Stable Clustering Technique for Vehicular Adhoc Networks

by

NS Saira Khan

A thesis submitted to the Department of Electrical Engineering, Military College of Signals, National University of Sciences and Technology, Islamabad, Pakistan, in partial fulfillment of the requirements for the degree of MS

in

Electrical Engineering

FEBRUARY 2020

SUPERVISOR CERTIFICATE

Certified that final copy of MS thesis written by Ms. **NS Saira Khan**, Registration No.**00000172571** of Military College of Signals has been vetted by undersigned, found complete in all respect as per NUST Statues/Regulations, is free of plagiarism, errors and mistakes and is accepted as partial fulfillment for award of MS degree. It is further certified that necessary amendments as pointed out by GEC members of the student have been also incorporated in the said thesis.

Signature: ___________________________________

Name of Supervisor: **Asst Prof.Abdul Waheed Khan, PhD**

Date: _______________________________________

Signature (HoD):______________________________

Date: _____________________________________

Signature (Dean):_____________________________

Date: _______________________________________

ABSTRACT

Vehicular Ad-hoc Network (VANET) plays an important role in the realization of the intelligent transportation system (ITS) which leads to a plethora of new applications such as traffic safety, traffic management, and infotainment. However, the high mobility and dense distribution of the vehicles on the road causes problems for routes management and network scalability. These issues can be effectively resolved by employing clustering techniques which not only supports scalability of network thereby eradicating broadcast storms caused by packets flooding but also simplifies medium access control. Despite its numerous advantages, cluster formation and sustainability of clusters in high mobility scenarios is one of the major challenges in VANETs. To improve the stability of the cluster, efficient cluster head selection in accordance with the various traits of VANETs among candidate vehicles is desired. In this research work, a Multi Criteria based Stable Clustering technique (MCSC) for VANETs is proposed. The proposed MCSC technique includes a novel feature of average Past Cluster head Lifetime (PCL) along with relative speed, relative distance and degree of connectivity for efficient selection of cluster head (CH) and elects substitute cluster head (SCH) to maintain the stability of cluster structures. Along with that cluster head selection, cluster formation, maintenance and clusters merging features are incorporated. A simulation based performance evaluation is conducted to evaluate stability of proposed technique through different parameters and benchmarking with state-of-the-art. Demonstrated by simulation results, the proposed MCSC technique outperforms the existing clustering techniques in VANETs in terms of the stability indicators.

DEDICATION

Dedicated to
MY BELOVED PARENTS, RESPECTED TEACHERS, FAMILY AND FRIENDS
for their guidance, encouragement, incredible support and love
that always lightened my ways.

ACKNOWLEDGEMENTS

I am thankful to Allah Almighty (all praise belongs to Him) for giving me the strength and ability to achieve my objectives and successfully complete this research work.

I am highly grateful to my supervisor, Asst Prof Dr. Abdul Waheed Khan for guiding and supporting me throughout my research work. His timely encouragement has led me to complete this research successfully. He not only imparted significant knowledge to me but also contributed extensively in my work. I am highly obliged to my Guidance and Evaluation Committee (GEC) members as well, that included Assoc Prof Dr. Naima Iltaf , Asst Prof Dr. Muhammad Imran and Asst Prof Dr. Yawar Bangash for dedicating their precious time for my research work and always guiding me through it.

Finally I would like to pay my gratitude to all those people without whom I could never have accomplished my aim including my family, especially my parents and my teachers. I am grateful to them for their constant prayers and persistent support throughout this journey. May Allah bless them all with eternal happiness.

Table of Contents

LIST OF FIGURES

LIST OF TABLES

ACRONYMS

BN	Bridge Node
CCF	Composite Clustering Factor
CH	Cluster Head
CLS	Connectivity Lifespan
CM	Cluster Member
DSRC	Dedicated Short Range Communication
GPS	Global Positioning System
ITS	Intelligent Transport System
MANET	Mobile Ad-hoc Network
OBU	On Board Unit
OMNET++	Objective Modular Network Testbed
PCL	Past Cluster head Lifetime
PU	Processing Unit
QoS	Quality of Service
RSU	Road Side Unit
SCH	Substitute Cluster Head
SUMO	Simulation of Urban Mobility
V2I	Vehicle to Infrastructure
V2V	Vehicle to Vehicle
VANETs	Vehicular Ad-hoc Networks
VEINS	Vehicles In Network Simulation

Chapter 1

INTRODUCTION

Vehicular Ad hoc Networks (VANETs) are an emerging domain of research that leads to the creation of Intelligent Transport Systems (ITS) by utilizing Vehicle to Infrastructure (V2I) communication and Vehicle to Vehicle (V2V) communication. In these types of communications, infrastructure includes Road side units (RSUs) and vehicles which are equipped with wireless devices called on board units (OBUs) that allow them to communicate directly with each other in an infrastructure less manner. In this way, vehicles can avail numerous applications which include improved traffic management, traffic safety, traffic congestion avoidance and sharing infotainment data [1].

In order to get benefit from VANET, many approaches have been presented to design a communication system for vehicles and increase its performance. Many have focused on V2I communication by using RSU for managing communication network and others have worked on a different approach by building routing techniques for V2V communication considering dynamic nature of VANETs. On a middle ground, an approach has been presented to divide moving vehicles into logical groups called clusters and converting flat network into hierarchical network to avail benefits of infrastructure based network without physical deployment of units.

Clustering is a method to partition nodes into several clusters. Every node in a cluster is classified based on its role. A cluster consists of one Cluster Head (CH), several Cluster Members (CMs) and one/more Bridge Node(s) (BN) [2]. Clusters can be formed on the basis of different set rules of an technique. An efficient technique allows nodes to form cluster that maintains network topology and ensures less overhead. These techniques include cluster head selection and cluster formation & maintenance. But, in VANETs vehicular nodes move in high speed due to which there is frequent change in topology that cause instability in clusters which increases maintenance overhead and cost of re-clustering. In order to form stable clusters, considering dynamic nature of VANETs, efficient stable clustering technique is required to form stable clusters and reduce cluster formation and maintenance cost. Stable clusters help in improving reliability of an ad hoc network. In this thesis, our goal is to develop a new stable clustering technique for VANETs that can increase performance of vehicular ad hoc network.

1.1 Motivation

Clustering technique is an eminent solution to decrease the network complexity. There are two main objectives for clustering, to reduce overhead and to increase scalability and efficiency of the network. In the literature, some of the researchers have investigated many clustering techniques for VANETs in order to reduce overhead but ignored high dynamic nature of vehicular nodes which cause instability and affect the performance of network. Some of the clustering techniques are infrastructure based which violates the nature of ad hoc network and areas where no infrastructure is available these techniques cannot be applied. The cluster is considered as stable cluster when it has maximum cluster head and cluster member duration and minimum re-clustering rate. So, the clustering technique should be capable of efficient cluster head selection, cluster formation and maintenance, considering high mobility of vehicular nodes. Many parameters should be considered to elect the CH for cluster in VANET, such as location, velocity, direction and degree of connectivity.

The main motivations of this thesis are summarized as follows:

a. To reduce communication overhead in VANET by forming clusters
b. To increase scalability of network in high mobility scenarios by forming stable clusters
c. To increase stability of clusters by efficient CH election
d. To reduce maintenance overhead of clusters
e. To avoid re-clustering caused by high mobility of vehicles.

1.2 Problem Statement

In urban scenarios - characterized by dense distribution and mobility of vehicles, VANETs are subject to high congestion which might lead to increased packets drop ratio and/or latency. Considering such vulnerabilities, cluster formation can help in reducing network load and improving QoS of the network. Each cluster consists of several vehicles, in which one vehicle is selected as cluster head (CH) by other vehicles called cluster members (CM). CH is responsible for faster communication within cluster with minimum delay. Many researchers have proposed the use of various clustering techniques for VANETs. But, highly dynamic topology of VANETs can disturb cluster formation and causes frequent re-clustering that leads to cluster instability. The high-mobility nature of VANETs will bring huge computation overheads to vehicles for electing cluster head and forming new cluster. Therefore, a clustering technique should to be able to form stable cluster even in high mobility scenarios and strive to cluster structure for as long as possible, otherwise frequent re-clustering will increase overhead, that ultimately degrade the performance of network and invalidate the purpose of clustering. [3].To decrease the maintenance overhead and increase network quality, the clustering technique for VANETs should also be able to form stable clusters.

1.3 Objectives & Dissertation Goal

The main goal of this research is to design and develop a stable clustering technique for VANETs. To achieve the goal of this research, several objectives have been identified which are listed as follows:

- The first objective is to design a clustering technique to minimize network congestion caused by packet flooding sent by vehicles associated with each other.

- The second objective is to form stable clusters for VANETs thereby selecting the most appropriate vehicle as cluster head among a set of candidate vehicles considering mobility parameters to achieve maximum cluster head duration.

- The third objective is to incorporate an intelligent cluster-maintenance feature such that to avoid the need of frequent re-clustering of the already formed clusters.

This work should solve the following main issues:

a. How to reduce communication overhead in VANET?
b. How to increase scalability of network in high mobility scenarios by forming stable clusters?
c. How to reduce maintenance overhead of clusters?
d. How to avoid re-clustering caused by high mobility of vehicles?

The main goal of this research is to address the aforementioned issues thereby designing and developing a stable clustering technique for VANETs.

1.4 Thesis Organization

The remainder of this thesis is organized as follows. In Chapter 2, background literature on VANET is presented along with an overview of existing clustering techniques. Chapter 3 describes the proposed clustering technique. Simulation based results and benchmarking with state-of-the-art is presented in Chapter 4. Finally, Chapter 5 provides conclusion of this research along with recommendation of future work.

Chapter 2

LITERATURE REVIEW

A detailed literature survey is carried out for the establishment of framework of knowledge, upon which the presented methodology will be build. Firstly, it is discussed that what VANETs are and what is clustering in VANETs. The work related to clustering in VANETs is then discussed to analyze various prevailing techniques/techniques to identify the research gaps which provide the basis for proposing novel solution considering the strengths and weaknesses of existing literature.

2.1 Vehicular Adhoc Networks

In recent times, a major domain has been explored in the field of computer science which is communication among vehicles. This type of communication can be achieved by using a Vehicular Ad-hoc Network (VANET). VANET is a lot like Mobile Ad-hoc Network (MANET) which basically performs the task of transferring information either between cars moving in close vicinity or between cars and the road side units (RSUs). The prime aim of VANETs is to give comfort and security for the passengers in these vehicles. To achieve the aforementioned objective, electronic equipment like a wireless modem needs to be inserted in the vehicles in order to provide communication for the customers. In VANET, all such vehicles that are enabled with an ad-hoc network device are taken to be as nodes which are capable of sending and receiving information to and from other vehicles as well as the RSUs.

VANET is a research area which characterizes a specific set of MANETs. The basic idea of VANET is quite simple and straight: creation of a broad and economical wireless technology that connects the nodes (vehicles) to one another and to the RSUs for receiving and sending out information. Some significant properties of VANETs are: in VANET, vehicles and RSUs are considered as nodes. These can travel and move very rapidly and the network under consideration is greatly dynamic, meaning that the network topology changes continuously with the variation in the exact pinpoint location of the nodes and density [4],[5]. Hence, it can be said that VANET is a technology used for communication among vehicles as well as the RSUs.

Nodes in VANETs can be of two types [3], the static nodes called Road Side Units (RSUs) and the mobile nodes called On Board Units (OBUs); as shown in Figure 2.1. Furthermore, a different type of communication that takes place in VANETs is also illustrated in Figure 2.1; such as communication between vehicles and RSUs/infrastructure (V2R or V2I) and the Inter Vehicle Communication (IVC). Moreover, there can be Inter-Roadside Communication as well in which the RSUs communicate with each other.

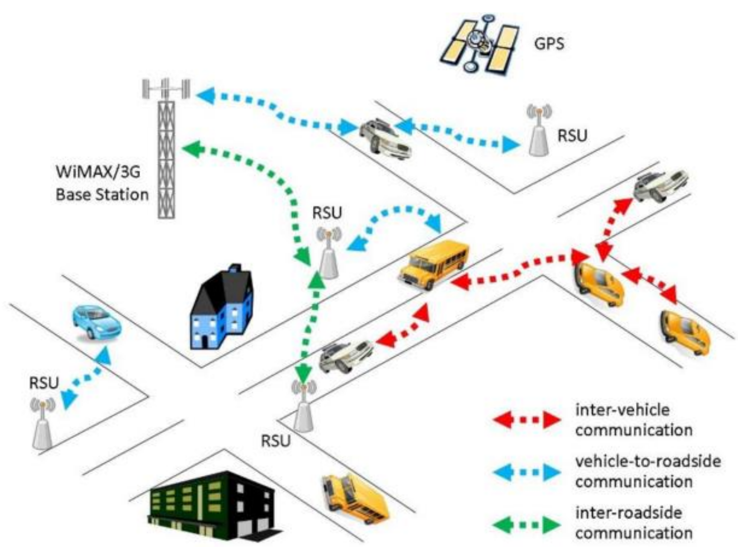

Figure 2.1: VANETs architecture and types of communication

In order to solve the traffic issues, wireless communication technology is considered as an effective solution that focuses on the third strategy. To solve these issues, based on the wireless technologies Vehicle to Infrastructure (V2I) and Vehicle to Vehicle (V2V) Communication have been designed. V2V and V2I communication found various implantations in the ITS so as to get the transportation process more well planned and efficient.

VANET topology is considered to be the most effective method for such type of wireless communication among vehicles because of its unique characteristics such as a network topology that changes rapidly and the rapid moving speed of nodes that cause mobility and the constrained or unnatural pattern caused by the blocked roads.

2.2 Characteristics of VANETs

As stated before in the previous segment, VANETs have various distinct properties VANET is considered to be an extension of MANET therefore it has most of the features that are attributed to MANET. In addition, they have several other new features that make them significantly different from MANETs. Therefore, compared with other ad-hoc networks, the characteristics of VANETs are unique. In MANETs, there is no stationary infrastructure and in order to perform the task of routing of messages and network management, they are dependent on ordinary nodes. On the other hand, in vehicular networks the human communication, limitation on movement and continuously and constantly varying speed of vehicles contribute to the generation of an entire set of properties for such networks. Furthermore, a VANET can be designed as continuous but to some extent a predicted changing protocol, similarly fragmentation takes place frequently in the network, additionally compared to MANETs the communication range of VANETs is little and hence significant numbers of networking challenges are introduced by VANETs. Following are some of the important characteristics of VANETs [7]:

a. High Fragmentation of Network: The unavailability of VANET gadgets for all nodes causes fragmentation in the network with the consequence of isolation for the portion of the network. Fragmentation occurs due to the unavailability of a transceiver installed in OBU of every vehicle in the initial deployment of the network.
b. Scalability: In VANET, the network has a small effective diameter. Moreover, due to the rapidly varying vehicle movement, various tracks are broken or disconnected before being utilized therefore resulting in a poor connectivity. Thus, it is not suitable that the nodes follow some global topology.
c. Security and Privacy Constraints: In VANET, every node is primarily a real person; and the data being transmitted by the vehicle somehow reveals the identity of the one that is driving the vehicle. So, to make this technology to be accepted by the public, such types of security bugs needs to be eliminated from VANETs. Likewise, in any case there is no such provision that the transmitted message can be tempered by the user. This will cause automatic crash making it highly dangerous for the safety applications.
d. Power: In OBU, the life of the battery used is not an issue owing to the fact that the vehicle battery is normally used to power them and compared to the vehicle own equipment, their power consumption is considerably lower. Hence, when it comes to power consumption, there is no significant design challenge.

e. Variable Network Density: The network density is continuously varying because of the traffic movement. In case of traffic jam, there may be extreme congestion in the network whereas at night time, because of a lesser traffic there would surely be a scattered network.

f. Mobility: In VANETs, a communication link has a very short lifetime owing to the high movement of cars. Moreover, if the nodes are moving in direction opposite to each other, a worst case scenario is created.

g. Low Communication Latency: In an emergency situation, latency becomes a crucial factor to be considered for the broadcast messages.

2.3 Potential Applications of VANETS

The growing VANET technologies will define various applications for the assistance of drivers, have efficient traffic, safety etc. Numerous prospective applications can be available in VANET, (V2V as well as V2I). These applications can be thought of as based on safety (safety or non-safety related) or on the basis of methods of communication (V2V, V2R). In the subsequent sections, various potential applications of VANETs will be discussed along with the examples for each type.

2.3.1 Safety

In order to minimize the accidents and injuries caused by them and to save lives, VANET technologies can possibly be exploited. Few instances of the use of these technologies to avoid accidents and injuries include warnings for the accident, collision, lane departure and work zone, detection of obstacles, vehicle breakdown etc.

In every application, the data after being processed is disseminated to their destination that could be some other vehicle in case of V2V communication or infrastructure in case of V2I communication, determined based on the causes and set of rules for sending such a message. In the applications related to safety, two different kinds of messages could be there: event-driven messages and periodic messages. Event-driven messages are generated in case of an actual accident or danger detection. On the other hand, periodic messages, also known as beacons, are continuously generated for the purpose of keeping the neighboring vehicles informed. These beacons carry the information about the direction of car, its speed, lane, position etc. and are utilized for the prediction of a potentially hazardous situation.

- **Periodic Messages:** In order to avoid any hazardous situation, the vehicle-related information like speed, position and direction, about the neighboring vehicles must be known and taken under consideration for taking a decision. All this information is transmitted by the periodic messages, they are taken as an important type of messages that support the decision to be taken in safety applications; however, it only causes wasted bandwidth utilization, particularly in environments which are dense, but also increases the probability of occurrence of a storm problem.
- **Event-Driven Messages:** This type of messages are broadcasted only in hazardous and dangerous conditions, elsewise there is no event-driven message. It has a high priority level; in this type of message, the main difficulty is an increased necessity to guarantee the delivery of it to all those vehicles that need to know about it.

2.3.2 Entertainment/ Information Applications

The applications for information or entertainment, occasionally called as the non-safety applications, aim at leveraging the traffic efficiency and making the journey more comfortable for the drivers. For instance, giving information to the passenger about the nearest fuel station, informing of weather conditions in some specific area, providing restaurants that exist in the area and their menus, communicating information from the nearest cark parks about the available parking spaces, offering the internet access facilities in smooth way while in travelling and allowing passengers to play online games, Coupling/Decoupling, Payment of the parking area Electronic Toll Collection (ETC) and communication between vehicles [8].

2.3.3 Traffic Efficiency

For reducing the traffic congestion and for the improvement of efficiency of traffic, VANET can be used. For instance, electronic toll collection, managing highway traffic, cooperative adaptive cruise control, information related to congestion in order to control the traffic etc. [6].

2.3.4 Driver Assistance

For the improvement of safety and security, VANET can be used so as to provide effective communication and accurate data to the vehicles. For instance, downloading digital road maps, navigation system, warning information, automatic emergency call, information of the real life traffic, parking information etc.[6].

2.4 Clustering Technique in VANETS

Clustering is a beneficial and great technique for organizing ad-hoc networks and grouping nodes in the form of small clusters. In distributed networks, clustering simplifies the aggregation and management of information for each network [11].

Grouping of nodes into clusters is carried out to provide an easily manageable network according to specific application requirements.

In protocols which are cluster-based, comparison of nodes is done with each other and the ones that are found to be most similar on the basis of their patterns of movement are carefully chosen to become the part of same cluster. The criterion for this comparison is defined on the basis of application requirements of the protocols. In VANET applications, the use of clustering techniques is beneficial and is being extensively utilized [12].

Mostly the use of clustering in VANETs is for data dissemination and routing [9],[10]. However, for target tracking in VANETs, the use of cluster-based techniques is still a challenging task; therefore it has not being used frequently.

In a cluster, the main entities are: Cluster members (CM), cluster head (CH) and Bridge nodes (BN). CH is considered as leader or commander of the Cluster which is responsible for managing the clusters as well as the communication with other clusters or infrastructure of the network. Relaying information from nodes of the cluster to other clusters or between nodes in a cluster is also the responsibility of CH. The second entity of a cluster is CM which is the node that becomes part of a cluster on the basis of their similarities and their characteristics. The responsibilities of these nodes include sending their information and data based on their application to the CH. CMs that are part of a single cluster are assumed to have no communication with the CHs or CMs of the other clusters. The last entity of a cluster are the GW nodes that are basically the nodes at the boundaries of two clusters and are shared between them and are responsible for communication between the two clusters.

2.5 Advantages of Clustering in VANETs

In large scale and distributed networks, clustering is an effective technique for data aggregation and network management. Attributed to the special characteristics of VANETs, introducing an aggregator node in a specific part of the network for data aggregation, would be effective. This node is possibly known as the CH or the head node. The role of a CH is the establishment and maintenance of the cluster topology for the purpose of communicating application based data. It gets the different types of messages from the cluster member and combines this information. The nodes that are not the part of cluster will simply be able to receive the messages that have been aggregated rather than receiving all the messages coming from each node individually. In VANETs, this approach makes the dissemination of safety messages efficient. The vehicles present in danger zone or in its vicinity, will convey message to a CH rather than sending the messages in the whole network. It is the then the task of the CH to collect and process the information and then shares it with other members of cluster or other cluster head within the network. Clustering process helps in splitting the network into small parts known as clusters which are managed easily. A lot of work has been done on techniques of clustering regarding VANET [12], [13], [14], [15]. Major reasons for using clustering are: to increase the scalability of network by creation of network segments , to reduce the amount of messages disseminated within the network [12], reduction in the amount of congestion in V2V as well as V2I communications [16],[17], to provide excellent quality of service (QoS) and proper messages routing [18], handling the variable network connectivity caused by either density variations or link breakage [19], to reduce the problems of contention and hidden terminals [20].

2.5.1 Significance of Stable Clustering

Some other significant advantages of clustering in a VANET environment are to deal with the dynamic nature of VANETs and to adapt to frequent changes in topology. In the clustering process, the entire network gets divided in smaller parts or pieces known as segments. As compared to the global network, these smaller parts called clusters are lesser dynamic because the relative mobility of a cluster is less than the relative mobility of a network. The goal is to select the similar nodes having similar patterns of mobility to get associated with each other in a same cluster [18] and form stable clusters in order to avoid frequent re-clustering and maintenance overhead. In MAC protocol [19], the role of clustering is to assist in channel contention reduction, offering fair access to the channel, controlling the topology and organizing medium access in order to increase the network capacity. Furthermore, the use of cluster-based techniques for the reduction of handoff latency effect and packet loss due to handoff in VANETs is proposed in [14]. In [21], a handoff scheme based on Network Mobility (NEMO) is presented, in which the network is divided into clusters and communication among the cluster is used to get the available access points in advance in order to reduce handoff latency.

2.6 Performance Metric for Clusters Stability

Various performance metrics can be used to measure the cluster stability. In this section, these metrics will be described in detail. The goal of all the clustering techniques is to improve these performance metrics in order to form a robust and more stable clustering protocol that is capable of functioning effectively in the VANET environment that is highly dynamic and adapting to the frequently occurring variations in topology and density. In most of the clustering techniques, following features are mainly considered for stability and efficiency. In order to design and implement an efficient as well as stable clustering technique, these stability features need to be improved.

2.6.1 Cluster Head Lifetime

It is the time interval for which a cluster head stays active and controls the cluster management and maintenance. For the reduction of variations in cluster structure, in all clustering techniques most aim at increasing the lifetime of the cluster and reducing the change in CH as much as possible

2.6.2 Cluster Member Lifetime

It refers to the interval of time when a vehicle becomes the part of a cluster as its member till the time it leaves it. By increasing the lifetime of a cluster member, a strong, robust and more stable and steady clustering technique can be developed. This is because of the reduction in the amount of variations in the structure of the cluster owing to the existence of the members of the cluster that have a long life.

2.6.3 CH Change Rate

The CH change number refers to the amount of CH changes for the time duration of simulation [14], [20]. The criteria for the selection of CH need to be implemented in such a way that the total number of changes in the cluster head is reduced as much as possible; still satisfying the requirements of the application. If the clustering technique is stable and robust, the amount of changes observed in the cluster will be less.

2.6.4 Average Number of Cluster

As the amount of clusters formed decreases, the network contention also decreases. Decreasing the amount of clusters, however, results in an increase in the size of the cluster that is not beneficial at all times. Hence, there should be a trade-off between the size of the clusters and number of clusters.

2.6.5 Cluster Lifetime

The way how cluster lifetime is defined, depends on design of the clustering technique and the application for which cluster is formed. For example, in majority of techniques, lifetime of a cluster is dependent on the lifetime of the CH and if the CH leaves the cluster, the cluster no longer exists. In spite of this, there is a high probability that CM might lost connection with CH in highly dynamic environment of VANETs. Thus, in such scenarios, clustering techniques can be considered for the assignment of a new CH without re-clustering, which can improve the performance of the technique considerably. An extensively used technique is the secondary CH or substitute CH selection that can play the role of CH in case CH is lost or left the cluster [13]. This technique alleviates the CH lifetime and mitigates the delay caused by re-clustering. In Chapter 3, the idea of priority assignment to the vehicles for the multi-criteria based stable clustering (MCSC) will be presented. In lost CH situations, this technique helps to increase the CH lifetime and avoids re-clustering.

2.6.6 Control Overhead

Control packets are used for cluster maintenance and in retaining the cluster topology, but sending control packets within a cluster can cause overhead in the network.In a cluster, the overhead caused by these control packets needs to be reduced so that delay can be decreased and delivery ratio can be increased. This reduction in overhead can be achieved by using various techniques such as passive clustering technique [22],[23] and predicting the behavior of member nodes rather than frequently sending their information.

2.6.7 Convergence Time

The time required for the creation of clusters and the selection of CH for each these clusters is referred to as convergence time. Essentially, it indicates length of the initialization phase. It is an important metric that needs to be reduced in order to ensure an efficient and fast clustering technique [24].

2.6.8 Packet Delivery Ratio

Packet delivery ratio is defined as the ratio total number of received packets to the total number of sent packets. This indicates the successful delivery of data/packets in the network. In various clustering techniques, this ratio has been evaluated as a performance metric [23]. The large value of packet delivery ratio is an indication of better performance of the technique.

2.6.9 End-to-End Delay

The average amount of time taken by a packet to reach from its source to the destination is called End-to-end delay. This metric is dependent on numerous network factors such as size of the cluster, network density, communication range and so on. Owing to the frequently varying nature of VANET topology and structure, reducing the delay is an essential requirement. Furthermore, various critical applications of VANETs require that messages be delivered to the destination rapidly, such as the notifications for driving safety and for any hazards etc.

2.7 Desired Features for Stable Clustering in VANETs

There has been substantial work on increasing the efficiency of clustering and stability of clusters in VANETs recently. Owing to the dynamic nature of VANET, it is a challenging task requiring innovative ideas and techniques to design efficient clustering technique that has high cluster stability. The most common features that are deemed important for stable clustering are described as follows:

2.7.1 Appropriate CH Selection Metric

In clustering protocols, one of the crucial entities is the CH that has to be a node that has a long life and must be selected based on the application requirements. Suggesting a suitable CH selection metric allows selecting the most efficient node as the CH and improving the lifetime of CH that helps in stabilizing the cluster structure. One of the techniques which is advantageous for the selection of CH is to make use of prediction about the behavior of node in order to select it as the best CH which last for a longer time duration [12].

2.7.2 Appropriate Cluster Membership Criteria

In most of the clustering techniques for VANET, selection of CMs is done on the basis of their direction of movement and relative mobility. Generally, in VANET the vehicles that are moving in opposite direction from the cluster are not added as a part of the cluster. This is because of the instability which arises due to the short-term membership of these nodes. In spite of this, addition of nodes having different directions might be advantageous in certain applications and under special conditions. Similarly, it would be beneficial to reduce the change rate of CM and to increase CM lifetime.

2.7.3 Reduction of CH Changes

Adjustments in the cluster structure are needed in order to change the CH. Reducing the rate of CH changes would therefore aid to maintain the topology of cluster and increase its stability. In majority of clustering techniques, CH is characterized as the lowest mobile node with respect to other member nodes in the cluster. At each defined interval, the CH needs to be evaluated and if required it can be re-selected on the basis of CH selection rules. Because of the rapidly changing VANET topology, it is highly probable that the CH would no longer be eligible. Despite the fact that another node can possibly be more suitable to become CH, majority clustering techniques do not frequently change the CH in order to keep the values CH change as low as possible. In MCSC technique (Chapter 3), for the reduction of number of CH changes is to include prediction mechanisms for the selection of CH. According to this technique, a node will be selected as CH only if it is an eligible CH for longer time duration as compared to other members.

2.7.4 Association of Nodes to Cluster instead of CH

The CMs use a CH ID in order to associate to a CH and when the CH changes, there is a need for changes in the cluster structure as well [13]. In such a situation, an increase in re-clustering occurs and consequently the lifetime of cluster will decrease. One solution to this problem is to allow CM to communicate with arch in the absence of CH .By doing so, the cluster lifetime will increase and the re-clustering overhead will also reduce.

2.7.5 CH Recovery Techniques

In a cluster, CH is considered as most important and responsible entity. In some techniques, loss of CH results in breaking the overall cluster structure and hence the initialization phase needs to be run again. In order to prevent switching between initialization phases and the cluster maintenance, certain techniques aim at selecting a substitute cluster head (SCH) to handle the responsibilities of a CH if the current CH is lost [13]. This SCH selection, in case of CH loss, makes the technique stable to some extent and prevents the delay resulting from the re-clustering. Another effective method to account for the CH loss is to allocate priority to the member nodes. This priority is assigned to the nodes using the same procedure as for the selection of SCH on the basis of the defined application. Each node then advertises its priority to all the other member nodes to inform them about it. A member list is created by the CMs and the priority value of each node is saved in it. This approach helps in the selection of next CH among the nodes without necessarily having an active CH. This method, however, has a problem associated with it, that is the increased overhead caused by the beacon messages that are sent for announcing the priorities. Overall we can say that this technique is effective in the creation of stable and robust clusters that are not solely dependent on the CH for their activities. Further in depth details about this approach are discussed in the clustering technique in Chapter 3.

2.8 Review of Existing Clustering Techniques in VANETs

In the literature, VANET clustering has been done using different techniques for increasing QoS, load balancing and data dissemination in highly mobile vehicular network. Generally, it has been observed that Clustering technique divide the network in smaller and little groups, called clusters. Cluster Heads are responsible for establishing inter and intra cluster connections. The main purpose of cluster formation is to decrease the control overhead and to increase the scalability of a network.

Fan [26] proposed a clustering scheme where a utility based cluster formation technique is used by making advancement in Spatial Dependency which was proposed in [25]. Utility function is made up of position and velocity, closest to a predetermined threshold value. The threshold value is calculated on the basis of former traffic statistics. A status message is sent by all the neighboring vehicles periodically. After receiving this information, each vehicle elects its CH according to the utility function. The vehicle having the highest value is chosen as the CH. But, this scheme fails to adapt traffic dynamics of VANETs.

Despite of great diversity in the methodology, clustering techniques still share almost same mechanism. The basic clustering procedures include cluster head selection and cluster formation and maintenance techniques. Variable CH selection methods are used in the literature. The usual selection methods can be classified into threshold based and weight based CH selection methods. There are some examples of threshold based clustering technique to select the CH.

TB [27] is specifically designed for the areas with faster mobility like highway, in which the vehicle moving with slowest pace with respect to its local neighbors commences the cluster formation process. Local neighbors will affiliate with a node only in the case when the relative velocity of a node and local neighbors in less than a specified threshold.

UFC [28] is another threshold based clustering technique which aims to improve scalability of network by using neighbor sampling technique and back off cluster head selection. The vehicle which first declares itself CH wins and it becomes the cluster head. The drawback of this type of scheme is that it may skip eligible CH because of threshold values and first come and get scenario which ultimately affects stability of cluster.

In weight-based method, each vehicle are assessed by different metrics to act as CH, vehicle with high value is selected as CH. MOSIC [29] is a clustering scheme to form clusters on the basis of relative distance and velocity of the vehicles and future position by using Gauss Markov Model. But, this probabilistic approach is vulnerable to degraded network performance in case of high variation in mobility.

In [30],[31] a center-based clustering technique is introduced in order to aid the self-organized VANETs so that they can form a stable and steady cluster and the frequent stats change of the nodes can be decreased. Cluster head selection is based on mobility metrics which include relative velocity, distance and acceleration. But, there is an infrastructure based cluster maintenance and reforming which is against the nature of ad-hoc network and increases maintenance overhead.

Along with mobility metrics, some researchers have added reputation and trust metrics for cluster head selection. TACR [32] appends velocity and the position of vehicles with Certificate Authority trust metrics to calculate a weighted cluster head selection metric. These metrics include reputation for correct data packet forwarding and traffic obedience. This type of approach has multiple purposes that ensures reliably functioning cluster head and provides security around clusters by forbidding malicious vehicles to become a Cluster head or become part of the cluster.

VWCA [33] takes into consideration the direction of vehicles, the number of neighboring nodes based on dynamic transmission range, the entropy calculated from [34], and the distrust value metrics. These metrics can increase connectivity and stability and also help to minimize the overhead which exists in the network. VWCA introduced adaptive Allocation of Transmission Range technique, which adjusts the range of transmission between the vehicles based on the density of traffic and Hello messages adaptively around vehicles. VWCA calculates distrust value through proposed technique and use it in the weighted sum operation. Vehicles which possess a distrust value which is lower than that of neighboring vehicles are nominated as CH. So, the selected CH's are most trustworthy vehicle in the whole of network. This technique aims to improve CH duration, security and the timing for which node remains part of the cluster. Using VWCA, communication overheads that is needed in order to become a part of new cluster becomes decreased because of increase in CM duration. Along with that VWCA is able to minimize the value of overheads because of rapidly moving speed vehicles by calculating entropy.

MOFA [35] considers direction, position, velocity and degree of connectivity, ID of lane and reputation of each node for stable topology of VANETs. Reputation score is calculated on the count of vehicle performs the task of CH. The drawback of this technique is that it may increase reputation score of vehicle which become CH multiple times without considering its lifetime and performance.

Vehicles in VANETs are characterized with high dynamic nature, due to which it is difficult for vehicles to communicate with each other in the form of cluster and sustain its topology. In this scenario, efficiency of network will decrease due to re clustering and high cluster maintenance cost and undermine the idea of clustering. Therefore, to form stable clusters in a network and maintain their stability are important issues in clustering techniques for VANETs. Researchers have proposed many clustering techniques considering mobility of vehicles to form stable clusters.

Some researchers have used a parameter of link lifetime (LLT) also called link expiration time (LET), to filter adjacent neighbors and form cluster with filtered neighbors to attain stability. MDMAC [24] introduced Time-To-Live parameter in periodic status message to form k-cluster so that vehicles can be k-hops away from CH. This aims to decrease number of cluster changes and avoid re-clustering to achieve cluster stability.

Density Based Clustering (DBC) [36],[37] is based on several points like the level of connectivity, quality of link , reputation of the node, predicted future position of vehicle and the relative position of the vehicle. The given technique has a total of three stages. Firstly, a vehicle evaluates its connectivity level to find density of neighboring vehicles. Numbers of active links are assessed by counting the received acknowledgments from neighbors. By making comparison between the defined threshold value and connectivity level, it is determined if the node is a part of the sparse or dense areas of networks. Then, in second stage it selects steady links among all the current links by taking into consideration the previous knowledge of their direction and speed of the moving vehicle. This makes the ground for estimating and calculating the quality of the link. Signal-to-noise ratio of the link is also used in this evaluation. In the third stage, communication history is used to determine the reputation and stature of the vehicle before it joins the cluster. The results of multipath fading are also considered in this technique.In [38] proposed clustering mechanism includes sampling of stable neighbors based on link lifetime and targets high cluster lifetime. The shortcoming of this mechanism is that it encounters increase in overhead in case of cluster head role shifting and re clustering considerably affects performance of network in high mobility scenarios.

In most of the techniques, each cluster is maintained or operated by a CH. But, in cases when the CH loses capability to continue its role as a CH or resigns, re clustering is inevitable. So, for the purpose of maintaining the steadiness and integrity of network and avoid re clustering, many researchers have proposed different techniques to select secondary cluster head that take over the responsibility of CH once the previous CH leave the cluster to maintain cluster topology and its functionalities.

A stability-based clustering technique (SBCA) [39] aims to increase the lifetime of the cluster and to minimize the communication overhead which is caused due to cluster formation and maintenance. SBCA makes use of movement, degree of connectivity, secondary CH and CH duration for the aim of providing a stable network. In most existing clustering approaches the vehicles are associated with each other with the help of

CH. When one CH leaves the cluster, secondary CH takes command; the overall structure of the cluster does not vary but role shifting occurs. SBCA significantly improves the cluster lifetime, reduce overhead and thus enhances the performance also.

In [40] proposed a clustering technique which takes into account the vehicles behavior for efficient cluster head selection and also selects a backup CH to uphold the stability of cluster structures. But, selection of cluster head is based on unrealistic parameter that is intention of vehicle to leave the network or not, because vehicle is unaware of it.

DHC [41] is a clustering technique which uses mobility metrics and link quality metrics which includes the SNR and the LET, for cluster formation. Along with that, secondary CH (SCH) is selected for cluster maintenance and reviewed cluster merging scenarios to increase the life of cluster. The drawback of this technique is that overhead increases for taking all CMs into confidence before making final decision while evaluating cluster merging options.

2.8.1 Findings of Literature Review

Based on literature review, it is revealed that some techniques used neighbor sampling technique to filter out unstable neighbors and some techniques incorporated different metrics other than mobility metrics like reputation to select CH. All techniques are summarized in Table 2.8.But, majority of existing clustering techniques for VANETs result into unstable clustering which increases communication overhead. So, taking this into account this research work aims to develop a stable clustering technique that is not only in accordance with the traits of VANETs but also avoids frequent re-clustering caused by high mobility of vehicles.

Table 2.8 : Criteria for CH selection in different techniques

Technique	Criteria for CH selection				Secondary CH
	Direction	Velocity	Degree	LLT	
LIC[26]	✓	✗	✗	✗	✗
TB[27]	✓	✓	✓	✓	✗
UFC[28]	✓	✓	✓	✓	✓
MOSIC[29]	✗	✓	✓	✗	✗
CBSC[31]	✓	✓	✗	✗	✗
TARC[32]	✓	✓	✓	✗	✗
VWCA[33]	✓	✗	✓	✗	✗
MOFA[35]	✓	✓	✓	✗	✗
MDMAC[24]	✓	✓	✓	✓	✗
DBC[37]	✓	✓	✓	✓	✗
LRCA[38]	✗	✓	✓	✓	✗
SBCA[39]	✓	✓	✓	✗	✓
ScaIE[40]	✓	✓	✓	✗	✓
DHC[41]	✓	✓	✓	✓	✓

Chapter 3

PROPOSED CLUSTERING TECHNIQUE

3.1 Introduction

In Chapter 2, there is detailed discussion on various design approaches to the clustering problem and emphasized on potential flaws in the methodology of recent designs. After literature review, it is observed that because of high demand of VANET, it is the need of hour to search for some process that will increase performance of VANETs by enhancing efficiency of communication among its different components.

Clustering processes play an important part in VANET communication by forming clusters of vehicular nodes. It is significant for any clustering technique to focus on wisely selecting It is significant for any clustering technique to focus on wisely selecting the cluster head, as the cluster head acts as centralized entity and is communicates with the other clusters and RSU, so that we can avail benefits of a virtual centralized infrastructure. A lot of parameters exist which can be taken into consideration for selection of CH. In this thesis, a clustering technique is proposed for selection of the CH based on the average speed, direction, vehicle position and its past cluster lifetime. Stable clusters can be formed from the proposed technique by:

- Increasing Cluster head lifetime
- Increasing Cluster member lifetime
- Reducing Re-clustering rate

The basic goal in clustering techniques is to have minimal change in the selection of CH as frequent changing in cluster heads or clusters eventually lead to communication overhead which defies the purpose of clustering

3.2 Anatomy of Clustering Technique

Cluster formation and maintenance involves series of fundamental procedures that need to be updated and performed again according to the set of rules in the technique and network dynamics. A flow diagram showing process of clustering is in Figure 3.1. Nodes seeking to join clusters or participating in a cluster have to follow some or all of the set of rules and procedures, with references to Figure 3.1. The procedural flow is described below.

3.2.1 Neighborhood Discovery

In VANETs, when a vehicle initially wants to join communications system in an ad-hoc manner it starts scan for the neighbors by receiving periodic beacon messages from the n-hop neighboring vehicles. This beacon message mostly consists of vehicle information about its position, direction and velocity. This information is stored in a neighbor table for further processing.

3.2.2 Cluster Head Selection

Vehicle, after collecting information from surrounding, then scan the neighbor table to find an efficient vehicle for the role of cluster head CH. The role of cluster head depends on the technique. Mostly CH is responsible for inter and intra cluster communication, it may include relaying functions or routing and managing clusters. During the process, every vehicle assesses itself to act as CH. If it receive CH beacon from its neighbor then it send join request and moves to step 4, elsewise if node finds itself suited to be CH so it makes an announcement and proceed to step 7.

3.2.3 Join Request

The node will contact the neighboring CH which it finds suitable and tries to join cluster as cluster member. In some techniques, join request can be sent to already establish CH while in others request can be received unclustered or any member of the cluster. An additional step might be involved in the case if techniques are targeting application with security sensitivity where an acknowledgement response of joining is sent to requesting node followed by a step for authentication. After receive response from CH, it become a cluster member and enter step 5.

3.2.4 Announcement

The node finds itself most suitable to become CH, send out an announcement message to neighboring node to form cluster [7]. When the node receives join request from neighbors it proceed to step 5a.

3.2.5 Maintenance

Cluster maintenance has different scenarios according to the role of node in the cluster as a member or as cluster head.

a) As Cluster Head: After cluster formation, cluster head monitors connection with its cluster member [8]. In several techniques, maintenance processes include changing cluster heads, cluster merging and tracking connection with members [9],[10]. There can be number of events or causes that can change the state of nodes: if a CH loses all of its members [11], the resigns from its role [14], and returns to initial states. If cluster come across with other cluster with greater number of cluster member, then two clusters are likely to merge to form large cluster instead of two small overlapping clusters and proceed to step 5.

b) As a Member: the cluster member evaluates its link with CH [5], by receiving periodic messages from CH. If the node doesn't receive beacon messages, that means connection between cluster member and CH is lost [6],so it will return to step 1.

In most of the clustering techniques these steps are the same, the major difference is in selection process for CH using different parameters

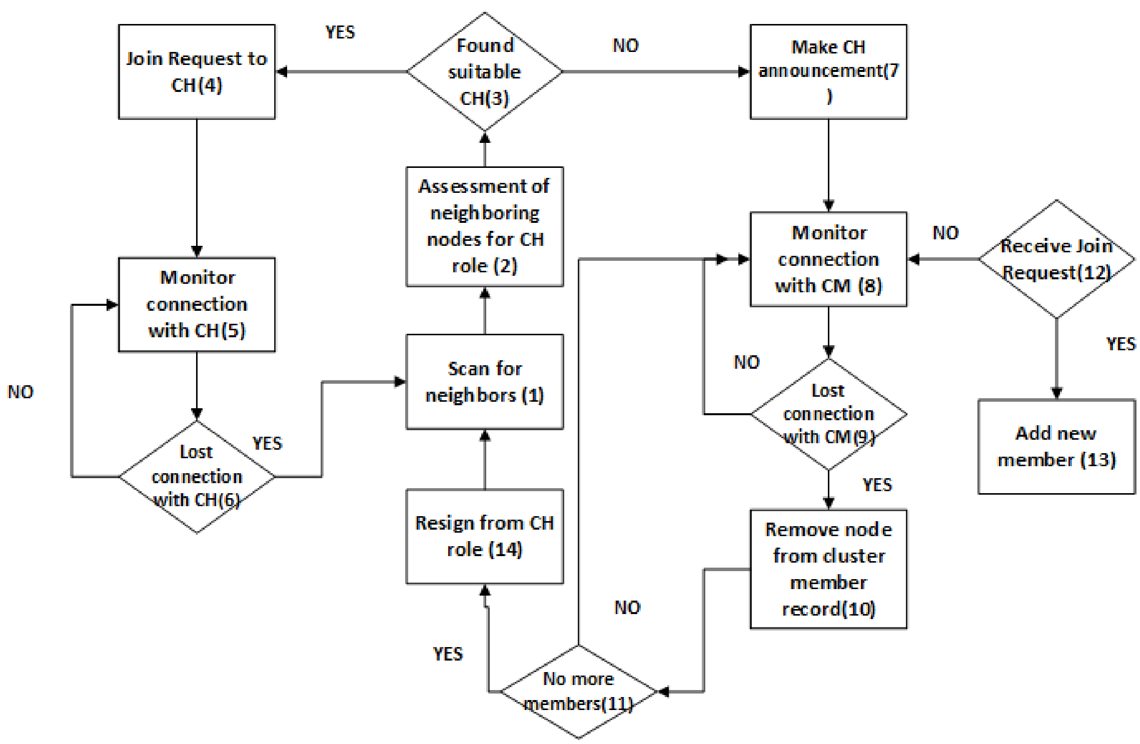

Figure 3.1: Anatomy of Clustering Technique

3.3 Stable Clustering Technique

In this section, steps and techniques to form stable clusters are presented in high mobility scenarios through neighbor filtration and multi metric cluster head selection. First, the vehicular nodes willing to form an ad-hoc network or to join the network, start with neighborhood discovery by sending and receiving beacon messages from neighboring nodes. It is noted that all the neighboring vehicles are not likely to form a cluster together because of movement of vehicles in different direction. For this reason, CLS based Neighbor Filtration technique is proposed to filter out stable neighbors among all surrounding neighbors. Secondly, a parameter called composite clustering factor is introduced to select most suitable cluster head for the cluster. Thirdly, technique for cluster formation is proposed. After cluster formation , in order to maintain the cluster structure to avail the benefits as long as possible, cluster maintenance technique is proposed considering different scenarios that helps clusters to remain intact and keep functioning in particular manner. At the end, cluster merging is also proposed in maintenance process in case of overlapping clusters to merge them under one of them CH with large value of clustering factor.

3.3.1 Proposed Technique

In this research work, a cluster-based vehicle-to-vehicle (V2V) communication technique is proposed without any need of deployed infrastructure such as RSUs for the purpose of communication between vehicles. We assume that every vehicle is mounted with an On board Unit (OBU) containing a Global Positioning System (GPS), a Dedicated Short-Range Communication (DSRC) wireless unit and a Processing unit (PU). The vehicle uses the GPS to get the actual real-time and exact position, velocity and moving direction, on each vehicle the PU runs the clustering technique separately. Vehicles periodically share their information with each other via hello messages. These messages include vehicle's identity, current velocity, current position, moving direction, and past cluster head lifetime (PCL).Vehicle has not played any CH role in the past then its PCL value is considered as zero. Our technique is applicable for both urban and highway traffic. The roads may have multiple lanes and bi directional but with no intersection.

The proposed technique MCSC is a distributed technique. Every vehicle runs this technique independently after getting information of other vehicles through hello messages. In this section, vehicles state with and without clustering, neighbor filtration strategy and technique for cluster formation, maintenance and merging are illustrated. The general flow chart of our proposed clustering technique is showed in Figure 3.2.

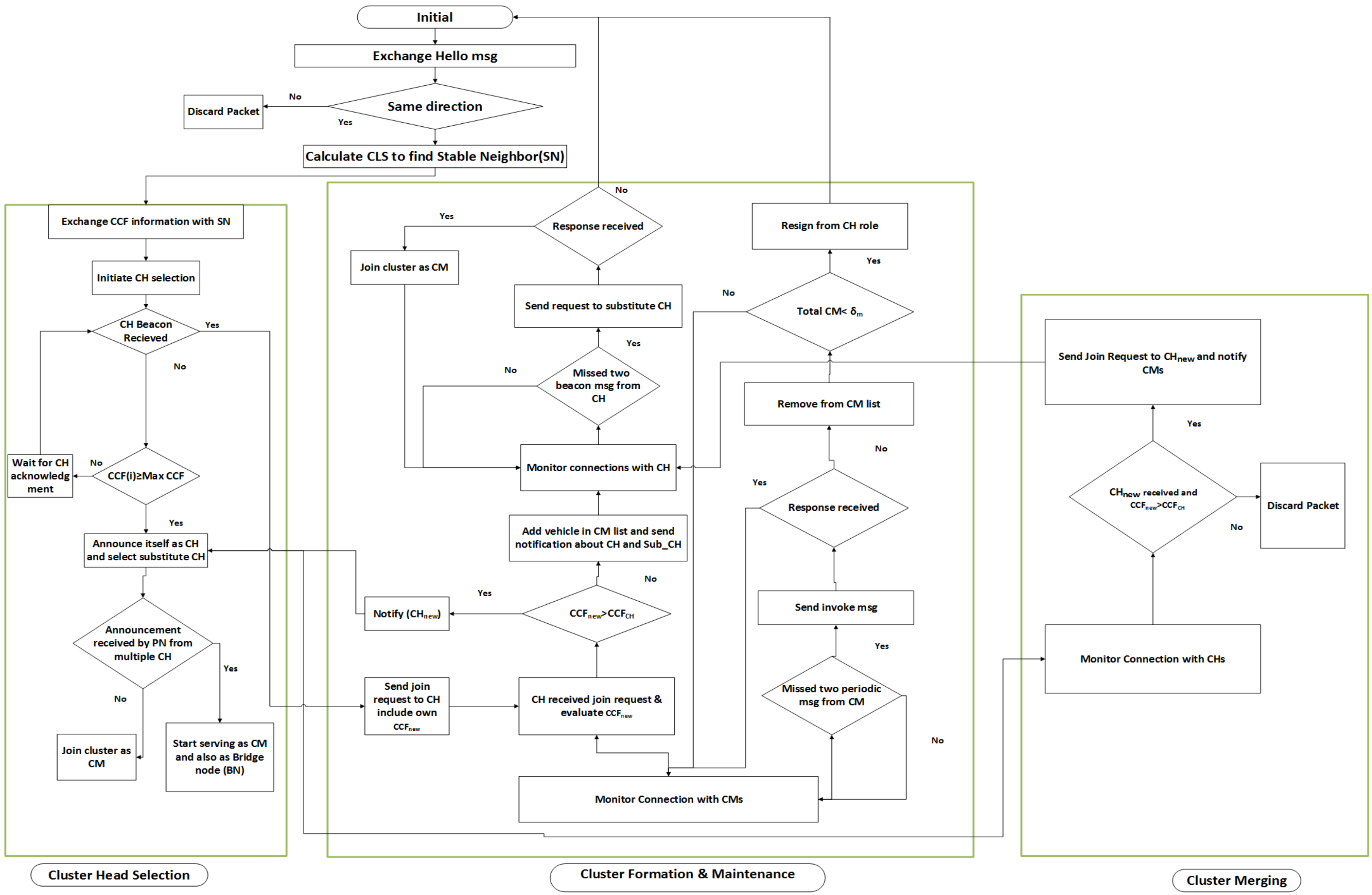

Figure 3.2: The general procedure flow of MCSC

3.3.2 Initial Cluster Formation

Initially upon deployment of vehicles along the roads they don't belong to any clusters, as no clusters are in place yet. Therefore, upon climate vehicles are said to be unclustered state (UC).Later on, the vehicles might acquire cluster head (CH) , cluster member (CM) ,substitute cluster head(SCH) and/or Bridge node(BN) status, depending upon the road they are delegated. Figure 3.3 shows an example of clustering in VANETs using MCSC.

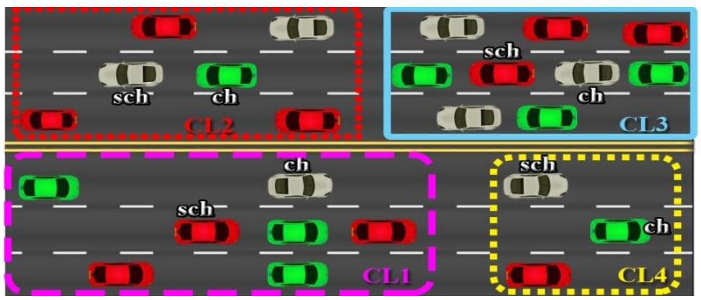

Figure 3.3: Clustering in VANET

A brief description of these states is given as follows.

- UC: starting phase of vehicles when vehicle s not part of any clusters.
- SN: Those neighbors which qualifies connectivity lifespan (CLS) criteria to be considered as stable neighbor vehicles.
- CH: To supervise and coordinate all communication among its members. Become the leader
- CM: The normal vehicle is a one-hop neighbor of a CH.
- SCH: The vehicle which operates as backup of the CH when CM lost connection with CH.

- BN: Bridge Node is such a vehicle which is receiving beacon messages from multiple CH and can help in interconnecting or passing messages between adjacent CH.

The conversion between these states is caused by different scenarios. The details are given in the following section for the process of state transition. Following notations are used in this clustering technique.

Table 3.1 : Notations

Notation	Description
UC	Unclustered Vehicle
CH	Cluster head
SCH	Substitute Cluster Head
CM	Cluster member
BN	Bridge Node
SN	Stable Neighbor
Dir	Direction of vehicle
Vi	The ID of vehicle i
State(V_i)	State of Vi
R	Communication Range
PCL	Past Cluster head lifetime
CLS	Connectivity Lifespan
Deg_conn	Degree of connectivity of the vehicle indicating number of connected stable neighbors
CCF	Composite Clustering Factor
JOIN_REQ	Join request message sent from CM to respective CH
JOIN_RESP	Join response message sent from CH to respective CM
CH_Beacon	Cluster Head Beacon Message broadcasted periodically
Invoke_msg	Invoke message from Cluster Head to Cluster Member and is used as last resort to verify connectivity
δ_{SN}	Threshold for Stable Neighbor
δ_m	Threshold for members in Cluster

Vehicles seeking to be clustered will go through various stages namely neighborhood discovery, CLS based neighbor filtration and cluster head selection. Detailed description of these stages is given in following sub-sections.

3.3.3 Neighborhood Discovery

In the beginning tall the vehicles joining the road are in UC state. when any vehicle wishes to join VANET network, it starts transmitting a Hello message periodically to tell about its existence and for mobility information sharing with other neighbors. This includes the ID of vehicle (VID), two dimensional position (x,y), the velocity (Vx), direction (Dir) and average Past cluster head lifetime (PCL_{avg}).

Once a Hello message is received from neighboring vehicles, not all vehicles are ideal to be in the same cluster. Firstly , considering the direction of vehicles , vehicles moving in opposite direction will be removed from the neighbor list and then CLS based neighbor filtering scheme is proposed to classify neighbors into stable and unstable neighbors considering transmission range of the vehicle , relative velocity and distance between the vehicles.

Hello	**VID**	**(x_i,y_i)**	**V_i**	**Dir**	**PCL_{avg}**

Hello Message

3.3.4 CLS Based Neighbor Filtration

For the purpose of improving stability of the clusters, this paper presents a CLS-based filtration strategy technique for selecting a stable neighbor (SN) among neighboring nodes. Connectivity lifespan (CLS), also known as link expiration time (LET) provides the forecasted time for which two vehicles that are adjacent remain connected. CLS is calculated by Equation (3.1). Δvij and Δdij constitute the difference in velocity and the amount of distance between Vi and Vj. The transmission range of a vehicle is donated by

R. For evaluating the connection sustainability CLS is introduced. The large the value of CLS the more sustainable is the link.

$$CLS_{ij}=\frac{R-\Delta d_{ij}}{\Delta v_{ij}} \tag{3.1}$$

The information of the filtration sequence is given in Technique 1. In the start, all the vehicles gather information of their neighboring nodes. The vehicle in SN which is going to maintain a constant connection for given or predetermined time is defined as neighboring vehicle. For every vehicle Vi, a set of stable neighbors is maintained SNi, which contains entries of vehicle of sometime SNi(i)

Technique 1 : Stable Neighbor Filtration

Input: UC
Output: SN_i;
for each vehicle V_i where State(V_i) = UC do
    if V_i receives a Beacon message from V_j then
    if Dir(V_i) = Dir (V_j) then
        V_i calculates CLS_{ij};
  end if
end if
    if $CLS_{ij} > \delta_{SN}$ then
    if $V_j \in SN_i$ then
V_i updates $SN_i(j)$
else
      V_i adds a new $SN_i(j)$ to SN_i
      Send Deg_msg to SN_i
    end if
  end if
end for

3.3.5 Cluster Head Selection

After filtering stable neighbors, vehicles automatically start cluster head selection. An eligibility parameter, Composite Clustering Function (CCF), is defined to assess the fitness of a vehicle to act as a cluster head. CCF is formulated in Equation (3.2). CLS_{ij} denotes connectivity lifespan with stable neighboring vehicles, Deg_i denotes numbers of stable neighbors of specific vehicle and PCL gives the value of past cluster head lifetime of vehicle which is an add on parameter to check the eligibility of vehicle in a way that if value of PCL is large it shows that vehicle has experience to form stable cluster, this helps in effective cluster head selection and increases performance of network.

$$CCF_i = \alpha .avg(CLS_{ij}) + \beta. Deg_i + \gamma. PCL_{avg(i)} \tag{3.2}$$

where α, β, and γ are weighted coefficients. α+β +γ =1 .Firstly, stable neighbors share CH election message to compete in election by calculating composite clustering factor. Vehicle with highest CCF among the neighbors announce itself as CH according to Technique 2. Along with that update other vehicles about substitute cluster head (SCH).

Hello	**VID**	**CCF_i**

CH election message

Technique 2 : Cluster Head Selection

Input: Set of SN
Output: Set of CH,BN
(1) while V_i initiate CH selection do
(2) if V_i receives CH _Beacon from CH_j then
(3) goto Cluster Formation & Maintenance
(4) else V_i calculates CCF_i
(5) end if
(6) if $CCF_i \geq MAXV_m \in SN(CCF_i)$ then
(7) $State(V_i) \rightarrow CH$
(8) V_i broadcasts CH_Beacon & update SCH
(9) end if
(10) if CH_Beacon >1 received by V_i then
(11) State(Vi)→ BN
(12) end if
(13) end while

3.3.6 Cluster Formation & Maintenance

Due to the high mobility rate of the vehicles in VANET the scenarios and roles of the vehicles keep jumping and changing causing un necessary maintenance overhead. After selection of the cluster head, the aim is to maintain the structure of the cluster as stable as possible in different scenarios. A set of procedures are proposed to sustain cluster topology in high dynamic nature of network. Technique 3 explains the process considering different scenarios.

3.3.6.1 Join Request from UC

UC receives beacon message from neighboring CH, it sends join request to the CH with its CCF. CH compares its clustering factor with the incoming join request vehicle, if the value is greater than the CH that means the new UV is more capable to manage the cluster, then CH notify the UC that it can act as CH. Here , technique for cluster head is recalled. The state of UC changes into CH and the previous CH is selected as substitute CH , otherwise CH add the new UC into CM list and its state is set as CM.

3.3.6.2 CH lost connection with CM

After cluster formation, CH and CM monitor connection with each other. In this scenario, when CH doesn't receive two consecutive beacon messages from its CM, in order to make sure it sends invoke message to CM. If it receives response from CM then it monitors connection with the member otherwise remove it from the from CM list. CH also checks the count of members in CM list , if it is less than threshold δ_m then CH resign from its role and become UV.

3.3.6.3 CM lost Connection with CH

While monitoring connection with CH, when CM misses two consecutive beacon messages from CH it sends join request to SCH to make sure cluster remain intact even in the absence of selected CH. After getting response from SCH , CM join the cluster and monitor connection with SCH as CH.

Technique 3 : Cluster Formation & Maintenance

Input: Set of UV, CM, CH
Output: Set of CM, CH

for each vehicle V_i where State(V_i) = UV do
    if V_i receives CH_ACK or Beacon from CH_j then
    V_i unicasts JOIN_REQ to CH_j
    CH_j evaluate CCF_i
    if $CCF_i > CCF_{CHj}$
        State(Vi)→ CH then
    goto Cluster head Selection
else State(Vi)→ CM then
    Monitor connection with CH
        end if
    end if
end for
for each vehicle Vi where State(Vi) = CM do
    if Beacon msg received by CM from CH_j < 2 then
    CM unicasts JOIN_REQ to Sub_CH
    if CM receives response then
    Join Cluster & Monitor connection with CH
        else State(V_i)→UV
        end if
    end if
end for
for each vehicle V_i where State(V_i) = CH do
    if periodic message received from CM <2 then
        Send Invoke_msg to CM
    if CH doesn't receive invoke response then
        Remove CM from CM_list
    end if
    end if
end for

3.3.6.4 Cluster Merging

Vehicles moving on road in the form of clusters may overlap with one another. Heavily overlapping and moving clusters produce redundancy in inter-cluster management and communication overhead. In order to overcome this problem , cluster merger technique is proposed. When the distance between two CH is less than transmission range R , then it is convenient to merge overlapped clusters. Technique 4 explains this process, in which when CH receives beacon message from neighboring CH it compares its CCF value with the neighboring CH. If neighboring CH has greater value of CCF , then CH send join request to neighboring CH and notify its cluster member to join the neighboring cluster.

Technique 4 : Cluster Merging

Input: Two Clusters
Output: Merged Cluster
(1) for each vehicle V_i where State(V_i) = CH do
(2) CH_i received beacon msg from CH_j
(3) If $CCF_{(CHj)} > CCF_{(CHi)}$
(4) CH_i unicasts JOIN_REQ to CH_j & notify CM
(5) State (CH_i) $\rightarrow$ CM
(6) go to Cluster formation & maintenance
(7) end if
(8) end for

Chapter 4

RESULTS AND DISCUSSION

4.1 Introduction

Deployment of real life scenario of VANET practically is very expensive and a lot of resources are required for that. An alternative solution to evaluate and check the performance of VANET is to use simulators, not only are they cost effective but are also easily implementable and safe. A lot of different type of simulators can be found in the market, such as NS-2, MATLAB, OMNET++ and VEINS.

The combination of traffic and network model is one of challenges involved for simulation in VANET. In our work,Objective Modular Network Testbed (OMNET++) [43] as the network simulator and Simulation of Urban MObility (SUMO) [42] is used as the road traffic model generator and The commonly used simulator for the purpose of research is SUMO due to the fact that it is able to import real world maps and it is an open source interface. It possesses the feature of being able to do simulation microscopically on multi models which is why it can simulate the VANET environment and its different nodes. OMNET++ is a C++ based discrete event network model, which is widely used to build almost every type of network. Finally, Vehicles In Network Simulation (VEINS) [44] is used to integrate OMNET++ and SUMO. It connects SUMO and OMNET by a TCP socket for bi directionally and coupled simulation. Figure 4.1 shows the VEINS architecture.

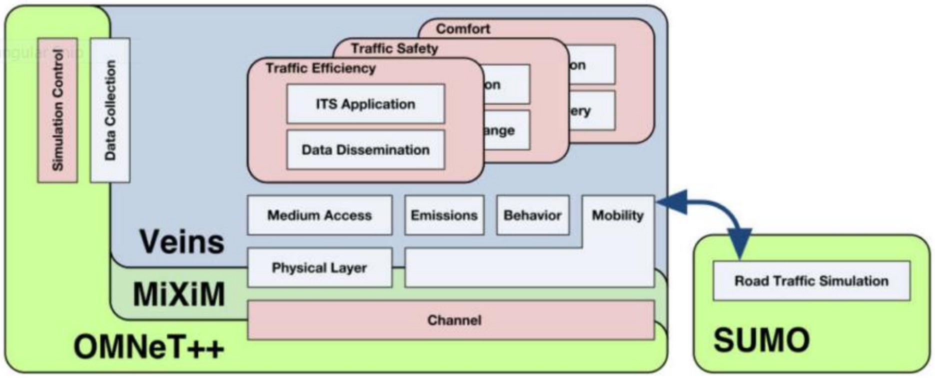

Figure 4.1: Veins architecture (OMNET++ and SUMO)

4.2 Simulation Setup

Simulation is set up by running SUMO version 0.32, OMNET++5.3 and VEINS version 4.7.1. In our simulation, a road of length 28.0 km having two ways traffic with three lanes on both sides of road in an urban setting is considered. In all our experiments, simulation has been run for 200s with different deployment of vehicles. Every experiment was repeated 10 times and the results were averaged out for robustness purposes. Along with that in our experiments, the total number of vehicles varies from 50 to 300 having velocity ranging from 10m/s to 35m/s. Similarly in different set of experiments, wireless transmission range of vehicles is set between 200m and 500m.

4.3 Performance Metrics

Three different sets of experiments has been performed to evaluate the performance of the proposed MCSC against other state of the art [37], [28] by varying the velocity of vehicles (v), their transmission range (R) and total number of vehicles (N) respectively. Following metrics are considered to evaluate the performance of our technique:

- Average CH Lifetime: The CH lifetime is the period when the vehicle becomes a CH till the time when it acquires a CM role or leaves the cluster's premises. In this regard, higher the average CH lifetime is, the more stable the clusters would be.
- Average CM Lifetime: CM lifetime represents the duration at which a CM stays in the same cluster. The average CM lifetime is the average length of all vehicles' CM lifetime. Like average CH lifetime, it also reflects stability of clusters if vehicles remain part of some clusters and are not left unassociated due to frequent re-clustering.
- Re-clustering rate: It indicates how frequently re-clustering is performed during simulation time. This demonstrates the case when the cluster is completely dissolved and all vehicles acquire the state of UC.

4.4 Results and Discussion

The following subsections describe the performance of MCSC in terms of aforementioned metrics.

4.4.1 Impact of Velocity of Vehicles

This subsection represents the impact of velocity of vehicles on the performance of MCSC and other techniques in terms of CH duration, CM duration and re-clustering rate. In this set of experiments, velocity of vehicles is varied from 10 to 35m/s while keeping values of R and N as 200m and 200 respectively. Figure 4.2 represents impact of velocity on CH lifetime. In these results, it is observed that with the increase in number of vehicles, lifetime of CH comparatively decreases in all the three techniques. This is because; increase in velocity causes decrease in CLS which ultimately makes difficult for CH to retain connection with their neighboring vehicles for a long period and network topology become unstable due to its dynamic nature. It is also observed that our technique is less affected by high mobility of vehicles as compared to LRCA and UFC because of efficient CH selection based on PCL which allows experienced vehicle to be selected as CH thereby performing well even in high mobility scenario.

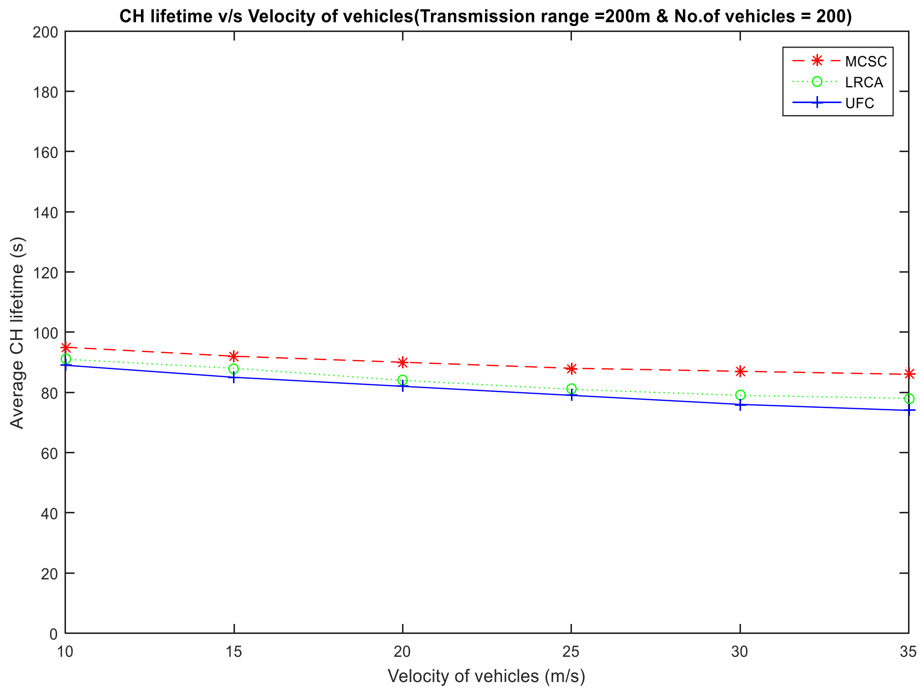

Figure 4.2: Impact of Velocity of Vehicles on CH Lifetime

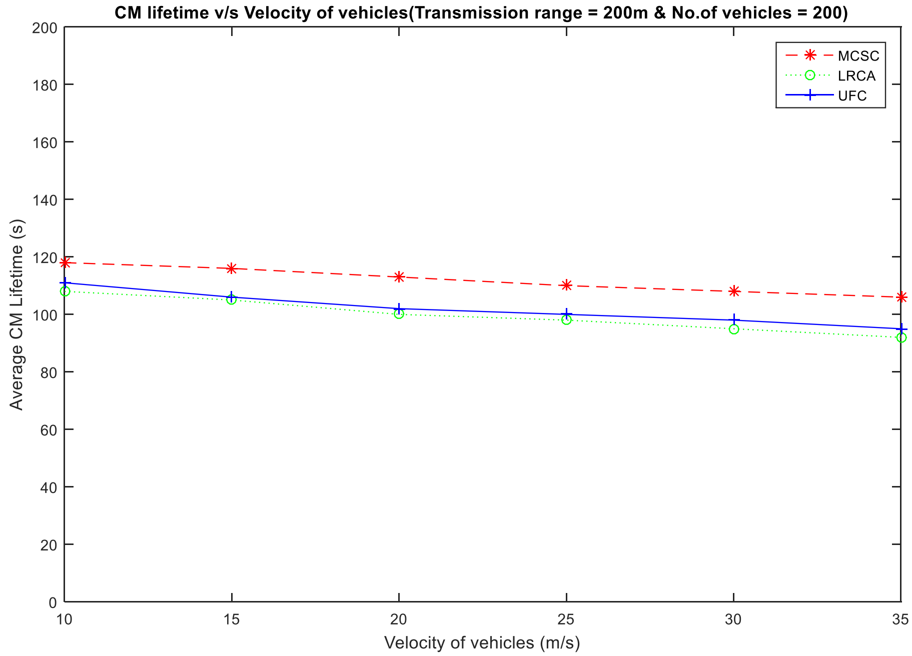

Figure 4.3: Impact of Velocity of Vehicles on CM Lifetime

Figure 4.3 shows performance of clustering techniques at different values of velocity in terms of CM duration. It is observed that the CM duration follows the same trend as CH duration because of high dynamic nature of vehicles it is challenging for CM to remain intact with CH in the form of clusters. By virtue of substitute CH, in case of temporary unavailability of primary CH, the proposed MCSC outperforms LRCA as the cluster members would need to discover and join another cluster. In terms of CM duration, UFC closely follows MCSC because both techniques introduced SCH as backup.

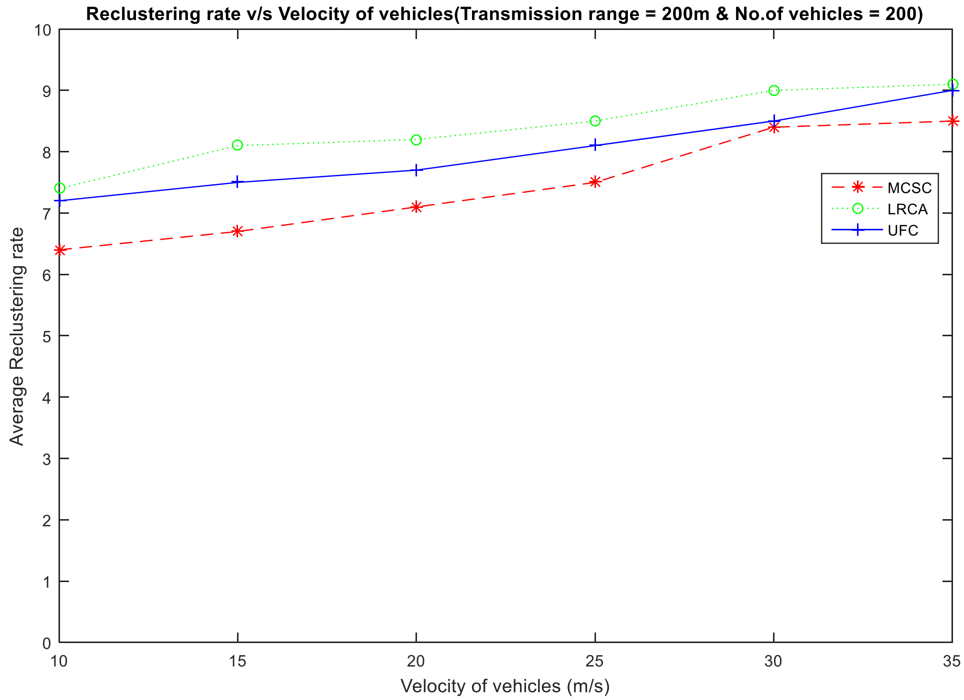

Figure 4.4: Impact of Velocity of vehicles on Re-clustering rate

Figure 4.4 shows impact of velocity of vehicles on re-clustering rate. It is observed from the results that the re-clustering rate increases with the increase in velocity .The reason is that the increase in velocity accelerates the change of network topology. LRCA has worst re-clustering rate because there is no secondary CH that can perform the task of CH after previous CH left the network. The relatively better performance of MCSC than UFC can be attributed to its efficient CH selection based on CCF.

4.3.2 Impact of Transmission Range of Vehicles

This subsection describes how MCSC reacts at different transmission range of vehicles. In this experiment, the transmission range was varied from 200m to 500m.The velocity of vehicle was chosen as 25m/s where the number of vehicles was kept at 200. The performance of MCSC against other techniques, with regard to CH and CM duration at different transmission range, has been shown in Figure 4.5 and Figure 4.6 respectively.

From the results, it is observed that both CH and CM duration have large values at high-transmission range. This is because high transmission range allows the vehicles to connect with more neighboring vehicles .MCSC performs better than LRCA and UFC in this experiment because in our technique CLS is introduced to filter neighboring vehicle and form cluster with stable neighbors, which is directly proportional to transmission range.

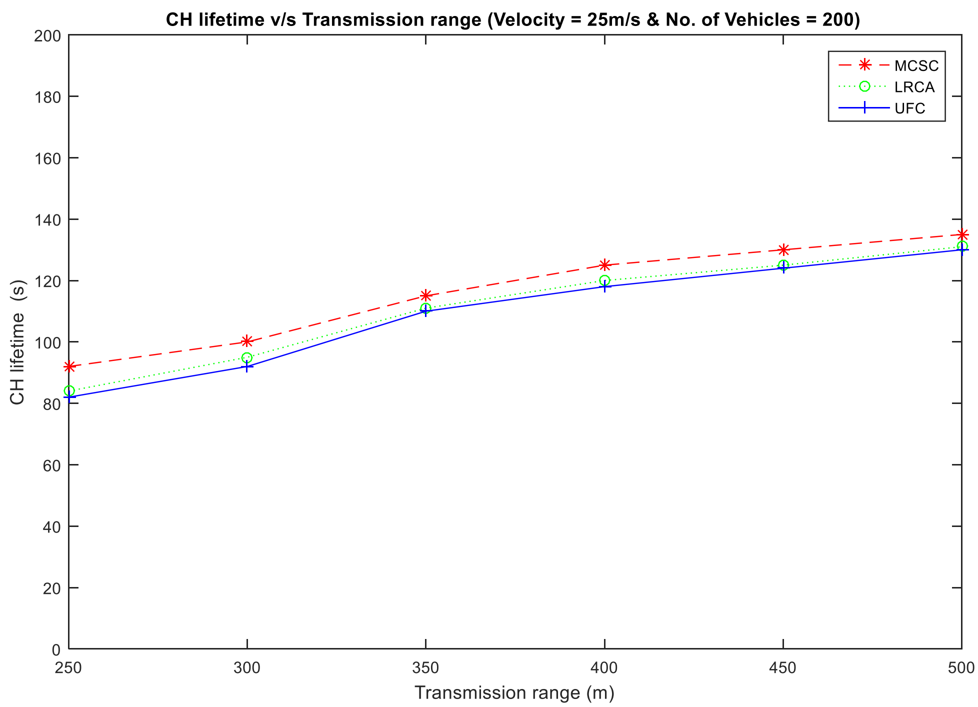

Figure 4.5: Impact of transmission range on CH Lifetime

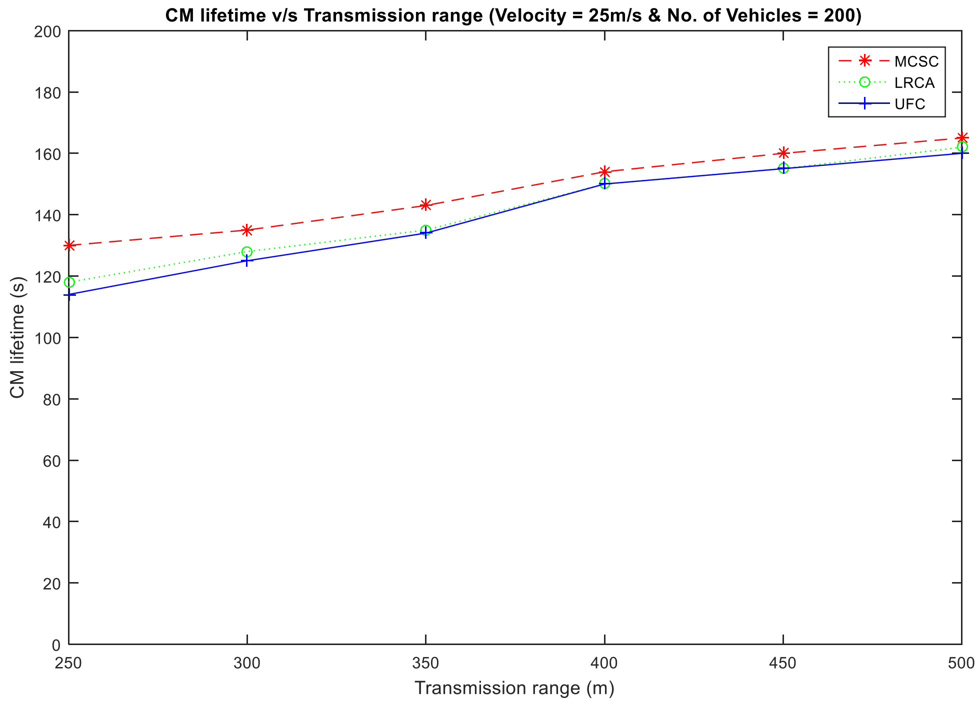

Figure 4.6: Impact of Transmission range on CM Lifetime

Figure 4.7 represents re-clustering rate of MCSC compared to other techniques at different transmission range. Results show that re-clustering rate decreases with the increase in transmission range because higher transmission range offers more connectivity among vehicles and mitigates the change of CH. MCSC outperforms LRCA and UFC because of efficient CH selection based on its past cluster head lifetime that depicts its performance as CH .

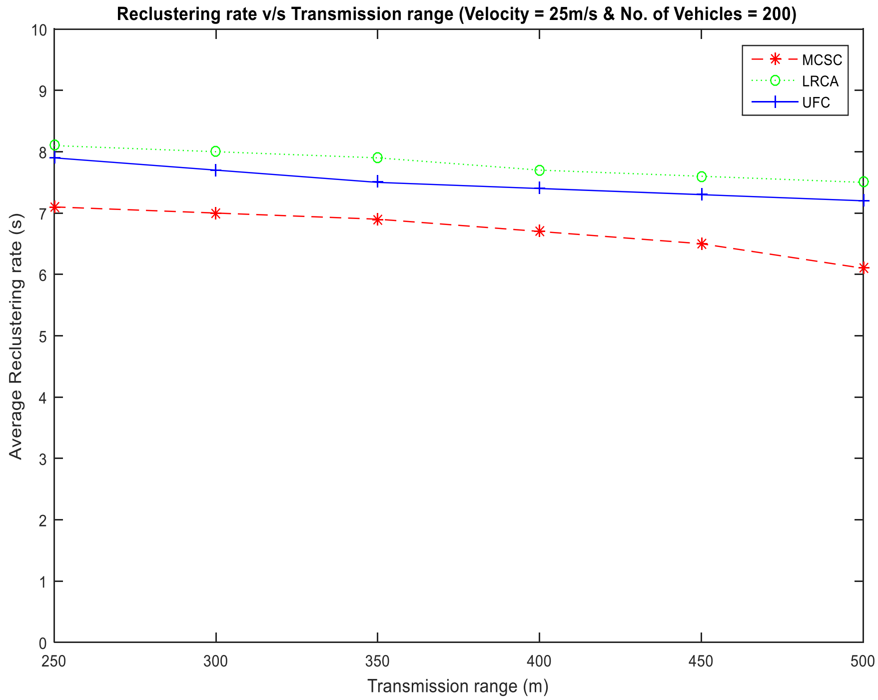

Figure 4.7: Impact of Transmission range on Re-clustering rate

4.3.3 Impact of Number of Vehicles

This subsection evaluates the performance of MCSC when exposed to different network sizes. Figure 4.8 shows the performance of MCSC in terms of CH duration ratio where the total numbers of vehicles are varied from 50 to 300. In this experiment, the velocity of vehicle was kept at 25 m/s and the transmission range at 200m. Results show impact of number of vehicles on CH duration in which it is observed that with the increase in vehicles density, CH duration decreases because the higher density leads to large number of clusters which eventually increases the possibility of clusters merging and ends the duration of certain CH. MCSC performs relatively better than LRCA and UFC, because in other techniques cluster merging is performed according to threshold value but in our technique cluster merging is based on CCF in which cluster merges under more eligible CH among neighboring clusters.

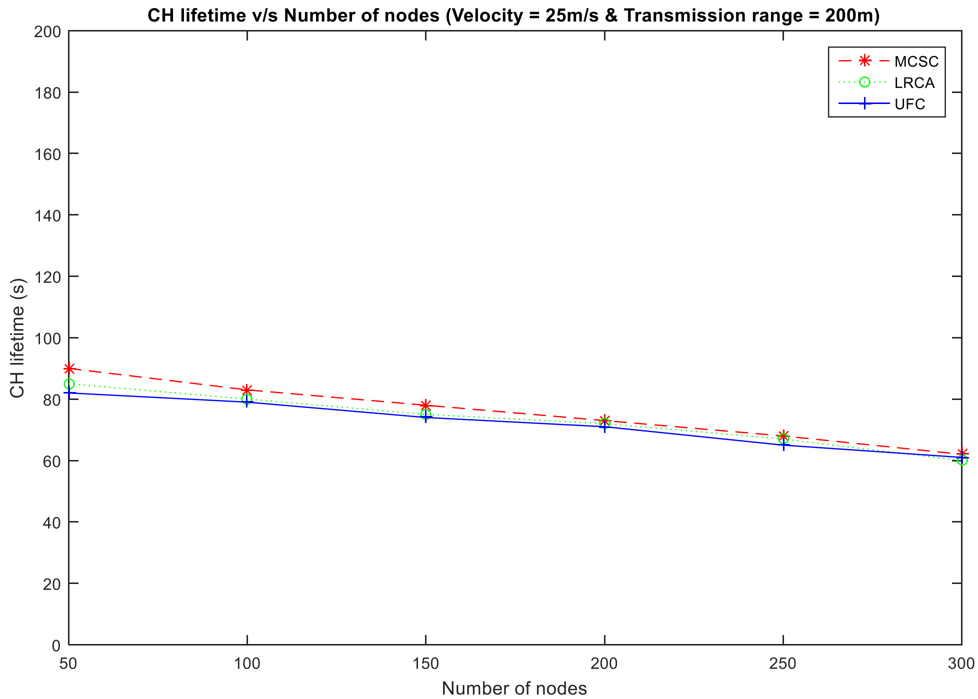

Figure 4.8: Impact of Number of vehicles on CH Lifetime

Figure 4.9 represents the impact of varying number of vehicles on CM duration. It is observed that CM duration decreases with the increase in density of vehicles. The reason is that increase in the total amount of vehicles in vicinity also increases qualified vehicles to become CH and afterwards CM disassociate with previous CH and re associates with new CH, which eventually decrease CM duration. Although there is slight decrease but duration in which vehicle is not associated with any CH is not significant. In MCSC cluster merging is performed when more eligible enter the proximity of existing cluster so CM duration is less affected by the density of vehicle that is why MCSC outperforms LRCA and UFC.

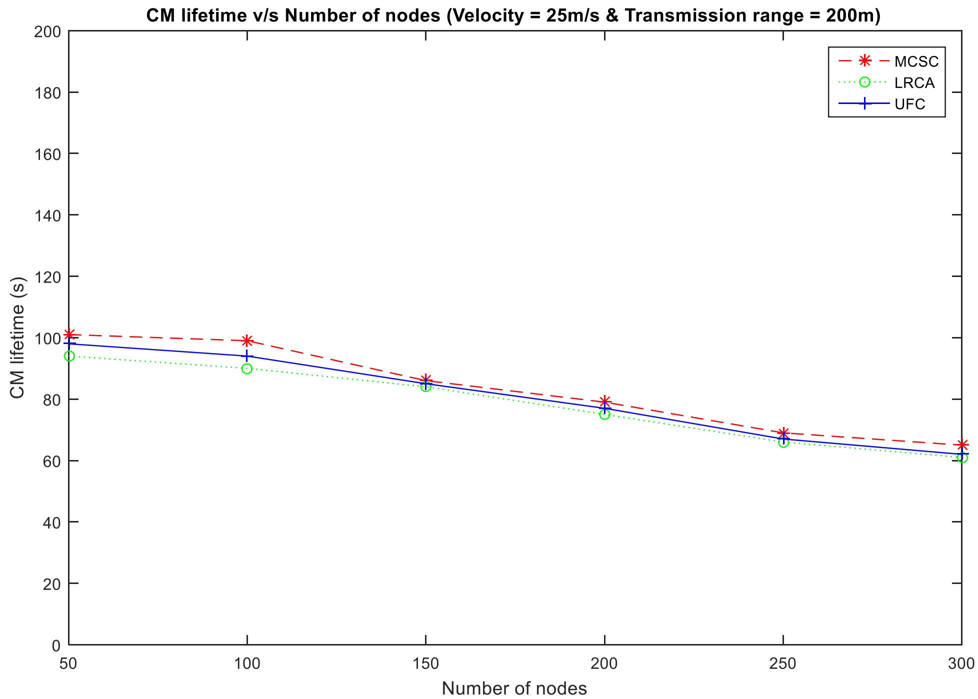

Figure 4.9: Impact of Number of vehicles on CM Lifetime

Figure 4.10 illustrates the impact of different network sizes on re-clustering rate. Results show that with the increase in number of vehicles, re-clustering rate also increases in all three techniques. The reason is that increase in number of vehicles in vicinity also increases more eligible vehicle to compete for CH role which cause frequent change in CH role. MCSC has performed better than other techniques because of CCF based efficient criteria which doesn't allow vehicle with lower value to become CH and ultimately prevent frequent re-clustering.

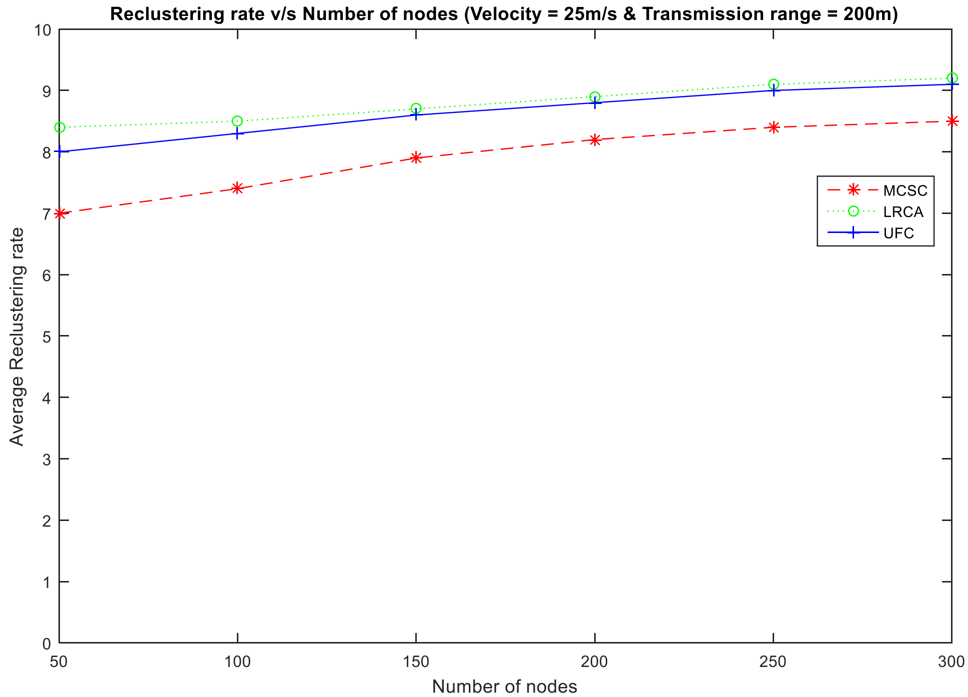

Figure 4.10: Impact of Number of vehicles on Re-clustering rate

Chapter 5

CONCLUSION AND FUTURE WORK

5.1 Conclusion

In this research work, a novel clustering technique, called MCSC, is proposed for stable clustering in VANETs. Initially, it filters out unstable neighbors on the basis of CLS in order to form cluster with stable neighbors only. Then, among stable neighbors most consistent vehicle is selected as CH on the basis of CCF. In CCF, a novel feature of PCL is introduced, apart from other mobility metrics, in order to assess suitability of candidate vehicles for CH role. In addition, due to variation in speeds when vehicles belonging to different clusters come in proximity of each other (overlapping region), cluster merging is performed with more suitable CH having large value of CCF. Furthermore, the concept of SCH is also employed to accommodate significant variation in speed of CH vehicle so that the clusters are not left un-administered. Simulation results demonstrated improved performance of MCSC in terms of average CH lifetime, average CM lifetime and re-clustering rate at different velocity of vehicles, transmission range and number of vehicles as compare to existing work.

5.2 Future Work

In the given thesis, a new technique is demonstrated for clustering in VANET. The starting results have given out some great and promising results. In the given section some paths are discussed for future research that can be implemented and done to take our work ahead.

- Our work is based on single straight road. It can further be implemented on intersection and other scenarios close to real world cases.
- A routing protocol built on top of MCSC technique would be developed and its performance can be compared with the existing protocols.
- We can perform data dissemination and analyze the performance of clustered network through different metrics like end to end delay, packet delivery ratio and control overhead

BIBLIOGRAPHY

[1] Eze, E. C., Zhang, S. J., Liu, E. J., & Eze, J. C. (2016). Advances in vehicular ad-hoc networks (VANETs): Challenges and road-map for future development. *International Journal of Automation and Computing*, *13*(1), 1-18.

[2] Aissa, M., Belghith, A., & Bouhdid, B. (2015). Cluster connectivity assurance metrics in vehicular ad hoc networks. *Procedia Computer Science*, *52*, 294-301.

[3] Hannes Hartenstein (Editor), Kenneth Laberteaux (Editor), VANET Vehicular Applications and Inter-Networking Technologies, John Wiley & Sons ISBN: 978-0470-74056-9.January 2010.

[4] M. Fiore, J. Haerri, F. Filali, and C. Bonnet, \Vehicular mobility simulation for VANETS," in Proceedings of the 40th Annual Simulation Symposium (ANSS 2007), Norfolk, Virginia, March 2007.

[5] Vaishali D. Khairnar, S. N. Pradhan, "Comparative Study of Simulation for Vehicular Ad-Hoc Network", International Journal of Computer Applications (0975 – 8887) Volume 4– No.10, August 2010.

[6] Collier, W.C.; Weiland, R.J.; , "Smart cars, smart highways," Spectrum, IEEE , vol.31, no.4, pp.27-33, April 1994 doi: 10.1109/6.272224.

[7] Ali Bin Tariq, "Simulation of Beaconing in Vehicular Ad-Hoc Networks", Master of Science Thesis, December 2011, Tampere University of Technology.

[8] H. Hartenstein and K. Laberteaux. VANET: Vehicular Applications and InterNetworking Technologies. John Wiley and Sons, 2009.

[9] Maia, G., et al. Data dissemination in urban Vehicular Ad hoc Networks with diverse traffic conditions. in Computers and Communications (ISCC), 2013 IEEE Symposium on. 2013.

[10] Tiecheng, W. and W. Gang. TIBCRPH: Traffic Infrastructure Based Cluster Routing Protocol with Handoff in VANET. in Wireless and Optical Communications Conference (WOCC), 2010 19th Annual. 2010

[11] Basu, P., N. Khan, and T.D.C. Little. A mobility based metric for clustering in mobile ad hoc networks. in Distributed Computing Systems Workshop, 2001 International Conference on. 2001.

[12] Maglaras, L.A. and D. Katsaros. Distributed clustering in vehicular networks. in Wireless and Mobile Computing, Networking and Communications (WiMob), 2012 IEEE 8th International Conference on. 2012.

[13] Ahizoune, A. and A. Hafid. A new stability based clustering technique (SBCA) for VANETs. in Local Computer Networks Workshops (LCN Workshops), 2012 IEEE 37th Conference on. 2012.

[14] Zhang, Z., A. Boukerche, and R. 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. 2011, ACM: Miami, Florida, USA. p. 19-26.

[15] Hang, S. and Z. Xi, Clustering-Based Multichannel MAC Protocols for QoS Provisionings Over Vehicular Ad HocNetworks. Vehicular Technology, IEEE Transactions on, 2007. 56(6): p. 3309-3323.

[16] Wei, F., et al. A mobility metrics based dynamic clustering technique for VANETs. in Communication Technology and Application (ICCTA 2011), IET International Conference on. 2011.

[17] Tizghadam, A. and A. Leon-Garcia, Autonomic traffic engineering for network robustness. Selected Areas in Communications, IEEE Journal on, 2010. 28(1): p. 39-50.

[18] Rawshdeh, Z.Y. and S.M. Mahmud. Toward Strongley Connected Clustering Structure in Vehicular Ad Hoc Networks. in Vehicular Technology Conference Fall (VTC 2009-Fall), 2009 IEEE 70th. 2009.

[19] Hafeez, K.A., et al. A fuzzy-logic-based cluster head selection technique in VANETs. in Communications (ICC), 2012 IEEE International Conference on. 2012.

[20] Shea, C., B. Hassanabadi, and S. Valaee. Mobility-Based Clustering in VANETs Using Affinity Propagation. in Global Telecommunications Conference, 2009. GLOBECOM 2009. IEEE. 2009.

[21] Zhenxia, Z., A. Boukerche, and R.W. Pazzi. A Novel Network Mobility Management Scheme for Vehicular Networks. in Global Telecommunications Conference (GLOBECOM 2010), 2010 IEEE. 2010.

[22] Gerla, M., T. Kwon, and P. Guangyu. On-demand routing in large ad hoc wireless networks with passive clustering. in Wireless Communications and Networking Confernce, 2000. WCNC. 2000 IEEE. 2000.

[23] Sheng-Shih, W. and L. Yi-Shiun. Performance evaluation of passive clustering based techniques for inter-vehicle communications. in Wireless and Optical Communications Conference (WOCC), 2010 19th Annual. 2010.

[24] Wolny, G. Modified DMAC Clustering Technique for VANETs. in Systems and Networks Communications, 2008. ICSNC '08. 3rd International Conference on. 2008.

[25] Fan, P., Haran, J. G., Dillenburg, J., & Nelson, P. C. (2005, October). Cluster-based framework in vehicular ad-hoc networks. In *International Conference on Ad-Hoc Networks and Wireless* (pp. 32-42). Springer, Berlin, Heidelberg.

[26] Fan, P. (2007, April). Improving broadcasting performance by clustering with stability for inter-vehicle communication. In *2007 IEEE 65th Vehicular Technology Conference-VTC2007-Spring* (pp. 2491-2495). IEEE.

[27] Z. Y. Rawashdeh and S. M. Mahmud, "A novel technique to form stable clusters in vehicular ad hoc networks on highways," EURASIP J. Wireless Commun. Netw., vol. 1, pp. 1–13, Jan. 2012

[28] Ren, M., Zhang, J., Khoukhi, L., Labiod, H., & Vèque, V. (2017). A unified framework of clustering approach in vehicular ad hoc networks. *IEEE Transactions on Intelligent Transportation Systems*, *19*(5), 1401-1414.

[29] Ahwazi, A. Z., & NooriMehr, M. (2016). MOSIC: mobility-aware single-hop clustering scheme for vehicular ad hoc networks on highways. *IJACSA) International Journal of Advanced Computer Science and Applications*, *7*(9), 424-431.

[30] Cheng, X., Huang, B., & Cheng, W. (2018, October). Stable clustering for VANETs on highways. In 2018 IEEE/ACM Symposium on Edge Computing (SEC) (pp. 399-403). IEEE.

[31] Cheng, X., & Huang, B. (2019). A center-based secure and stable clustering technique for VANETs on highways. Wireless Communications and Mobile Computing, 2019.

[32] Sahoo, R. R., Panda, R., Behera, D. K., & Naskar, M. K. (2012, July). A trust based clustering with Ant Colony Routing in VANET. In *2012 Third International Conference on Computing, Communication and Networking Technologies (ICCCNT'12)* (pp. 1-8). IEEE.

[33] Daeinabi, A., Rahbar, A. G. P., & Khademzadeh, A. (2011). VWCA: An efficient clustering technique in vehicular ad hoc networks. *Journal of Network and Computer Applications*, *34*(1), 207-222.

[34] X. Liu, Z. Fan, L. Shi, Securing vehicular ad hoc networks, in: Second Conference on International Pervasive Computing and Applications, Amsterdam, The Netherlands, 2007, pp. 424–432.

[35] Joshua, C. J., Duraisamy, R., & Varadarajan, V. (2019). A Reputation based Weighted Clustering Protocol in VANET: A Multi-objective Firefly Approach. Mobile Networks and Applications, 1-11.

[36] Kuklinski, S., & Wolny, G. (2009, April). Density based clustering technique for VANETs. In *2009 5th International Conference on Testbeds and Research Infrastructures for the Development of Networks & Communities and Workshops* (pp. 1-6). IEEE.

[37] Kuklinski, S., & Wolny, G. (2009, April). Density based clustering technique for VANETs Int. J. Internet Protocol Technol., vol. 4, no. 3, pp. 149–157, 2009.

[38] Ji, X., Yu, H., Fan, G., Sun, H., & Chen, L. (2018). Efficient and Reliable Cluster-Based Data Transmission for Vehicular Ad Hoc Networks. *Mobile Information Systems, 2018*.

[39] Ahizoune, A., & Hafid, A. (2012, October). A new stability based clustering technique (SBCA) for VANETs. In *37th Annual IEEE Conference on Local Computer Networks-Workshops* (pp. 843-847). IEEE.

[40] Rossi, G. V., Fan, Z., Chin, W. H., & Leung, K. K. (2017, March). Stable clustering for ad-hoc vehicle networking. In 2017 IEEE Wireless Communications and Networking Conference (WCNC) (pp. 1-6). IEEE.

[41] Alsuhli, G. H., Khattab, A., & Fahmy, Y. A. (2019). Double-head clustering for resilient VANETs. *Wireless Communications and Mobile Computing*, *2019*.

[42] SUMO-Simulation of Urban Mobility. (2019). Retrieved from https://sumo.dlr.de/index.html

[43] OMNeT++ Discrete Event Simulator. (2019). Retrieved from https://omnetpp.org/

[44] Veins. (2019). Retrieved from https://veins.car2x.org/