEEE Transactions on, 12(9): 1724-1736, 2013.
[32]. Y Gunter, Bernhard Wiegel, and Hans Peter GroBmann. Medium access concept for vanets based on clustering. In Vehicular Technology Conference, 2007. VTC-2007 Fall. 2007 IEEE 66th, pages 2189-2193. IEEE, 2007.
[33]. Mohammad S Almalag, Stephan Olariu, and Michele 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, pages 1-6. IEEE, 2012.
[34]. Wang-Rong Chang, Hui-Tang Lin, and Bo-Xuan Chen. Trafficgather: An efficient and scalable data collection protocol for vehicular ad hoc networks. In Consumer Communications and Networking Conference, 2008. CCNC 2008. 5th IEEE, pages 365-369. IEEE, 2008.
[35]. Soheila V Bana and Pravin Varaiya. Space division multiple access (sdma) for robust ad hoc vehicle communication networks. In Intelligent Transportation Systems, 2001. Proceedings. 2001 IEEE, pages 962-967. IEEE, 2001.
[36]. Bouziane Brik, Nasreddine Lagraa, Mohamed Bachir Yagoubi, and Abderrahmane Lakas. An e_cient and robust clustered data gathering protocol (cdgp) for vehicular networks. In Proceedings of the second ACM international symposium on Design and analysis of intelligent vehicular networks and applications, pages 69-74. ACM,2012.
[37]. Khalid Abdel Hafeez, Lian Zhao, Zaiyi Liao, and Bobby Ngok-Wah Ma. A fuzzylogic- based cluster head selection algorithm in vanets. In Communications (ICC), 2012 IEEE International Conference on, pages 203-207. IEEE, 2012.
[38]. Neeraj Kumar, Naveen Chilamkurti, and Jong Hyuk Park. Alca: agent learning| based clustering algorithm in vehicular ad hoc networks. Personal and ubiquitous computing, 17(8):1683-1692, 2013.
[39]. Huixian Wang, Ren Ping Liu, Wei Ni, Wei Chen, and Iain B Collings. Vanet modeling and clustering design under practical traffic, channel and mobility conditions. Communications, IEEE Transactions on, 63(3):870-881, 2015.
[40]. Ramon Bauza and Javier Gozalvez. Traffic congestion detection in large-scale scenarios using vehicle-to-vehicle communications. Journal of Network and Computer Applications, 36(5):1295-1307, 2013.
[41]. Riccardo Crepaldi, Mehedi Bakht, and Robin Kravets. Quicksilver: applicationdriven inter-and intra-cluster communication in vanets. In Proceedings of the third ACM international workshop on Mobile Opportunistic Networks, pages 69-76. ACM, 2012.
[42]. Javier Barrachina, Piedad Garrido, Manuel Fogue, Francisco J Martinez, Juan- Carlos Cano, Carlos TCalafate, and Pietro Manzoni. Veacon: A vehicular accident ontology designed to improve safety on the roads. Journal of Network and Computer Applications, 35(6):1891-1900, 2012.
[43]. Jeremy Blum, Azim Eskandarian, and Lance Ho_man. Mobility management in ivc networks. In Intelligent Vehicles Symposium, 2003. Proceedings. IEEE, pages 150-155. IEEE, 2003.
[44]. Sheng-Tzong Cheng, Gwo-Jiun Horng, and Chih-Lun Chou. Using cellular automata to form car society in vehicular ad hoc networks. Intelligent Transportation Systems, IEEE Transactions On, 12(4):1374-1384, 2011.
[45]. Bidi Ying, Dimitrios Makrakis, and Hussein T Mouftah. Privacy preserving broadcast message authentication protocol for vanets. Journal of Network and Computer Applications, 36(5):1352-1364, 2013.
[46]. Jeremy Blum and Azim Eskandarian. The threat of intelligent collisions. IT professional, 6(1):24-29, 2004.
[47]. Maxim Raya, Adel Aziz, and Jean-Pierre Hubaux. Efficient secure aggregation in vanets. In Proceedings of the 3rd international workshop on Vehicular ad hoc networks, pages 67-75. ACM, 2006.
[48]. S Sivagurunathan, P Subathra, V Mohan, and N Ramaraj. Authentic vehicular environment using a cluster based key management. European Journal of Scientific Research ISSN, 36(2):299-307, 2009.
[49]. Tahani Gazdar, Abderrahim Benslimane, and Abdelfettah Belghith. Secure clustering scheme based keys management in vanets. In Vehicular Technology Conference(VTC Spring), 2011 IEEE 73rd, pages 1-5. IEEE, 2011.
[50]. MS Kakkasageri and SS Manvi. Multiagent driven dynamic clustering of vehicles in vanets. Journal of Network and Computer Applications, 35(6):1771-1780, 2012.
[51]. Rasmeet S Bali, Neeraj Kumar, and Joel JPC Rodrigues. Clustering in vehicular ad hoc networks: taxonomy, challenges and solutions. Vehicular communications, 1(3):134-152, 2014.