Hindawi
Wireless Communications and Mobile Computing
Volume 2022, Article ID 1426815, 15 pages
https://doi.org/10.1155/2022/1426815

Research Article

OCSR: Overlapped Cluster-Based Scalable Routing Approach for Vehicular Ad Hoc Networks (VANETs)

Pavan Kumar Pandey,[1] **Vineet Kansal**,[2] **and Abhishek Swaroop**[3]

[1]*Dr. A.P.J. Abdul Kalam Technical University, Lucknow, India*
[2]*Institute of Engineering & Technology, Dr. A.P.J. Abdul Kalam Technical University, Lucknow, India*
[3]*Bhagwan Parshuram Institute of Technology, New Delhi, India*

Correspondence should be addressed to Pavan Kumar Pandey; pavan.pandey.1312@gmail.com

Received 3 November 2021; Revised 26 January 2022; Accepted 7 February 2022; Published 7 March 2022

Academic Editor: Alessandro Bazzi

Vehicular ad hoc networks (VANETs) are eminent class of mobile ad hoc networks due to their applications. However, mobility management and network scalability are still addressable problems in VANETs. In the current paper, a hierarchical approach has been designed for handling significantly large VANETs by providing better mobility management. The formation of multiple overlapped clusters from large VANETs using k-means algorithm is major characteristics of this approach. Additionally, an addressing architecture has been introduced using two data registers. The derived algorithm allows preparing an appropriate route between source and destination vehicles. Correctness and performance of the approach have been discussed.

1. Introduction

Among researchers, distributed computing is one of the prominent technologies for large scale computing issues. Furthermore, recent advances in big data and communication enabled new paradigms of distributed computing such as cloud computing [1] and ad hoc networks. The characteristic of the mobile ad hoc networks (MANETs) [2] is to provide robust and efficient operations in wireless networks by comprising routing among mobile nodes. Several critical challenges such as routing, scalability, security, mobility management, and efficient QoS provisioning [3] also need to be handled with ease of deployment property of MANETs. Vehicular ad hoc networks (VANETs) [4] and flying ad hoc networks (FANETs) [5] are the most popular subsections of MANETs.

VANETs are a kind of networks formed by moving cars by integrating with other infrastructure nodes such as RSUs. The problem with traditional routing approaches in large VANETs is one of the major challenges in vehicular communication. Since, studies indicate that throughput for every VANET reduces significantly with increased number of nodes in VANETs upon using traditional routing approaches. Therefore, a flat and traditional routing used in vehicular networks suffers from poor scalability. The scalability and efficiency of the routing mechanism play a key role in VANETs.

Several studies presented that millions of people die in road crashes every year. Also, long expressway and highway faces the problem of internet and cellular networks. In such situations, VANETs are very helpful for handling emergency cases. Furthermore, VANETs are very useful in design and implementation of the intelligent transportation system (ITS) [6]. Using wireless communication framework, ITS aims to ease the traffic management by providing several features [7], e.g., transportation safety, traffic efficiency, comfort driving, and information passing. In order to provide these applications, VANETs rely on exchanged data between vehicles. Therefore, effective trust management [8] schemes must be available to manage security threats for entities.

By introducing recent communication technologies in development of automotive sectors, vehicles can communicate with other vehicles or infrastructure nodes effectively.

Similarly, wireless sensor networks (WSNs) also provide a wide variety of applications [9] such as monitoring, tracking, and sensing of remote vehicles. However, recent studies present that several limitations in WSNs impact their performance. Therefore, some optimization techniques [10] have also been proposed for sensor networks.

Several components presented in Figure 1 are used in VANETs for designing effective communication architecture. In addition to moving vehicles, some fixed nodes such as roadside units (RSUs) are participated in vehicular communication. Using several network components in VANETs, vehicular communication supports three different kinds of communication mode. First, vehicles can communicate directly to other vehicles through intervehicle communication. Secondly, vehicles can communicate to fixed nodes which is known as vehicle-to-roadside (V2R) [12] communication. Thirdly, inter-roadside communication enables RSUs to communicate with other fixed infrastructure nodes. V2R communication is also popular as vehicles to infrastructure (V2I) or infrastructure to vehicles (I2V) communication mode.

Unlike multihop networks, VANETs are a different kind of networks due to some unique characteristics. In large VANETs, high mobility of nodes and lack of centralized management cause frequent network partitions and weak connectivity among vehicles. Therefore, maintaining the complete network topology is difficult for any vehicle, and flat routing schemes are not much effective for vehicular communication. In order to target scalability challenges, several hierarchical techniques have been proposed which are also known as clustering schemes. The principle of virtualization supports the cloud paradigm [13] to provide huge storage and parallel computing. Similarly, based on some common characteristics virtual grouping [14] of vehicles are prepared which are supervised by cluster head. Cluster head belongs to the same cluster which is elected to serve as controlling authority for cluster. By following the hierarchical model, two levels of routings are supported named as intracluster communication and intercluster communication. In [15], a detailed survey of clustering approaches is presented.

In the proposed approach, *k*-means (Mac Queen, 1967) [16] algorithm is recommended for clustering. k-Means is a kind of unsupervised learning algorithm for clustering. This is one of the simplest ways to divide large network into a predefined fixed numbers of clusters. The way of clustering is to choose k centroids nodes by considering the significant distance between them. Then, other remaining nodes are associated with their closest centroid node to form k number of clusters. Sometimes, process of selecting k centroids nodes and association of other nodes are repeated multiple times to make centroids more stable.

The proposed approach is more suitable in VANETs scenarios where the network can be controlled by a central authority (CA). Additionally, some fixed nodes such as RSU and traffic controller can serve as supervisor nodes for clusters. In such cases, where an entity is handling several vehicles moving in large area, it is very difficult to establish a communication among those vehicles through that authority. As a solution, CA can facilitate those vehicles while applying some routing methodology, and then those vehicles can communicate independently without further intervention of CA in every communication. In such scenarios, CA can control a quite large network with vehicles moving around and take decision on number of clusters and designated supervisor nodes in the network. Since, few assumptions such as identification of cluster heads are associated with routing approach; the way of implementation plays a key role in performance of the routing.

In the current exposition, we discuss the effective clustering scheme and addressing scheme to provide scalability and mobility management in VANETs. The proposed scheme ensures a path for every source-destination pair in VANETs. The major contributions presented in current exposition are as follows:

(i) An effective k-means clustering technique is proposed to divide large VANETs into small logical subnets

(ii) An addressing architecture has been presented to design efficient routing in large VANETs

(iii) An efficient routing approach for VANETs using the clustering techniques and addressing architecture

(iv) Performance comparison of the proposed approach with MoZo and DACR theoretically and experimentally

The remaining paper is organized as follows: next section presents related works. Section 3 explains the concept of proposed approach. Section 4 consists of proposed approach in the form of algorithms, and proofs for the correctness of the algorithm have been presented in Section 5. Last section concludes the paper with a brief of future work.

2. Related Works

In a network, traversal of data from one node to another node in an effective manner is crucial for the efficient communication. Earlier, travelling salesman's problem (TSP) [17] was solved using heuristics for traversing the complete network. However, data transmission from source to destination vehicle is a significant problem in vehicular communication. Therefore, several routing schemes [18] have been designed by following different network environments. In [19–21], few popular routing approaches for vehicular communication have been discussed. It can be seen that performance optimization is the one of major goals to achieve while designing and developing any new routing approach or algorithm. These optimization techniques can be different based on used frameworks. Therefore, performance optimization techniques [22] are used in cloud computing are not same as optimization techniques used in VANETs. The performance of any routing can be measured using certain parameters which are known as performance metrics. In VANETs, performance metrics include end-to-end delay, packet-loss, round-trip-delay, and jitter and these are used

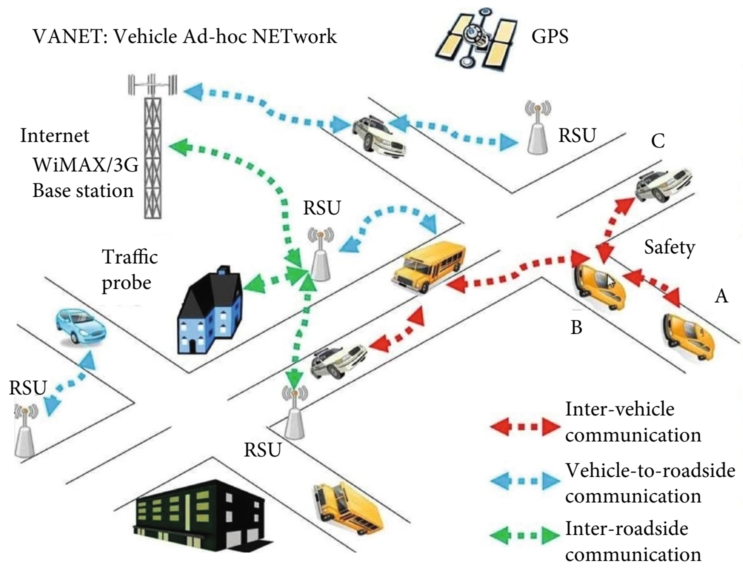


Figure 1: Components of VANETs [11].

to measure the quality of services (QoS) [23] between source and destination vehicle.

Based on the strategies and behavior, routing protocols can be classified into multiple subcategories. Few classifications of routing approaches have been discussed in [24]. Based on used methodologies, routing approaches can be divided into two subsections, proactive and reactive. Network structure can classify routing approaches in three subsections position-based, flat, and hierarchical routing. Furthermore, transmission type can categorize routing approaches in broadcast, multicast, and unicast. Similarly, routing approaches can be further classified by following packet forwarding techniques, QoS, and MAC communication.

In order to provide scalable routing, hierarchical techniques [25] and clustering approaches are commonly used in VANETs. Over the years, several cluster-based routing protocols have been proposed by researchers for vehicular communication. In these approaches, clusters are formed based on logical subnetting and physical position subnetting. However, these schemes face their own challenges such as dynamic allocation of unique cluster IDs and handling of rapid changes in clusters. These problems are not easy to handle in multihop wireless networks. Therefore, the hierarchical topology must be enhanced to improve network performance significantly.

Among all routing strategies in VANETs, hierarchical approaches try to provide relatively stable units as clusters. Therefore, cluster-based approaches are part of most effective techniques used in vehicular communication. In [26], clustering techniques used in vehicular networks are discussed. Despite wide varieties in clustering approaches, they share a few common fundamentals steps such as cluster formation and selection of cluster leader. A cluster is a collection of vehicles having some identical characteristics and all clusters to be headed by a leader vehicle. Therefore, all clustering schemes propose a way to divide a network into several clusters and the specific criteria to choose the head of that cluster. The performance of the clustering technique depends on the strength of formed clusters. Furthermore, the stability of clusters can be measured by the lifetime and transmission overhead of cluster members and cluster heads.

Some popular clustering approaches have been discussed here. Hadded et al. [27] proposed a multiobjective genetic algorithm based clustering approach. VMaSC [28] is a multihop clustering technique for achieving an increased packet delivery ratio and reduced end-to-end delay. In this approach, the cluster-head is selected based on link stability that ensures minimum possible overlap among clusters to provide more stable clusters. In order to handle frequent link breakage in VANETs, moving zone (MoZo) [29] architecture was proposed. MoZo suggests the preparation of moving clusters based on vehicle's movement pattern and discusses the maintenance of those clusters. The hybrid clustering approach DACR [30] is a hybrid approach which integrates geographical (segment-based) and dynamic (context-based) clustering. It explains the complete routing strategy in two parts, one within cluster (DACRintra) and another among clusters (DACRinter).

Mobility management is also one of the critical challenges which are associated with routing approaches in large vehicular networks. Therefore, in order to handle mobility, all vehicles are divided into several groups based on their characteristics and similarity patterns. Each group has a center vehicle which acts as cluster head. The movement of a center vehicle represents the whole group's motion in terms of direction, speed, etc. Some clustering approaches are specifically designed for mobility management. Ghada et al. [31] discussed the mobility-based double-head clustering technique for VANETs. In order to provide most stable clusters in large networks, this approach uses mobility metrics such as speed, direction, and position along with communication link quality. One more mobility-based and stability-based dynamic clustering has been proposed by Mengying et al. in [32]. This approach also uses a vehicle's moving direction, link stability, and relative speed for clustering.

The clustering approaches discussed above have been specifically designed for targeting mobility management. However, reliable routing in large VANETs is still an open problem using these clustering approaches. Therefore, we have introduced a new addressing scheme with the concept of using different databases for providing reliable communication irrespective of network size. In this paper, an effective clustering model with mobility management for large VANETs has been presented. Additionally, a new addressing scheme for each participating node has also been introduced in the present exposition.

3. Proposed Approach

The proposed approach aims to overcome the problem of scalability and high mobility in VANETs. It has been designed by considering the high mobility of vehicles as a major hurdle for efficient routing. This approach is based on decomposition of the complete network into several clusters, and every cluster is being monitored by its respective supervisor node (SN). Recently, the importance of mobility management techniques has increased in order to keep control of high mobile vehicles in VANETs. For better illustration, this section is further divided into few subsections.

(i) System modeling

(ii) k-Means clustering algorithm

(iii) Cluster formation

(iv) Network addressing architecture

(v) Routing model

(vi) Mobility management

3.1. System Model. This section explains system model and assumptions which are considered to design the proposed routing approach. On-Board Units (OBUs) are assumed to be associated with every vehicle those are participating in the communication. OBU provides limited storage and calculation capability into vehicles. Furthermore, OBU helps vehicle to detect significant change in position and to broadcasts relevant information to other vehicles. Based on practicality of proposed routing approach, one central authority is assumed to play an important role in clustering and selecting SN vehicle. In case other vehicles are introduced in network, it will be accommodated into nearest cluster and addresses of vehicles are assigned accordingly.

VANETs are presented as undirected graph $G = (V, E)$, where V presents a set of vehicles and other fixed infrastructure nodes and E presents set of edges in graph G. Let $L(x, y)$ is link between vehicle x and y that shows x and y vehicles are in their communication range and can communicate directly without any intermediate vehicles. Every link is assumed to be bidirectional. This approach helps in communication between vehicles which are not connected directly where other intermediate vehicles are to be added in a path by following discussed approach. As mentioned in Equation (1), current approach aims to derive the sequence of vehicles to be traversed from source (S) to destination (D) vehicles which are denoted by $P(S, D)$.

$$P(S, D) = S, V1, V2, \cdots \cdots Vn, D : V1, \cdots Vn \in V, \quad (1)$$

Where $P(S, D)$ denotes path between source (S) and destination (D) vehicles. $V1$, $V2$, and Vn are other intermediate vehicles to be traversed between both vehicles.

3.2. k-Means Clustering Algorithm. Earlier, several parameters such as position, speed, and movement pattern. are considered as key parameters for selecting any vehicle as cluster heads in clustering approaches. However, traditional clustering approaches face several challenges in order to support dynamic topology. Therefore, few k-means based dynamic clustering approach [33] have been designed for VANETs. The present approach considers random selection of centroid vehicles for each cluster that is designated as supervisor node (SN). Number of SNs depends on network layout that can vary according to network environment, e.g., urban, semi-urban, rural, and highways. By following communication range of vehicles, cluster size may also vary. Since, SN (may be a Roadside Unit) will not be changed for cluster, it is preferred to select some fixed nodes in network for serving as SN vehicle. Choosing fixed node as SN provides advantage that SN will not leave network until or unless that node is down. Least supported communication range among all vehicles is to be considered for clustering. In discussed clustering approach, selection of supervisor nodes (K) shall be picked from VANETs of (N) vehicles by minimizing the value of fitness function (FF) mentioned in Equation (2).

$$FF = \sum_{i=1,j=1}^{i=N,j=K} \|Vi - Cj\|^2, \quad (2)$$

where centroid vehicle is denoted as "Cj" of "jth" cluster and other vehicles are represented as "Vi". Distance between centroid vehicle and other vehicles is represented as $\| Vi - Cj \|2$.

When K is finalized, K number of supervisor node (SN) is randomly selected within a distance of double of communication range. Thus, we make sure shorter distance between two SNs and direct reachability of vehicles with other vehicles in same clusters. Let us assume that least supported communication range (CR) across vehicles. Then, Euclidean distance between two centroid vehicles measured using Equation (3), shall be less than $2 \times CR$.

$$\text{Euclidean Distance } d(C1, C2) = \sqrt{(x1 - x2)2 + (y1 - y2)2} \leq (2 \times CR), \quad (3)$$

where selected centroid vehicles are assumed as $C1$ and $C2$ which are located by coordinates ($x1$, $y1$) and ($x2$, $y2$) in x and y axis. Algorithm 1 shows steps to finalize number of K.

3.3. Cluster Formation. In order to design reliable routing in VANETs, each node must be aware of routing updates from

Input: G
1. Choose any random number of K
2. **For** ($i = 1$ to K AND $j = 1$ to N)
3. Initialize centroid vehicles ci
4. Assign other vehicles to the closest ci
5. Calculate value of FF based on Euclidean distance
6. Repeat from steps 3 to 5
7. Break from loop for minimized FF
8. Use K

Algorithm 1: Selection of K.

each participating vehicle in the network. Additionally, data transfer through these nodes also to be tracked. This is easily feasible in small size networks. However, it can be possible to happen in the large networks also, by reducing network size significantly. Therefore, the first step of approach suggests decomposition of complete network into several connected overlapped clusters and cluster heads. The cluster head is appointed as controlling authority for each cluster. The cluster head which is also known as supervisor node (SN) is solely responsible for maintaining and monitoring the cluster.

This first phase of the approach is purely oriented towards hierarchical routing strategy and plays a vital role to solve the problem of routing in large VANETs. Using k-means algorithm, the approach begins with the arbitrary selection of K, where K is the number of clusters to be prepared from the network. After that, the assignment of other vehicles to the cluster may be random or systematic, by following the network layout. Based on the network, designed clusters are allowed to be overlapped. However, every node should be capable to communicate directly with other nodes within the cluster. Several clusters with the feasible number of vehicles are created using the k-means clustering algorithm.

First, K vehicles are selected among total N number of vehicles in the network by following Algorithm 2. As mentioned in Figure 2, one vehicle is selected corresponding to each cluster. Other vehicles from the remaining (N-K) nodes are assigned to the respective cluster based on distance from the centroid vehicle. In each cluster, computed distance of the vehicle from the centroid should be less than communication range (CR). If any node is not suitable for the cluster with the closest centroid, this node will be switched to another cluster. Furthermore, moved vehicle updates new centroid of the cluster for being added as new node in cluster as in Figure 3. This assignment process is repeated until either convergence is achieved or pass through nodes cause no new assignments in the cluster.

At the end of clustering process, some clusters may contain few common nodes with other clusters. A key characteristic of this approach is to choose number of supervisor nodes (SN) in large vehicular networks that must be decided before starting decomposition of network. Subsequently, all K selected vehicles will be designated as supervisor nodes of the clusters. The number of SN depends on several factors such as total number of nodes in a network, network layout, and communication range. The selection of K has already been discussed in previous section of the proposed approach.

3.4. Network Addressing Architecture. The most important aspect of any network is the addressing scheme to be used for each participating nodes in the network. Effective addressing technique makes each node capable to communicate with other nodes in the network. Logical partitions of networks play a key role in mobility management. Therefore, a new addressing scheme has been introduced in current approach that recommends the association of logical addresses in specified format with MAC addresses. By following Algorithm 3, address of vehicle is suggested to use cluster address that is a node identifier of respective supervisor node (SN) as well as host address that is node identifier of that vehicle. These addresses follow a format similar to the IP network, and they can be viewed as private IP addresses in the network.

When complete network is divided into several clusters, each vehicle is to be assigned by new address by using new addressing format presented in Equation (4).

$$\forall X \in G \mid \text{Address}(X) = \text{Concat}(\text{NodeID}[SN(X)], \ \text{NodeID}[X]), \quad (4)$$

Where Address (X) represents address of node X, NodeID [SN (X)] is unique identifier of SN appointed for particular cluster having node X and NodeID [X] is unique identifier of node X.

By following the approach, the entire network is divided into multiple logical subnets and each subnet has one primary SN. In case of primary SN's failure, a new SN is selected. In VANETs, each vehicle can be identified by unique number that is Node-ID which is derived from a physical hardwired address, i.e., MAC addresses. The full address of every vehicle is combination of two different addresses: Node-ID of SN and Node-ID of Host, i.e, <Supervisor Node-Id> and <Host Node-Id> as mentioned in Figure 4 where the SN node id is used to identify the logical subnet and the host node id is used for local routing.

3.5. Routing Model. Routing overhead has been reduced by applying the clustering approach into large VANETs. After preparing clusters and assigning new addresses to each participating vehicles in the network, routing model has been proposed to route the packet from source to destination reliably. Algorithm 4 explains about the routing procedure. Two level routings have been discussed in proposed routing model. First, local routing is used for communication within a same cluster and intercluster routing for communication through vehicles belong to different clusters too.

For local routing, each node including the supervisor node from the cluster is recommended to maintain routing information of the complete cluster in table namely home register (HR). Since routing information is maintained within cluster, suitable proactive routing approach shall be used for communication within cluster. Figure 5 specifies HR to store routing information of vehicles within a cluster.

Input: G, **input:**G, K
1. **For** ($i = 1$ to K)
2. Fetch nearest SN
3. Set vehicle as SN [i].
4. **For** ($j = 1$ to N-K)
5. Compute D [j] of vehicle from their respective SN [i]
6. **If** (D[j] < CR)
7. Assign vehicle into respective cluster head by SN [i].
8. **End if**

Algorithm 2: Prepare Cluster.

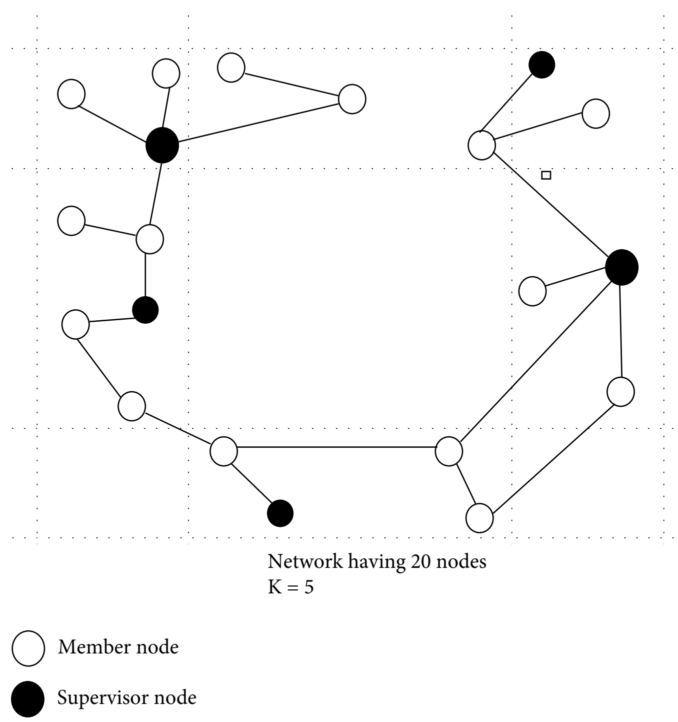


Figure 2: Selection of arbitrarily nodes.

For reaching destination within the same cluster, the source vehicle checks the destination vehicle in the list of nodes maintained in HR and finds next node to be visited with metric value. The metric value indicates how many nodes to be traversed to reach the destination. Similarly, other node checks HR again, till the message reaches to the destination vehicle. In this way, HR helps to find the best route towards every other node in a cluster.

In addition to HR, supervisor node also maintains an additional table which is known as mobility register (MR). MR keeps the routing information of all other supervisor nodes in the networks. Also, it keeps track of vehicles moving out from current cluster. Figure 6 presents the format to be used for storing routing information in MR. For intercluster routing, SN of source vehicle checks respective MR and finds next node visited towards SN of destination vehicle. Similarly, next node checks respective MR up to the message reaches to the destination cluster. As soon as messages received by SN of destination vehicle, message gets forwards to destination using routing mentioned in HR.

In order to design a reliable communication framework, two-tier routings are suggested for deriving the effective path between source and destination vehicle. First, the source vehicle looks for a destination in same cluster using the local routing information stored in HR. If the destination vehicle is not available in HR, the source vehicle sends destination address to designated SN of that cluster. Then, SN further triggers an intercluster routing and parses cluster-id information from full address of destination vehicle. Furthermore, SN checks MR for finding whether the parsed cluster-id is present or not. If SN finds cluster-id of destination in a table, it forwards the packet to the next node mentioned against found SN. Subsequently, SN of the destination cluster finds a destination vehicle in its cluster using local routing information maintained in HR. Set of all traversed vehicles need to be appended for preparing final route to the destination vehicle. A combination of both routing strategies ensures effective and efficient communication between any two vehicles in VANETs. Furthermore, based on network properties and structure suitable routing

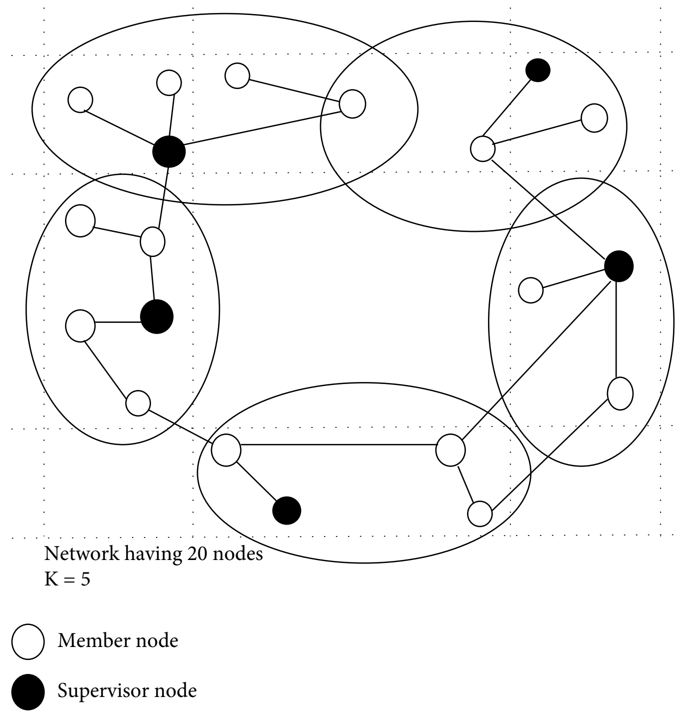


FIGURE 3: Cluster formation using selected nodes.

Input: Vehicle V
1. Fetch node-id of vehicle V and set to id (V)
2. Fetch SN[V] of vehicle V
3. Fetch node-id of SN[V] and set to id (SN[V])
4. Address (V) = id(SN[V]) | id(V)

ALGORITHM 3: Assign Address.

Supervisor node-Id	Host node-Id

FIGURE 4: Address format of each node in network.

algorithms among all existing protocols in VANETs can be selected to implement both routing models.

3.6. Mobility Management. Effective mobility management technique ensures communication between moving vehicles without any centralized control in VANETs. If the network address keeps using hierarchical addressing then proper mobility management must be used to handle routing in large VANETs.

Algorithm 5 explains about mobility management technique which is used with current approach and the algorithm. In the proposed approach, each cluster has its supervisor node that works as a location manager. SN keeps track of all nodes in the cluster and also assists to locate nodes which are moved out from cluster. Mobility management has been designed through a two-level hierarchy of databases. One is home register (HR) maintained by every node in networks, and another one is the mobility register (MR) maintained by SN of each cluster. HR of vehicles keeps registered other vehicles in the same cluster. However, MR of SN vehicles registers routing information of those vehicles which have been moved into its cluster or moved out from its cluster.

The key idea of mobility management is to keep address of vehicles remains unchanged even after moving into cluster or moving out from cluster. When a vehicle moves within the same cluster, the moving vehicle broadcasts the change in topology to other vehicles inside the same cluster only for updating information maintained in their HR. For reducing routing overhead and avoiding broadcast storm problem, the message is broadcasted within the cluster only. This broadcast is possible by matching SN vehicle identifier from address of vehicles participating in broadcasting. Then, HRs maintained by other vehicles in the cluster are also updated to accommodate the vehicle's movement within cluster. Routing information maintained by each node in the cluster may increase some overhead in some cases. However, routing information maintained by SN is not changing frequently due to the rare changes in SN of the clusters. Therefore, overall routing overhead is not increased significantly in comparison to other similar clustering approaches. The mobility of vehicles beyond the cluster is handled by the MR database. Hence, the movement of vehicles from one cluster to another cluster triggers update into MR of both SNs belonging to different clusters. SN of new cluster and previous cluster both updates their MR to accommodate information changes between their clusters. Subsequently, the same update is propagated to other nodes within a cluster for updating their HRs as well. MR of both SNs gets modified to accommodate this movement. While handling the mobility of vehicles, both databases play a key role to accommodate the movement effectively. In case, new

Input: S, D vehicles
1. S node interprets address of D
2. Parse NodeID [D] and NodeID [SN (D)].
3. If NodeID[$SN()$] == NodeID[$SN()$]
4. $R = S \cup v1 \cup v2 \cdots .. \cup D$, where $v1, v2 \in$ Cluster of S
5. **Else**
6. S sends packet to SN (S), with route R1 from S to SN (S).
7. **End if**
8. SN (S) finds route R2 from SN(S) to SN (D)
9. SN (D) derives further route R3 from SN (D) to D
10. $R = S \cup R1 \cup R2 \cup R3 \cup D$

Algorithm 4: Routing.

List of nodes (Within cluster)	Next node to be visited	Metric

Figure 5: HR format maintained by nodes within cluster.

List of all supervisor nodes	Next node to be visited	Metric

Figure 6: MR format maintained by SN of cluster.

Input: G, V
1. **If** vehicle V moves within cluster
2. Broadcast changes to vehicles in same cluster
3. Vehicles update their HR
4. **Else if** vehicle V moves from one cluster to another
5. Update MR maintained by new SN (V)
6. Update MR maintained by previous SN (V)
7. No update required in HR
8. **Else**
9. No movement, no update is required
10. **End if**

Algorithm 5: Mobility Management.

vehicles join the network, these vehicles are to be assigned into nearest cluster and address of those vehicles are derived accordingly with address of corresponding SN vehicle. As soon as a new vehicle join cluster, it broadcasts its routing information to other vehicles inside the cluster only. On the other hand, when a vehicle leaves the network, then this case will be handled in a manner similar to intercluster movement of vehicles. Therefore, respective SN will take care of routing towards such vehicle which no longer exists in the network.

4. Example as an Illustration

As shown in Figure 7, an example has been considered to explain the working of proposed approach. There are seventeen vehicles placed in VANETs and all vehicles are associated with a unique identifier. These vehicles are connected through a wireless channel. Let five be the number of clusters (K) which must be decided before starting the cluster formation. Therefore, five arbitrarily selected vehicles are designated as supervisor nodes for their respective clusters.

Suppose, vehicle “1” wants to transmit the data packet to vehicle “14”. First, “1” checks for “14” in its cluster and found that it is not present. Vehicle “1” is having nodes “1,” “2,” “3,” “4,” and “6” only in its cluster. Therefore, “1” sends data packet to “6” which is the corresponding SN in example. “6” verifies the address of “14” and finds “13” as cluster head of “14”. Subsequently, “6” forwards packet to “13” through vehicle “10” and “13” further sends the same packet to “14”. These routing decisions are based on local routing information which is maintained by HR. This way, the routing process has been completed and the path from “1” to “14” has been discovered as $1 \Leftrightarrow 6 \Leftrightarrow 10 \Leftrightarrow 13 \Leftrightarrow 14$.

In consideration of node mobility in the same example, suppose vehicle “14” moves out from the current cluster to the nearby cluster as shown in Figure 8. The proposed approach ensures that this movement will be informed to the corresponding SN as soon as the movement happens. Therefore, “13” which is designated as SN of “14” will update its MR to accommodate this intercluster movement of “14”. Since “14” joins new cluster supervised by vehicle “8,” “13” will propagate the same update to the “8” as well. Subsequently, rest of the nodes from both the clusters will also update locally maintained HRs by adding or removing tuple corresponding to “14.”

For better illustration of considered example, required update in MR maintained by “13” has been presented below. Table 1 presents the MR of “13” based on initial structure of a network.

Similarly, Table 2 presents the updated MR of “13” in order to accommodate discussed intercluster movement of “14.”

Due to a significant change in network structure, already discovered paths are no longer valid between vehicle “1” and “14.” Therefore, a new path between these two vehicles needs to be rediscovered by following the updated structure of the network.

Since address of “14” remains same and “13” will still be SN of “14”, every path up to “13” is same as earlier and “13” will update further routes towards “14” by following the entry of “14” in MR maintained by “13.” Therefore, a new path between “1” and “14” will be $1 \Leftrightarrow 6 \Leftrightarrow 10 \Leftrightarrow 13 \Leftrightarrow 8 \Leftrightarrow 14$.

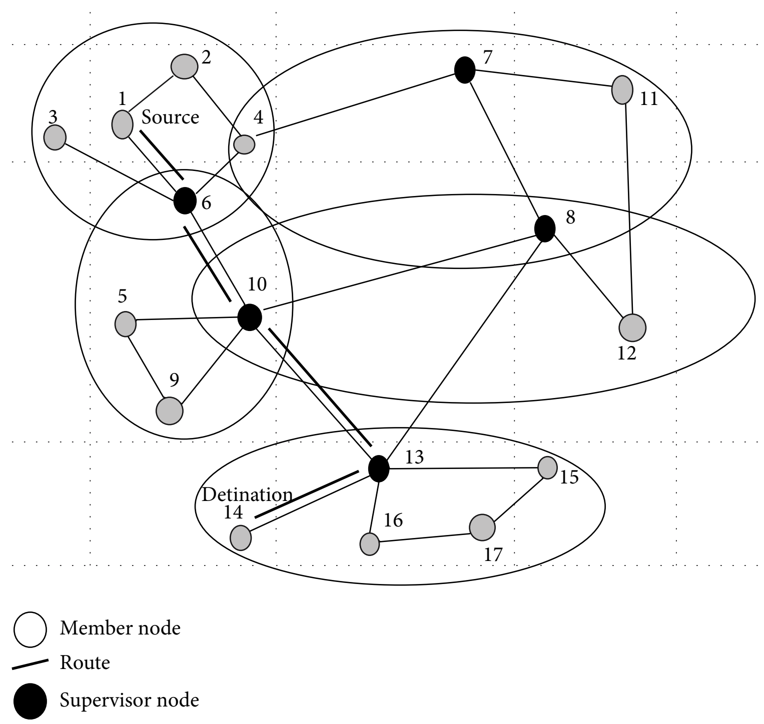


Figure 7: Cluster formation using selected nodes.

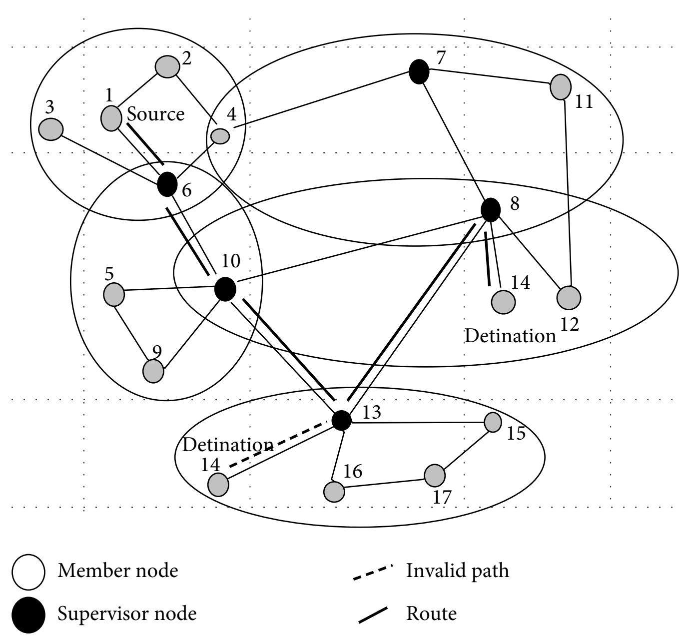


Figure 8: Network after intercluster movement of Node-14.

Table 1: MR of node-13 before movement of node-14.

SN-ID	Next node to be visited	Metric
Node-6	Node-10	2
Node-7	Node-8	2
Node-8	Node-8	1
Node-10	Node-10	1

Table 2: MR of node-13 after movement of node-14.

SN-ID	Next node to be visited	Metric
Node-6	Node-10	2
Node-7	Node-8	2
Node-8	Node-8	1
Node-10	Node-10	1
Node-14	Node-8	2

5. Correctness and Performance

According to the proposed approach, each node in vehicular networks with unique identifier has participated in the routing process, and a large network is divided into several overlapped clusters which are being supervised by one SN only. However, some queries are still to be answered for correctness and performance of this approach such as: Can clustering be extended up to any number of vehicles in the network? Can this approach always provide a route for every source-destination pair in the network? These questions are concerned with some major characteristics of this approach, e.g., scalability and mobility management. Hence, the correctness of the approach has to be proved. Besides that the performance also has to be discussed. Hence, correctness and comparative performance analysis of the proposed approach have been discussed in subsequent two subsections.

5.1. Proof of Correctness. The following theorems assure correctness of the discussed approach, and these theorems have been proved in this section using mathematical induction methodology.

Theorem 1. *Every newly added vehicle to the existing network must be part of at least one of the existing clusters.*

Proof. For $V = 1$, clustering is not needed for the network and the desired situation is true for $V = 1$.

Suppose, the same case is true for $V = n$, i.e., n nodes are divided into several clusters using some selected nodes.

By assuming clustering is correct for $V = n$, clustering must be correct for $V = n + 1$ also. If all n nodes have completely participated in clusters, then, the addition of one node in a connected graph will also be included in either of any clusters. Due to the characteristics of a connected graph, this additional node must be connected to any of existing nodes in network. Since that existing node is already part of one or more clusters, then new node must be part of the same or nearby cluster. Hence, no nodes are skipped from clustering in case of connected graph G. □

Theorem 2. *At least one route shall be available between every pair of source-destination vehicles.*

Proof. We need to prove Route $(S, D) = \{S, v1, v2, v3 \ldots\ldots\ldots D\}$ always exists, where vj ($j = 1, 2, 3 \ldots V$) are vehicle nodes.

For $V = 1$, no path is needed, hence this case is true.

Suppose the same case is true for $V = n$, i.e., source (S) and destination (D) always form a path through several other nodes nj ($j = 1, 2 \ldots V$) using proposed addressing architecture.

So for $V = n + 1$, this additional node must belong to any of the clusters by following theorem 1. Then, additional node must be a neighbor of some nodes that belong to n by following property of the connected network. Therefore, some existing nodes from n must have some path established to that new node and the valid path must be there for $n + 1$ nodes also. □

Theorem 3. *One or more routes must be available for every pair of source and destination vehicles, even after the movement of several vehicles in VANETs.*

Proof. There are two different subcases one for intracluster movement and another for intercluster movement using mathematical induction.

For $V = 1$, the single node itself is aware of all kinds of its movement and no update is required in HR and MR.

Suppose for $V = n$, this case is true. In case of intracluster movement, other nodes can easily update new locations within the cluster due to periodic updates from other nodes. In case of intercluster movement, the supervisor node of respective cluster updates its MR. The corresponding SN of moving node always knows the actual location of that moving node. Therefore, a valid route can be derived easily using routing information maintained in MR.

Therefore for $V = n + 1$, this case must be true. Since additional node is connected to some other nodes in an existing network of n nodes, this node must update its HR and MR by following the movement. Furthermore, every movement of that node including intercluster and within cluster can be tracked by HR and MR maintained by corresponding SNs and other nodes in cluster. This way mobility of vehicles can be managed properly. □

5.2. Theoretical Analysis. In the present section, a comparative study of the proposed approach and closely related MoZo and DACR approaches has been performed based upon various parameters.

5.2.1. Reliable Communication. Reliability is one of key parameters for evaluating the performance of any routing approach. Reliability in communication gets measured by value of some performance metrics such as packet loss and packet delivery ratio. The customized addressing architecture provides end to end connectivity of vehicles by parsing the address of destination vehicles. Furthermore, both registers keep track of every vehicle in the network by following a two-tier routing mechanism. Therefore, data transmission efficiency is improved in terms of increased packet delivery ratio and decreased packet loss. By improving these performance metrics, proposed approach provides more reliable communication than some approaches discussed in the related works section.

In the MoZo and DACR routing approaches, only the captain vehicle maintains the routing information of whole clusters. Consequently, any data transmission even within same cluster needs the involvement of captain vehicle. However, in the proposed approach, apart from SN, every node in the cluster also maintains local routing information that improves the reachability of the destination vehicle in a cluster. Moreover, intercluster routing also proceeds using the address of respective supervisor nodes which is associated with an address of the destination vehicle.

5.2.2. Mobility Management. Mobility management maintains the efficiency of the network even after the movement of vehicles. Moreover, improvement in performance parameters impacts the efficiency of a network. In the proposed approach, mobility management has been introduced by using two levels of databases for keeping the network information updated with all kinds of movement patterns. Every movement of vehicles either within a cluster or out-side of cluster is tracked properly that enhances reachability for every pair of vehicles. Therefore, respective performance metrics such as packet-loss, end-to-end delay, and jitter are also improved if the path between every source and destination vehicle is always computable.

In contrast with MoZo and DACR approaches, SN nodes are always same in proposed approach instead of reassigning the cluster vehicles in the cluster. Reassigning of the captain in the new cluster requires recalculation of all routes maintained in the previous cluster. However, in the current approach, the supervisor node is always same and only cluster members are considered to move from one cluster to another. It enables all intercluster movements of vehicles to be tracked from their respective SN itself that reduces packet drops and round-trip time of messages in data communication.

5.2.3. Scalability. Scalability allows VANETs to be extended up to increased number of nodes without any significant impact on the network performance. The proposed clustering approach in-tends to reduce hop count up to the manageable level by using efficient clustering that makes communication feasible even in very large VANETs. Moreover, single large VANET is divided into several small subnetworks headed by supervisor nodes. Therefore, network efficiency is not reduced even after increasing participating vehicles into the same network, in terms of performance metrics such as packet-loss, end-to-end delay, and jitter.

Unlike, MoZo and DACR routing approaches, the proposed approach takes advantage of overlapping clusters with the participation of every vehicle in clusters. Overlapping clusters in vehicular networks reduce the probability of vehicles not being part of any cluster that enhances the connectivity of vehicles in a large network as well. The vehicles that are part of any cluster are always able to compute route towards the destination vehicle. Therefore, the discussed approach is more efficient and suitable for large VANETs.

5.2.4. Routing Overhead. This represents complexity in data transmission that includes effort for maintaining routing table and for discovering new route as well. The proposed approach uses two-tier routing by maintaining routing information on each vehicle including the supervisor vehicle that provides better connectivity. However, routing overhead is increased if vehicles are changing cluster frequently. In such cases, increased routing overhead may impact energy consumption and some performance metrics also such as delay and jitter.

The discussed approach introduces two-tier routing and maintains routing information on every vehicle of a cluster. Consequently, frequent change of cluster by any vehicle requires the involvement of several supervisor nodes to tracks route from the original supervisor node to the current supervisor node. Additionally, multiple MR are keeping track of the same vehicles in the network. Therefore, routing overhead is increased in such network environments where vehicles are traversing through several clusters such as vehicles moving on highways. However, overhead is not increased, if vehicles are moving in some specified zone only.

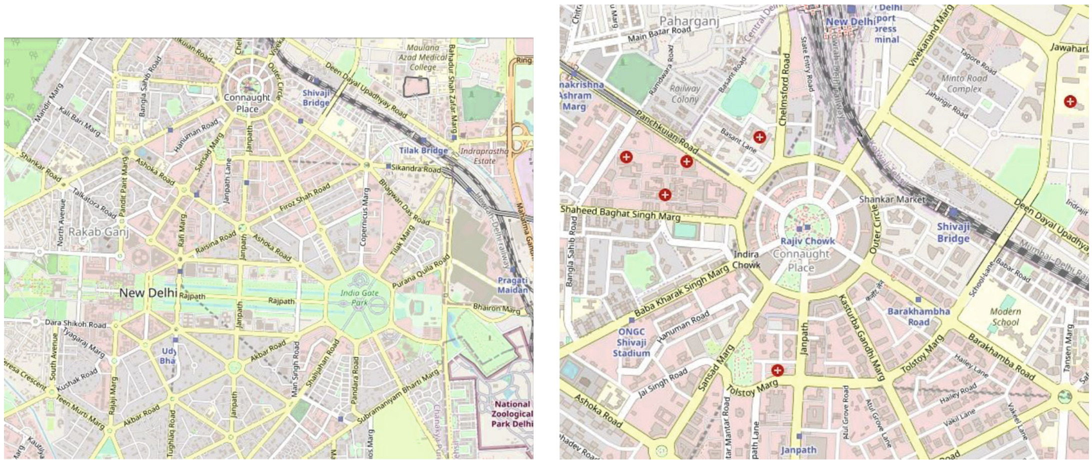
6. Experimental Analysis

Based on defined theorems and their proofs, the correctness of the proposed approach has been presented in the previous section. Furthermore, the performance of the OCSR routing protocol has been examined using simulation experiments. For better illustration, the proposed approach has been analyzed on different vehicular environments. Also, results have been compared with a recent clustering approach namely, MoZo [29] and DACR [30]. In the first phase, the performance of the proposed approach has been analyzed in different size network environments. In the second phase, the performance of the proposed approach has been compared with MoZo and DACR. The simulation setup and configured parameters have been discussed in the next subsection. The next three subsections cover the performance of OCSR and comparative study of the proposed approach with two recent similar approaches.

6.1. Simulation Settings. NS-3(v3.29) and SUMO (v0.32) both have been used for simulating experiments as a network simulator and vehicular mobility simulator, respectively. Both the simulators have been deployed on Ubuntu (v16.04). For considering small and large environments, two different maps of New Delhi are considered in the simulation. 1000 m long and 1000 m wide with 200 vehicles is considered for small VANETs, and 5000 m long and 5000 m wide with 500 vehicles is considered for large VANETs. Both the maps are presented in Figures 9(a) and 9(b).

Varying parameters and other configurable parameters used in simulation have been presented in Table 3 with corresponding values.

6.2. Performance of OCSR. Packet delivery ratio (PDR), end-to-end delay (E2ED), and average throughput are performance metrics [34] which have been considered for presenting the performance of the proposed approach. All three performance metrics are recorded by varying pause times in packet delivery ratio (PDR), end-to-end delay (E2ED), and average throughput are performance metrics [35] which have been considered for presenting the performance of the proposed approach. All three performance metrics are recorded by varying pause times in both the environments. Pause time represents the mobility of nodes in networks. At the time of restarting the journey, vehicles are unavailable for communication up to the selected pause time. Size of the network is defined by map size with a significant number of vehicles used in the network. Simulation has been performed for both maps with 500 vehicles and 500 messages to be delivered. This helps in evaluating the performance of the proposed approach in the small and large networks on different mobility of nodes.



(a) (b)

Figure 9: (a) Large size VANETs. (b): Small size VANET.

Table 3: Simulation parameters.

Parameters	Values
Number of vehicles	100, 200, 500, 1000, and 1500
Pause time	10s, 50s, 100 s, 150 s, and 250 s
Number of packets	100, 200, 300, 400, and 500
Map size	1000 m × 1000 m
Communication range	250 m
Vehicle speed	10 m/s
Packet size	512 bytes
MAC	IEEE 802.11
Simulation time	100 s with 600 flows
Traffic type	CBR/UDP
Propagation model	Two-ray ground
Mobility model	Random way point
Data rate	2 Mbps

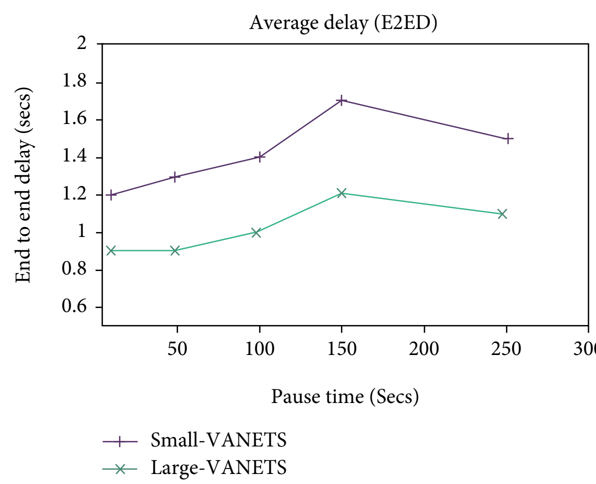


Figure 11: End to end delay versus pause time.

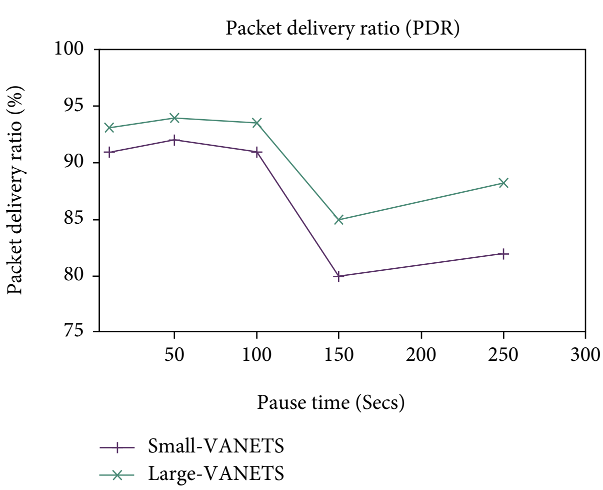


Figure 10: Packet delivery ratio versus pause time.

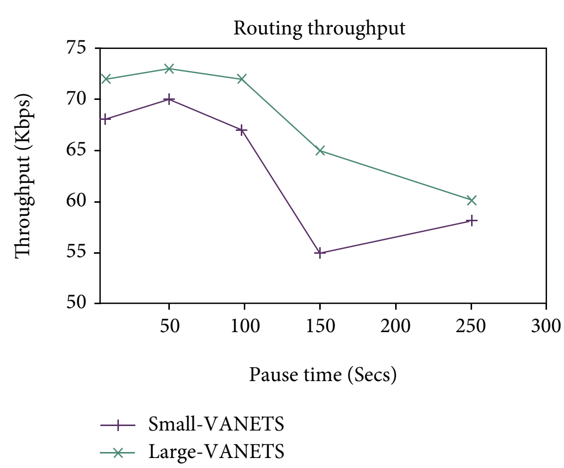


Figure 12: Throughput versus pause time.

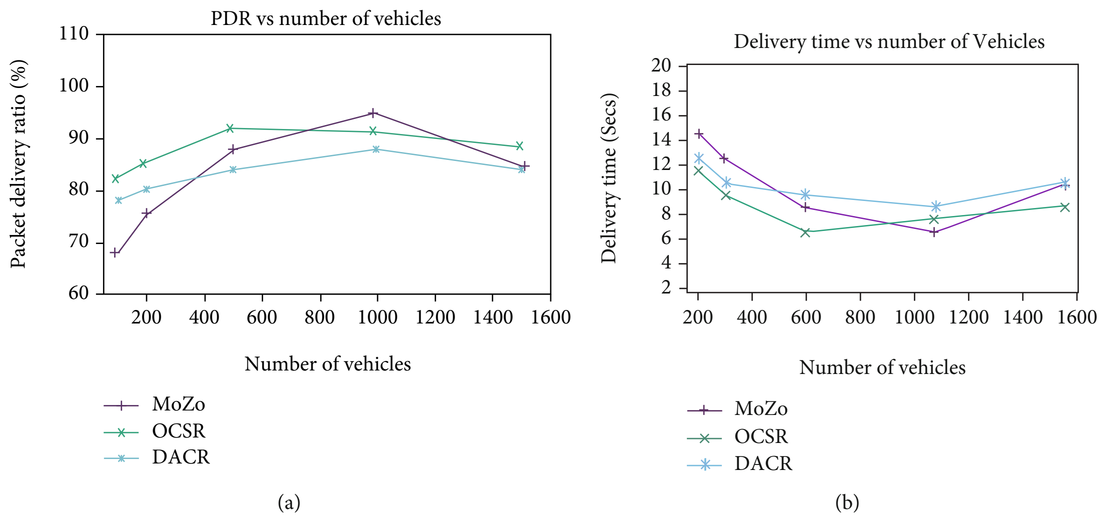


Figure 13: (a) PDR versus number of vehicles. (b) Delivery time versus number of Vehicles.

6.2.1. Packet Delivery Ratio (PDR). Reliability in communication is measured by value of some performance metrics such as packet loss and packet delivery ratio (PDR). PDR is the ratio of the number of messages delivered to the total number of generated messages. The customized addressing architecture provides end-to-end connectivity of vehicles by parsing the address of destination vehicles. Furthermore, both registers keep track of every vehicle in the network by following a two-tier routing mechanism. Therefore, data transmission is improved in terms of increased packet delivery ratio in large size network in high mobile environment as mentioned in Figure 10.

6.2.2. End-to-End Delay (E2ED). End-to-end delay (E2ED) presents time taken by every packet to arrive from source to destination vehicle. As shown in Figure 11, the proposed approach shows approximately 30% less delay in comparison larger network in compare to small size network. The reason behind this phenomenon may be clustering technique used and handling the large size network using smaller clusters.

6.2.3. Throughput. Routing throughput is calculated in terms of data transferred per time unit including control packets as well as data packets. As evident from Figure 12, the throughput of OCSR is not promising in small network environment, since maintaining two registers introduces some overhead on cluster head nodes. However, the throughput is further improved significantly in large six networks. Throughput is significantly improved in both sized network large as well as small when vehicles are comparatively high mobile. Because, both registers play a key role when nodes are high mobile.

Based on the simulation results of OCSR approach in both size networks by varying mobility of vehicles, it is found that OCSR approach supports scalability and mobility management in vehicular network. However in small size network throughput is slightly reduced due to handling of two registers for smaller networks.

6.3. Comparative Analysis. As recent similar work, MoZo and DACR approaches have been selected for a comparative study of the proposed approach. Therefore, the performance of the designed approach has been compared with both MoZo and DACR approaches based on the reliability and efficiency of the approach in different environments. Delivery ratio and delivery time have been considered for evaluating reliability and efficiency in communication, respectively. Both parameters are recorded by varying number of vehicles, and the number of messages to be delivered in the network. While varying number of vehicles in experiments, number of messages is set to 500. At the same time, number of vehicles is fixed to 500 while varying number of messages in simulation.

6.3.1. Varying Number of Vehicles. In current set of experiments, multiple runs have been performed by varying number of vehicles for recording delivery time and packet delivery ratio. Furthermore, OCSR approach has been compared with MoZo and DACR approaches via experimental results. The results shown in Figures 13(a) and 13(b) exhibit that the performance of OCSR is significantly better than other two approaches in terms of packet delivery ratio (PDR) and delivery time. As far as PDR is concerned, OCSR outperforms MoZo and DACR by manifolds when the number of vehicles are less, however, as the number of vehicles increases, MoZo tries to reduce this gap.

MoZo and DACR do not perform well in smaller network in comparison of OCSR. Because, only cluster head vehicle maintains the routing information of whole clusters in both the approaches. Consequently, any data transmission even within same cluster needs the involvement of captain vehicle and intercluster routing also involves some of the captain vehicles, which are not aware of the movement of destination vehicles. However, in the current approach apart from SN, every node in the cluster also maintains local routing information that improves the reachability of the destination vehicle in a cluster. And intercluster routing also proceeds using the address of respective supervisor nodes which is associated with an address of the destination vehicle.

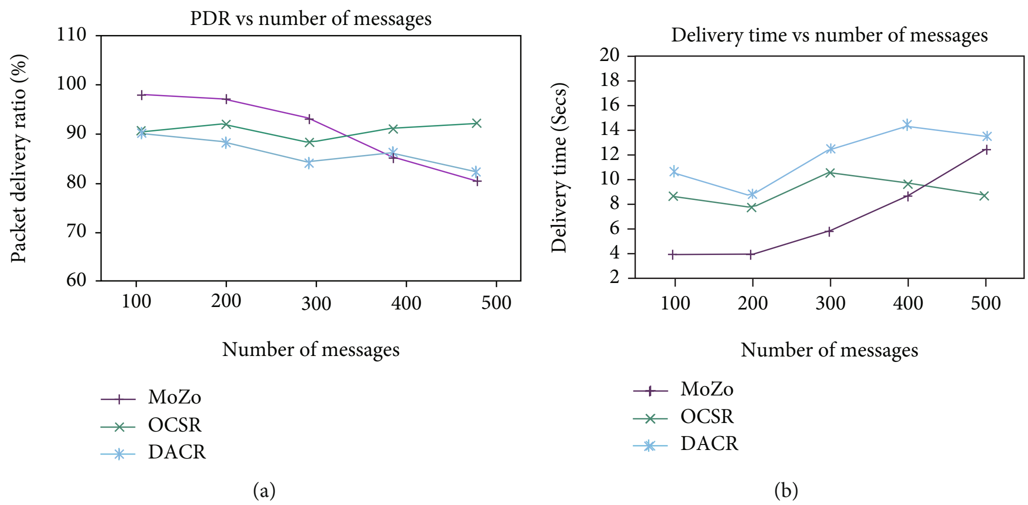


FIGURE 14: (a) PDR versus number of messages. (b) Delivery time versus number of messages.

6.3.2. Varying Number of Messages. This set of experiments covers recording of PDR and delivery time by varying number of messages to be delivered in network. Increased number of messages tends to increasing routing overhead in fixed size network.

As shown in Figures 14(a) and 14(b), comparative analysis of all three approaches presents that performance of OCSR is significantly improved when number of messages to be delivered is higher. Performance of DACR declined by increasing routing overhead. However, MoZo outperforms OCSR when routing overhead is comparatively low. Reason behind this phenomenon is that the captain reassignment mechanism in MoZo and maintaining routing expiry in DACR itself introduces some overhead that is why in higher overhead network these two show poor performance. On the other hand, reassignment of cluster head is not required in proposed approach and it is based on tracking the movement of vehicles using registers. Therefore, this approach is more suitable for networks in which the number of messages to be delivered is more.

7. Conclusion

A new clustering approach for large VANETs has been presented in the current exposition with group and individual mobility management. In order to provide scalability, the whole network is divided into several overlapped clusters and each cluster is monitored by one supervisor node. Each vehicle in a network is required to maintain two levels of the routing hierarchy. A customized addressing architecture has been embedded with the approach to make vehicular communication more reliable. Additionally, two levels of databases are proposed to be maintained in the network to handle mobility management effectively. Better mobility management in large VANETs makes this approach scalable too. The correctness of the proposed approach has been proved and effectiveness of approach has been established by comparing it with some other recent mobility management techniques. The proposed approach is useful in an environment where vehicles are moving in the specified zone such as urban cab services, school vans, and medical vehicles. Testing suitability of the proposed approach for other environments has been left as a future work.

Data Availability

This research is based on a hypothesis that is proved using mathematical modeling as well as simulation. Experimental results have been presented in the manuscript itself and there is no external data is involved in this research.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

References

[1] N. Tyagi, A. Rana, and V. Kansal, "Creating elasticity with enhanced weighted optimization load balancing algorithm in cloud computing," in *Amity International Conference on Artificial Intelligence (AICAI)*, pp. 600–604, Dubai, United Arab Emirates, 2019.

[2] S. Basagni, M. Conti, and S. Giordano, *Mobile Ad Hoc Networking: Cutting Edge Directions*, Book Second Edition, Willey IEEE Press Publisher, 2013.

[3] N. Bouchama, D. Aïssani, N. Djellab, and N. Nouali-Taboudjemat, "A critical review of quality of service models pin mobile ad hoc networks," *International Journal of Ad Hoc and Ubiquitous Computing*, vol. 31, no. 1, pp. 49–70, 2019.

[4] W. Liang, Z. Li, H. Zhang, S. Wang, and R. Bie, "Vehicular ad hoc networks: architectures, research issues, methodologies, challenges, and trends," *International Journal of Distributed Sensor Networks*, vol. 11, no. 8, Article ID 745303, 2015.

[5] A. Khanna, J. J. P. C. Rodrigues, N. Gupta et al., "A mutual exclusion algorithm for flying ad hoc networks," *Computers & Electrical Engineering*, vol. 76, pp. 82–93, 2019.

[6] S. Boussoufa-Lahlah, F. Semchedine, and L. Bouallouche-Medjkoune, "Geographic routing protocols for vehicular ad hoc networks (VANETs): a survey," *Vehicular Communications*, vol. 11, pp. 20–31, 2018.

[7] P. K. Pandey, V. Kansal, and A. Swaroop, "Vehicular ad hoc networks (VANETs): architecture, challenges, and applications," in *Handling Priority Inversion in Time-Constrained Distributed Databases Hershey*, U. Shanker and S. Pandey, Eds., pp. 224–239, IGI Global, PA, 2020.

[8] I. Souissi, N. B. Azzouna, and T. Berradia, "Trust management in vehicular ad hoc networks: a survey," *International Journal of Ad Hoc and Ubiquitous Computing*, vol. 31, no. 4, pp. 230–243, 2019.

[9] S. Varshney, C. Kumar, A. Swaroop et al., "Energy efficient management of pipelines in buildings using linear wireless sensor networks," *Sensors*, vol. 18, no. 8, article 2618, 2018.

[10] S. Gupta, A. Rana, and V. Kansal, "Optimization in wireless sensor network using soft computing," *Proceedings of the Third International Conference on Computational Intelligence and Informatics*, K. Raju, A. Govardhan, B. Rani, R. Sridevi, and M. Murty, Eds., , pp. 801–810, Springer, Singapore, 2020.

[11] S. Ullah, D. M. Khan, A. U. Rehman, M. A. Siddique, and A. Khan, "An effective modeling to minimize the transmission time in Vanet by reducing routing overhead," *Science International Lahore*, vol. 28, pp. 3041–3047, 2016.

[12] S. Benkerdagh and C. Duvallet, "Cluster-based emergency message dissemination strategy for VANET using V2V communication," *International Journal of Communication Systems*, vol. 32, no. 5, 2019.

[13] N. Tyagi, A. Rana, and V. Kansal, "Load distribution challenges with virtual computing," in *Intelligent Computing in Engineering*, V. Solanki, M. Hoang, Z. Lu, and P. Pattnaik, Eds., vol. 1125 of Advances in Intelligent Systems and Computing, pp. 51–56, Springer, Singapore, 2020.

[14] J. Xiang, Y. Huiqun, F. Guisheng, S. Huaiying, and C. Liqiong, "Efficient and Reliable Cluster-Based Data Transmission for Vehicular Ad Hoc Networks," *Mobile Information Systems*, vol. 2018, p. 15, 2018.

[15] M. M. A. Osman, S. K. Syed-Yusof, N. N. N. Abd Malik, and S. Zubair, "A survey of clustering algorithms for cognitive radio ad hoc networks," *Wireless Networks*, vol. 24, no. 5, pp. 1451–1475, 2018.

[16] M. Benmahdi and M. Lehsaini, "Performance evaluation of main approaches for determining optimal number of clusters in wireless sensor networks," *International Journal of Ad Hoc and Ubiquitous Computing*, vol. 33, no. 3, pp. 184–195, 2020.

[17] S. Gupta, A. Rana, and V. Kansal, "Comparison of Heuristic techniques: a case of TSP," in *2020 10th International Conference on Cloud Computing, Data Science & Engineering (Confluence)*, pp. 172–177, Noida, India, 2020.

[18] S. Malik and P. K. Sahu, "A comparative study on routing protocols for VANETs," *Heliyon*, vol. 5, no. 8, article e02340, 2019.

[19] P. K. Pandey, A. Swaroop, and V. Kansal, "A concise survey on recent routing protocols for vehicular ad hoc networks (VANETs)," in *2019 International Conference on Computing, Communication, and Intelligent Systems (ICCCIS)*, pp. 188–193, Greater Noida, India, 2019.

[20] A. Dua, N. Kumar, and S. Bawa, "A systematic review on routing protocols for vehicular ad hoc networks," *Vehicular Communications*, vol. 1, no. 1, pp. 33–52, 2014.

[21] S. Dhankhar and S. Agrawal, "VANETs: a survey on routing protocols and issues," *International Journal of Innovative Research in Science, Engineering and Technolog*, vol. 3, no. 6, pp. 13427–13435, 2014.

[22] N. Tyagi, A. Rana, and V. Kansal, "Resourceful system-level optimized placement of virtual machines for cloud computing," in *2018 4th International Conference on Applied and Theoretical Computing and Communication Technology (iCATccT)*, pp. 99–102, Mangalore, India, 2018.

[23] S. Khurana, G. Tejpal, and S. Sharma, "Efficient data dissemination approach for QoS enhancement in VANETs," *International Journal of Ad Hoc and Ubiquitous Computing*, vol. 31, no. 4, pp. 277–286, 2019.

[24] M. Altayeb and I. Mahgoub, "A survey of vehicular ad hoc NetworksRouting protocols," *International Journal of Innovation and Applied Studies*, vol. 3, no. 3, pp. 829–846, 2013.

[25] Y. Gao, Z. Zhang, D. Zhao, Y. Zhang, and T. Luo, "A hierarchical routing scheme with load balancing in software defined vehicular ad hoc Networks," *IEEE Access*, vol. 6, pp. 73774–73785, 2018.

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

[27] M. Hadded, R. Zagrouba, A. Laouiti, P. Muhlethaler, and L. A. Saidane, "A multi-objective genetic algorithm-based adaptive weighted clustering protocol in vanet," in *2015 IEEE Congress on Evolutionary Computation (CEC)*, pp. 994–1002, Sendai, Japan, 2015.

[28] S. Ucar, S. C. Ergen, and O. Ozkasap, "Multihop-cluster-based IEEE 802.11p and LTE hybrid architecture for VANET safety message dissemination," *IEEE Transactions on Vehicular Technology*, vol. 65, no. 4, pp. 2621–2636, 2015.

[29] D. Lin, J. Kang, A. Squicciarini, Y. Wu, S. Gurung, and O. Tonguz, "MoZo: a moving zone based routing protocol using pure V2V communication in VANETs," *IEEE Transactions on Mobile Computing*, vol. 16, no. 5, pp. 1357–1370, 2017.

[30] K. Aravindan and C. S. G. Dhas, "Destination-aware context-based routing protocol with hybrid soft computing cluster algorithm for VANET," *Soft Computing*, vol. 23, pp. 2499–2507, 2018.

[31] G. H. Alsuhli, A. Khattab, and Y. A. Fahmy, "A mobility-based double-head clustering algorithm for dynamic VANET," *2018 International Japan-Africa Conference on Electronics, Communications and Computations (JAC-ECC)*, 2018, pp. 91–94, Alexandria, Egypt, 2018.

[32] M. Ren, L. Khoukhi, H. Labiod, J. Zhang, and V. Vèque, "A mobility-based scheme for dynamic clustering in vehicular ad-hoc networks (VANETs)," *Vehicular Communications*, vol. 9, pp. 233–241, 2017.

[33] M. Ramalingam and R. Thangarajan, "Mutated k-means algorithm for dynamic clustering to perform effective and intelligent broadcasting in medical surveillance using selective reliable broadcast protocol in VANET," *Computer Communications*, vol. 150, pp. 563–568, 2020.

[34] A. Moravejosharieh, H. Modares, R. Salleh, and E. Mostajeran, "Performance analysis of AODV, AOMDV, DSR, DSDV routing protocols in vehicular ad hoc network," *Research Journal of Recent Sciences*, vol. 2, no. 7, 2013.

[35] P. K. Pandey, V. Kansal, and A. Swaroop, "ALMR: Alternate Link Based Multipath Reactive Routing Protocol for Vehicular Ad Hoc Networks (VANETs)," *Ad Hoc and Sensor Wireless Networks*, vol. 50, no. 1-4, pp. 27–53, 2021.