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A Cluster-Based Vehicular Ad-hoc Network Handoff Scheme Inspired by Ant Colony Optimization

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Abstract**—** In recent times, the drivers and passengers of vehicles are not confined to only travelling in their vehicles. They are feeling the need for enhanced services on the go. As a result, the time has come when it is necessary to bring about improvements in the current Intelligent Transport System (ITS). Handoff in VANET is one of the common areas that require attention of researchers. During the Handoff process, it is necessary to ensure that the vehicle maintains continuous connection with the network. This will decrease the amount of packet loss thus ensuring Quality of Service (QoS). In this paper we have proposed a novel scheme; Cluster Based Vehicular Handoff (CBVH) for reducing load on a single backbone device using the concept of clustering. The scheme also reduces packet loss during handoff by proactively caching packets intended for the node that is participating in the handoff process.

Keywords**—** VANET, Ad-hoc, Networking, Addressing, Cluster, Handoff, Vehicle.

I. Introduction

Vehicular Ad-Hoc Networks (VANETs) have become one of the most promising research areas due to rapid advancement in wireless communication technology. The vehicle manufacturers and academic researchers are showing a lot of interest in the enhancement of VANET. In VANET, the vehicular nodes are highly mobile. The nearby vehicles communicates with each other and also with the road side base stations [1].When two vehicles communicate with each other it is known as vehicle-to-vehicle communication (V2V) and when a vehicle communicate with the road infrastructure it is known as vehicle-to-infrastructure communication(V2I).The vehicular node can be equipped with significant communication and sensing capabilities [2].These capabilities update the driver about on road traffic enabling them to take dynamic real time decisions. The major challenge associated with the VANET is that the vehicular nodes that are the intrinsic part of VANET move around at a very high speed. Due to this high speed and frequent change of position the network topology changes continuously. Thus, there is frequent connection and disconnection of the links between the vehicles. A lot of communication overhead is incurred for frequent exchange of topology information. The number of participants in a VANET is usually many and it may span over the entire network of roads in a region [2].

In VANET, the nodes configure themselves to create a temporary network. This is done without the help of any centralized management or predefined infrastructure. One of the ways of managing such an ad-hoc network is by forming clustering structure in a network. Clustering allows a creation of dynamic virtual backbone for the network that helps to maintain the Quality of Service in the network. VANET experiences constrained bandwidth problem, and frequent topology changes. These problems can be efficiently handled in groups by cluster formation in the network [3][4].

In this paper, a scheme, Cluster-Based Vehicular Handoff (CBVH) is designed using clustering technique to manage vehicles on road. Clustering is the process of dividing the network into substructures known as clusters. This is done using K-Means clustering algorithm for vehicles. These clusters are interconnected with each other. Based on some specific characteristics one of the nodes is selected to serve as the cluster head. This cluster head is selected based on certain parameters and weight factors that vary according to time and density of vehicles on road. Within a particular substructure the cluster head plays the role of a coordinator. The cluster head perform the function of a temporary base station, within the cluster it belongs to. It also communicates with other cluster heads [5] [6]. Since the cluster head carries the responsibility of multiple vehicular nodes, selecting the cluster head from a group of nodes is very crucial. Thus, a cluster is made up of cluster head and member nodes. The cluster head is the one that coordinates the operations in a cluster. Member nodes are also known as ordinary nodes. Formation of clusters within a network helps in backbone formation and reducing load on a single point of attachment. Various handoff scenarios are also considered in this paper and taken care of.

This paper is classified into 8 sections. Section 1 gives the Introduction; Section 2 states the motivation and contribution of the proposed work; Section 3 discusses some related works; Section 4 demonstrates the overall system architecture of the proposed work; Section 5 proposes the cluster formation and handoff procedure; Section 6 shows the latency and power consumption of the proposed model; result and discussion has been given in Section 7 and Conclusion and future scope in Section 8.

II. MOTIVATION AND CONTRIBUTION

Integrating recent technologies such as wireless communication, sensing, video vehicle detection, Bluetooth services in vehicles makes transportation more intelligent. So, the passengers and drivers onboard are feeling the need to use various intelligent services to improve their on-board experience. However, as the vehicular networks are adhoc in nature it becomes a challenge to manage the network. The most important issue is managing handoff in VANETs. The vehicles must always remain connected to the network to ensure that quality of service is good and packet loss in the network is minimum. As the number of vehicles is increasing at an exponential rate so this increases vehicular density load on a single Mobile Access Gateway (MAG). There by increasing the chance of single point failure in the network. This not only results in packets loss but the quality of service desired from intelligent transportation system is degraded. So there is a need to prevent single point network failure to ensure desired quality of service in VANET. So, in this paper a cluster based handoff method is proposed. Network Cluster has certain advantages that have motivated us to implement the technique. Firstly, the overhead associated with node management and resource deployment is much less compared to methods that don't implement clustering. As a result, the system capacity is significantly increased. Secondly, the MAG does not have to manage every node in the network. Therefore, the load on the MAG is significantly reduced. Thirdly, the clustering method makes the network scalable.

We have made the following contributions in our proposed scheme: -

a. Vehicles have been clustered by choosing the appropriate cluster centers. Further cluster heads have been chosen in each cluster to reduce the load on a single MAG.
b. Proactive caching has been used to cache the packets intended for the vehicle that is getting handoff. This reduces the packet loss during the handoff process.

We have compared our scheme with PMIPv6 and found out the following results:

a. Significant decrease in IP acquisition latency.
b. Significant decrease in handoff latency.

III. RELATED WORK

A number of improved schemes have been proposed to enhance handoff procedure in VANET [7] [8]. This section provides a brief overview of some of the schemes. In the scheme proposed in [9] the Previous Mobile Access Gateway (PMAG) maintains a list of those Mobile Access Gateways (MAGs) that are in its neighborhood. The PMAG takes up the responsibility of discovering the New Mobile Access Gateway (NMAG) to which the vehicle will attach in the future. The limitation of this scheme is that since the MAG is responsible for the handoff of each individual vehicle, the load on MAG will increase exponentially with the number of vehicles. This might lead to single point failure in the network. In the scheme proposed in [10], a handoff mechanism using the concept of multi-way proactive caching has been proposed. According to the scheme data packets intended for a particular Mobile Node (MN) is cached in all the Road Side Units (RSUs) that has the probability of becoming the next RSU to prevent packet loss. After the handoff, The Target RSU to which the vehicle gets attached transmits a Move_Notify message for all other neighboring non-Target RSUs. This notification signals the non-Target RSUs to drop the cached packets meant for the intended vehicle, since handoff process is over. The drawback of this scheme is that the packet is not only sent to the Target RSU but also to other neighboring RSUs. This leads to huge packet flow in the network and eventually congestion. In [11], the duplicate address detection (DAD) procedure is eliminated to decrease latency during handoff. This scheme is not scalable as a global address is defined and maintained in the network operator's domain. In the handoff mechanism proposed in [12], an attempt is made to reduce the handoff delay by estimating the time when the vehicle will start to scan for the next RSU. The Previous RSU (PRSU) carries out the task of preselecting and preauthorizing the next probable RSU. This is done while the vehicle is still connected to the PRSU. Here the whole network is dependent on a single back bone server. If this back-bone server fails the whole network will fail. The clustering algorithm that has been proposed in [13] forms a stable cluster of vehicles. It also proposes the way in which the clusters are restructured. However, the scheme does not say anything about the handoff of the vehicles. In the scheme in [14] a network model based on clustering has been proposed.

To address the load on a single MAG, clustering algorithms play a vital role. Clustering also eliminates the problem of single point failure. The Weight-Based Adaptive Clustering Algorithm [15-19] plays a vital role in classifying the nodes in the transmission range of a particular MAG into clusters. It considers a number of parameters such as degree, mobility, transmission power, rate and battery power. Using these parameters weight of respective node is calculated. Depending on the weights of the nodes one of the nodes is selected as a cluster head. The concept of proactive caching [20-22] also minimizes the packet loss when the handoff phenomenon is taking place.

IV. PROPOSED SYSTEM ARCHITECTURE FOR CLUSTER BASED HANDOFF MECHANISM

In this scheme, CBVH, a three-level hierarchical architecture is proposed. The Mobile Access Gateways (MAG) forms the top most layer which are associated with each of the WiMAX base station (WBS). Below the MAGs, lies the second layer of cluster heads which is chosen from among the vehicles moving on road. The cluster head acts as a communication backbone for the group of vehicles known as clusters. It manages the network and assigns IP addresses to its members. It also acts as a mediator between the mobile access gateways and the member nodes(vehicles). The member nodes form the lowest layer of this architecture.

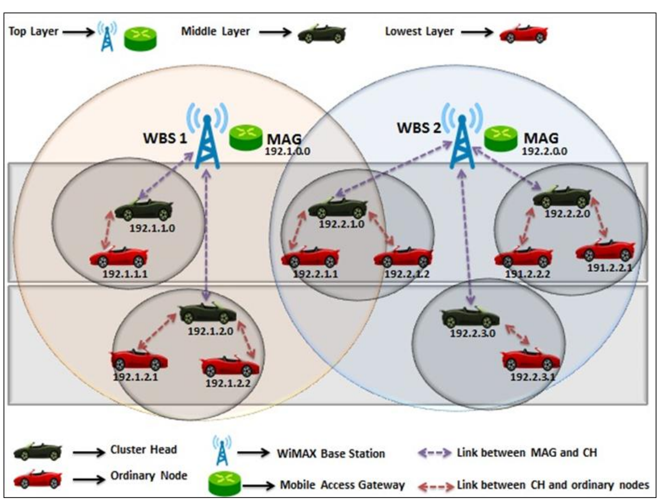


Figure 1. Layered System Architecture of the proposed handoff scheme

Each vehicle is equipped with a WiMAX mobile router. Figure 1 illustrates the system architecture of our proposed cluster based vertical handoff scheme. In the proposed scheme, the nodes are classified into two categories: -

Cluster Head: This is a single node or vehicle that has been chosen as head node in a cluster. The member nodes of the cluster have direct access to the cluster head which acts as a mediator between the member nodes and the MAG. The cluster head performs task like assigning IP addresses to member nodes and handover procedures of member nodes.

Member node: The member nodes are ordinary vehicles which did not qualify as the cluster head. These vehicles fall under the cluster heads in the hierarchy. It communicates with the cluster head which in turn communicates with the mobile access gateway.

A Dynamic Host Configuration Protocol (DHCP) server is associated with each MAG to supply IP address to each node. The MAG serves as the central point from which it controls the various operations that are performed within its transmission range. The DHCP server generate a group of IP addresses and assigns the first address of the group to the node elected as Cluster Head (CH) which then distributes the remaining address to its member nodes.

Addressing Scheme

IPv4 addressing scheme is used for addressing the various components of the network since it takes up less memory space and. Each MAG, CH and member node is assigned a unique IPv4 address. In this work the 32-bit address space of IPv4 is divided in the following manner as shown in Figure 2. The first 16 bit of the address space is allocated for the MAG (MAG_ID). Packets intended for a specific MAG are delivered using this MAG_ID. Every CH that belongs to the same MAG has the same MAG_ID. The next 8 bits are allocated for the CHs (CH_ID). Each CH that is associated with a particular MAG has a unique CH_ID. The remaining 8 bits are reserved for the member nodes (O_ID). Each member node that is associated with a particular CH has a unique O_ID. To address a MAG except the MAG_ID field all other fields are set to zero. In the same way if a CH is to be addressed the O_ID field is set to zero. Figure 3 shows the IPv4 addressing of vehicles, cluster heads and MAG.

MAG_ID	CH_ID	O_ID
16 bit	8 bit	8 bit

Figure 2. IPv4 format for the proposed scheme

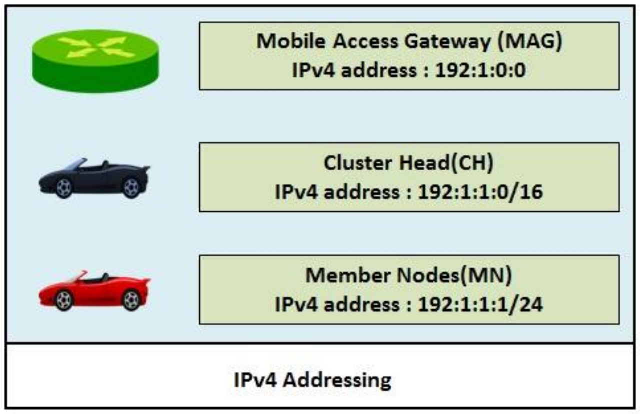


Figure 3. IPv4 addressing example

Tables maintained

There are three tables that need to be maintained in this scheme. The MAGs must maintain a NODE_INFO table which contains the following fields–a) MAC_id – Unique id for every vehicle, b) IP_ADDR- IPV4 address assigned by the MAG, c) TVAL- Trust value of the vehicle, d) Speed - speed with which the vehicle is moving, e) Signal strength- Signal strength of that node, f) Load – computation load of that node, g) Pos- Location of the vehicle, h) C_ID – MAC address of its cluster head, i) C_No – Cluster number, j) C_flag – Denotes whether the node is a cluster head or not. The NODE_INFOtable is shown in Figure 4 (a).It keeps track of all the vehicles, cluster heads and the clusters they belong to. The cluster head maintains a M_INFO table whose fields are – a) N_MAC_id- Contains the MAC id of every node belonging to the elected cluster head, b) ASSN_IP- The assigned IP address to the member node. The M_INFO table is shown in Figure 4(b).The M_INFO table keeps track of the member nodes under the cluster head. Another table that is maintained by the MAG is the NBR_INFO table which contains the field-a) MAC_ID of the neighbour MAG and b)IP_ADDR of the neighbour MAGs to keep track of the neighbouring MAGs. This table is populated when the MAGs are setup. The information in the table is also updated in situations when new MAGs are set up or the existing MAGs are brought down. The neighboring MAGs keep on exchanging HELLO and ACK messages at regular time intervals to keep themselves informed about each other status. Any change is updated in the NBR_INFO table from time to time. The NBR_INFO table is shown in Figure 4(c).

Messages exchanged

There are five messages that have been used in the scheme to carry out communication between the various components. The INFO_MSG message is given out by the vehicles. The message has the following payload- a) MAC_id – unique id for every vehicle, b) TVAL – Trust value of the concerned vehicle, c) V- Speed of the vehicle, d) S – Strength of the signal received by the vehicle from the MAG, e) L – Load on the computing resources of the vehicle, f) Position – Location of the vehicle. The structure of the INFO_MSG has been shown in Figure 4 (e). Using this message the vehicles send information about themselves to the MAG. The vehicles that have been elected as Cluster Heads transmit V_NOREPLY and V_ADD messages to notify the MAG about the exclusion and inclusion of a vehicle respectively. The payload of the V_NOREPLY and V_ADD messages is as follows – a) Bi – Bit indicator to differentiate V_NOREPLY and V_ADD messages. The value of Bi is 00 for V_NOREPLY and 11 for V_ADD, b) D_ADDR - the address of the MAG to which the V_NOREPLY or V_ADD message is being sent, c) S_ADDR - the address of the Cluster Head that is sending the message, d) MAC_id – is the unique id of the node that has left the cluster, e) IP_ADDR – the IP address of the vehicle that has left the cluster. When the Cluster Head itself leaves the area of the current MAG it sends out Q_MAG and Q_NODE messages. The Q_MAG message is sent to the respective MAG. It has the following payload – a) MAC_ID – it is the unique ID of the Cluster Head, b) D_ADDR – the address of the MAG. Using this message the Cluster Head notifies the MAG that it is leaving its area. Whereas, the Q_NODE message is used to notify the member nodes that are within a cluster that the Cluster Head is leaving the area of the current MAG. The payload of this message is – a) MAC_id – unique id of the Cluster Head, b) FLAG – a binary number to indicate that the cluster is getting broken. The Cluster Head broadcasts the Q_NODE message. Whenever a node receives a Q_NODE message it checks whether the MAC_id matches with the Cluster Head it belongs to. Thereafter, it takes appropriate action.

V. PROPOSED CLUSTER FORMATION AND HANDOFF PROCEDURE

Clustering creates a number of groups consisting of multiple nodes in a network. It is the responsibility of every cluster head to coordinate the activities in a cluster. The member nodes send packets directly to their respective cluster head. It is the responsibility of the CH to distribute the received packets to another member node. In case the destination node is not a member of the current cluster, the cluster head forwards the packets to the MAG that can deliver them to the destination cluster. Only the CHs and mobile access gateways participate in the propagation of the various packets and the update messages. The proposed work is divided into three phases they are – a) Cluster formation and cluster Restructuring, b) Selection of the cluster head, c) Intra-MAG-Cluster handoff and Inter-MAG-Cluster-handoff. The various symbols that have been used in the proposed scheme have been stated and described in Table 1.

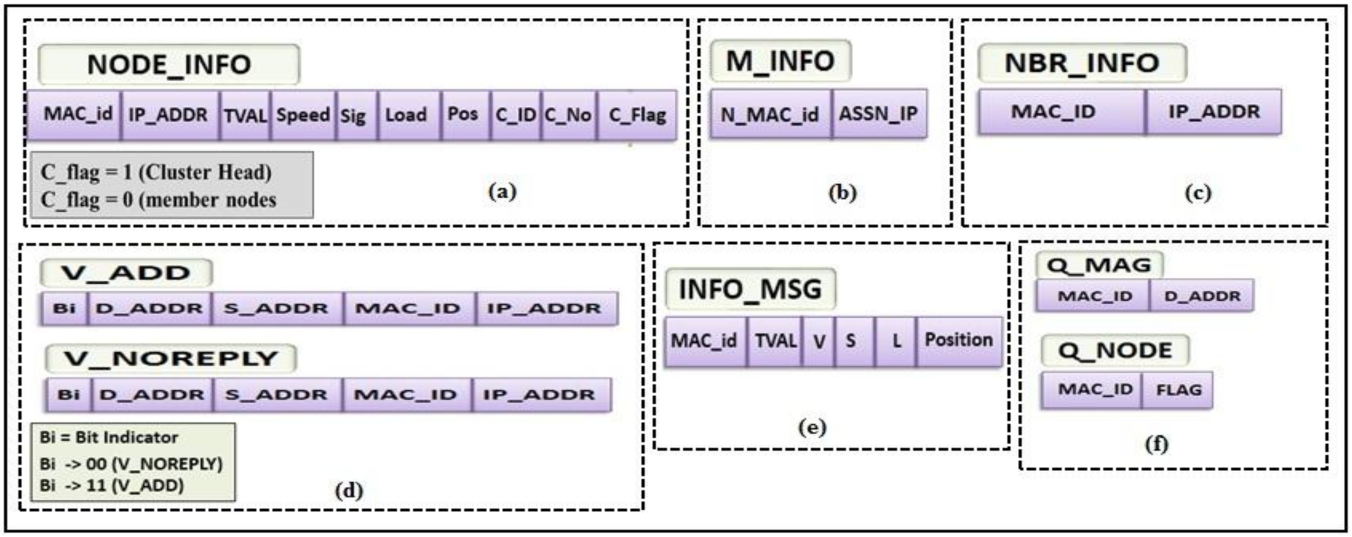


Figure 4. (a), (b) and (c) are the various tables and (d), (e), (f) are the various messages used during the clustering and handoff process

Table 1. Various symbols used in the scheme and their description

Symbol	Meaning
V_{d1}, V_{d2}	Sets of vehicles
H_{d1}, H_{d2}	Sets of vehicles to be chosen as centers
f_1, f_2, f_3, f_4	Weight calculation factors for cluster head selection
fit_i	Fitness value of the i^{th} vehicle in a cluster
T_{IP}	IP acquisition latency
T_{INFO}	Time required to send the INFO_MSG
T_{CF}	Time required for cluster formation
T_{CH}	Time required for cluster head choice
T_{ACC}	Time required to acquire IP address from the DHCP server
T_{DR}	Time required to distribute the IP among the member nodes
T_{HL}	Handoff latency
T_{CNCT}	Time required for the vehicle to connect with the cluster head
$T_{V_{ADD}}$	Time required to send the V_ADD message
T_{IPACC}	Time required for the vehicle to acquire an IP form the cluster head

A. Cluster formation

Classical Ant Colony Optimization

Ant Colony Optimization technique has been one of the popular optimization techniques among the mathematician and scientists. The algorithm has drawn its inspiration from the real ants. With the help of this algorithm it is possible to solve optimization problems that are combinatorial in nature. These are problems in which an attempt is made to find the optimal object from a set that consists of finite number of objects. In such problems it is not possible to perform an exhaustive search. Some of the well-known problems such as Vehicle routing, Travelling Salesman Problem, Network Model Problem and Scheduling have used this optimization technique. This optimization technique helps in discovering the shortest path between the source and destination. It does not implement the greedy approach and thus chances of getting stuck at the local maxima decreases. Ants are colonial insects. The Ant Colony Optimization (ACO) Problem draws its inspiration from the foraging behaviour showcased by the ants. Ants have natural ability using which they are able to find the shortest path between a food source and their nest. The ants follow random paths while searching for food. They deposit pheromone at the time of travelling through a path. The probability of a path getting followed increases with the increasing amount of pheromone being deposited. In case an ant discovers a food source it evaluates the quality and quantity of the food found. Thereafter, it carries back some of the food back to the nest. Based on the quality and quantity of the food, the ant deposits pheromone on the path while returning back. Other ants follow this trail to reach the food source. As the food source gets exhausted, pheromones are no longer deposited on the path. As a result, the pheromone slowly decays. The ant colony optimization technique is highly suitable for dynamic systems. Thus, it finds good application in VANET as the network topology changes at a very fast space. The algorithm is also suitable for multi-objective problem scenarios. VANET is such an environment. The classical ant colony optimization algorithm has been demonstrated in table 2.

Table 2. Classical Ant Colony Optimization Algorithm

Algorithm 1 : Classical Ant Colony Optimization
Start
Initialization of pheromone and other parameters
While (Stopping criteria is not met)
Each ant positioned at the start node
Repeat
For ant=1 to n (total number of ants is n)
Using the state transition rule the next node is chosen
During every step pheromone is updated

End For
Until solution for each ant has been built
Best solution is updated
Pheromone is updated offline
End While
Stop

Importance of Clustering

With the help of clustering it is possible to balance the load in the network. It also becomes easy to utilize the resources efficiently. The network can be also optimized and scalability can be ensured. The lifetime of the network can be increased significantly by dividing the network into a number of small logical groups.

The effectiveness of a clustering algorithm can be measured based on the stability of the cluster. With the help of clustering it is possible to simplify the process of routing and reuse the resources in an effective way. The members of the cluster also experience a stable network.

Decision parameters considered for cluster formation in VANET environment

- Distance between the cluster members and the cluster centroid (it is better if the distance is less)
- Speed of the centroid and cluster members (it is better if the speeds are similar)
- Direction of the centroid and cluster members (it is better if the nodes are moving in same direction)

The vehicles belonging to a network needs to be divided into clusters. A proper cluster formation mechanism is needed to identify various clusters within a coverage area of a WBS. The roads are assumed to have two lanes d1 and d2 respectively according to their direction. The vehicles under the transmission area of one single MAG is classified into two sets V_{d1} and V_{d2} consisting of vehicles belonging to lane d1 and d2 respectively. H_{d1} and H_{d2} consists of vehicles which forms the cluster centres, chosen from individual lanes using the proposed modified Ant Colony Optimization Algorithm such that set H_{d1} is a subset of V_{d1} and set H_{d2} is a subset of V_{d2}. Each vehicle from V_{d1} are then associated to a centre, which is a member of set H_{d1}.

Proposed Clustering Algorithm

Formation of optimal number of clusters is the main criteria for making a VANET stable. In a stable VANET the network resources can be utilized in an efficient manner. The number of clusters in the network can be optimized with the help of ACO due to its inherent evolutionary capability. In techniques that are based on ACO, a solution is known as ant. Group of such ants constitute a swarm. With the help of the proposed algorithm initially the centroid of a cluster is found out and then the neighbours of the centroid are found out. In this algorithm the real ant colony environment is represented in the form of graph.

The various components of a particular candidate solution are represented with the vertices of the graph. The edges of the graph are traversed by the ants. These ants create trails upon traversing. During the traversal the ants mark the various paths by releasing a chemical known as pheromone. The values of the artificial pheromone are related to the edges. Based on the quality of the trail these values are updated. The better the trail's quality, the greater is the pheromone concentration. The ants get attracted to such trails. A candidate solution for the problem is constructed by an artificial ant by adding solution components one after another. The movement of the ants is guided by the collaboration of the pheromone values and problem dependent heuristics. This is done before the complete candidate solution is built. With time the ants build their solutions one by one. Thereafter, they guide each other to find refined solutions. Those components that have greater pheromone concentration are considered to be better solution. These solutions appear again and again in the final solution. The ants converge to the optimal solution after sufficient number of iterations has been performed.

Search Space for the problem

It is necessary to define the search space for the proposed problem at the very beginning. In the present context the ants carry out the search in order to discover the candidate solutions. For the proposed clustering algorithm, the search space is a graph that is based on mesh topology. The mac_ids of the vehicles that make up the VANET are used to label the vertices of the graph. For example, if the VANET environment consists of 100 vehicles and clustering has to be performed then there will be 100 vertices in the search space. These vertices will be connected using mesh topology. There are two values associated with every edge that connect the vertices. They are heuristic value and pheromone value.

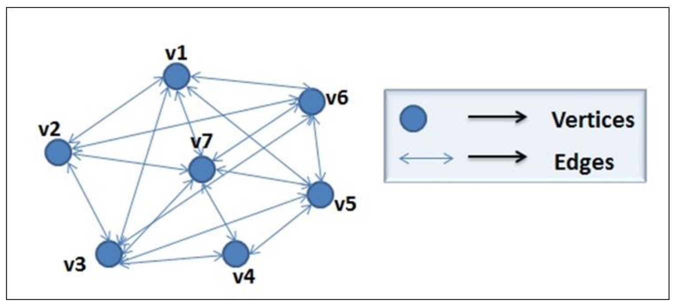


Figure 5. Search space for the proposed algorithm

Initialization of the Pheromone

At the very beginning low pheromone values are assigned to the edges of the search graph. Using equation (1) the initial pheromone is calculated. τ_{ij} is the pheromone initially assigned to the edge that connect two vertices i and j.

$$\tau_{ij}(at\ iteration\ 1) = \frac{1}{|v|} \quad (1)$$

Here, |v| denotes the total number of vehicles at that instant in the network.

Construction of the Solution

Every ant (in the present problem vehicle) builds its corresponding solution in each iteration of the for loop of the algorithm. In order to start the traversal of the graph an ant randomly selects a vertex from the search space that has been constructed. Considering the heuristic and pheromone values an ant selects and includes more vertices into the traversal as time progresses. Some constraints are also considered at the time of considering these values over the respective edges. The vertices that are traversed by an ant are the probable centroids to be considered for clustering. Thus, the traversal of a particular ant is made up of a number of centroids in a specific VANET environment. The selection of a vertex to be included in the traversal is subjected to following constraints:

a) A particular vertex can be only included in the traversal if it has not been already traversed. With the help of this constraint it can be ensured that a vehicle cannot be selected more than one time as a centroid during the traversal process. The vertices that constitute the traversal have unique labelling. These vertices represent the centroid vehicles.

b) In case one vertex in the transmission range of another vertex is already present in the traversal then the later cannot be included in the traversal. Once a centroid has been elected, all the vehicles that are within its transmission range becomes member of the particular cluster. With the help of this constraint it is possible to ensure that there is only one centroid in a cluster.

With the help of equation (2) it is possible to calculate the probability that a vertex will be added to the traversal being performed by a particular ant.

$$P_{ij} = \frac{Pher_{ij} X Heu_{ij}}{\sum_{k \in S} Pher_{ik} X Heu_{ik}} \qquad (2)$$

Here, i denotes the latest vertex that has been added to the traversal of the current ant.

j denotes the probable candidate vertex that might be selected by the ant next.

P_{ij} denotes the probability with which the edge connecting vertices i and j can be selected.

S denotes the set of all vertices that can be selected taking into consideration the constraints that have been already discussed in detail above.

The pheromone and heuristic values for the edge connecting vertices i and j are $Pher_{ij}$ and Heu_{ij} respectively. The probability of an edge getting selected is divided by the summation of all the selection probabilities of edges that are probable candidates for the traversal. The chance of an edge getting selected becomes better if its heuristic and pheromone values are higher. So that the problem of local optima does not occur, the edge is selected by the roulette wheel selection methodology [26]. This ensures that the edge is not selected in the greedy manner. As a result, the edge which has the lowest probability of getting selected still can be selected.

The current ant that is performing the traversal goes to a new vertex once it moves over an edge by selecting it. In other words, the selection of the next vertex to be included into the traversal of the current ant is done with the selection of the edge.

The traversal of the ant is finished when there are no more vertices left to be added to the traversal following the constraints mentioned above. The traversal lengths are variable. A traversal which results in the minimum number of clusters is preferable. Formation of minimum number of clusters results in lesser number of cluster heads. This will result in lesser handoffs as maximum number of vehicles will come inside a single cluster.

Evaluation of the Solution

Once an ant has completed its traversal, the solution or traversal thus obtained is evaluated. The clustering problem in VANET is multi-objective in nature. The function used to evaluate the traversal of an ant t is shown in equation (3)

$$tra_t = w_1(fac1) + w_2(fac2) \qquad (3)$$

Here, fac1 and fac2 are the two objective functions that have been used to evaluate the traversal of the t^{th} ant.

w_1 and w2 are the weights that have been assigned to the two objective functions. The value of the weights are equal, that is, 0.5. The two objective functions have been assigned equal weights. w1 and w2 sum up to 1.

fac1 represents the value of the delta difference for clusters associated with t. Delta difference calculates the difference between the degree of a cluster (ideal number of vehicles that can become the member of the cluster) and the number of vehicles that have actually become cluster member.

fac2 represents the sum of the distance of every cluster centroid from the members of their cluster.

Calculation of Delta Difference and Sum of Distance

To calculate the delta difference, which is denoted by d_{diff}, equation (4) has been used.

$$d_{diff} = \sum_{i=1}^{|c|} ABS(D - |n_i|) \qquad (4)$$

Here, D denotes the ideal degree for the clusters. The degree of a cluster is the number of vehicles that ideally become cluster member. This value is constant in nature. The network administrator assigns the value of D. This is done depending on whether the administrator wants dense clusters or not. For dense clusters the value of D will be higher.

|c| denotes the traversal length. In other words it is the total number of clusters obtained.

$|n_i|$ denotes the number of vehicles in the i^{th} cluster. This count does not include the centroid of the cluster.

The ABS function has been used to obtain the absolute value. If the value of d_{diff} is zero, then the clustering has been optimal because it satisfies the ideal degree requirements of the network administrator.

Secondly, the value of second objective function denoted by fac2 can be obtained by calculating the Euclidian Distance between the centroid of the clusters and the cluster members. With the help of equation (5) it is possible to calculate the distance between the centroid and member nodes of a particular cluster.

$$dist_{cent\_i} = \sum_{j=1}^{|n_i|} ED(cent_i, n_{ji}) \qquad (5)$$

Here, cent_i denotes the coordinate position of the centroid of the i^{th} cluster.

n_{ji} denotes the coordinate position of the j^{th} member if the i^{th} cluster.

$|n_i|$ is the total number of members in i^{th} cluster.

ED function returns the Euclidian distance between the centroid and member of the cluster.

Finally, the value of objective function fact2 can be obtained using equation (6):

$$fact2 = \sum_{i=1}^{|c|} dist_{cent\_i} \qquad (6)$$

Here, |c| is the length of the traversal, that is, the total number of clusters formed.

Similar to fact1, lower the value of fact2 it is better.

Calculation of the heuristic value

It is taken into consideration that an ant is currently situated at vertex labelled as i. It has to calculate the heuristic value associated with the edge that connects vertex i and j. Equation (3) can be used to calculate the heuristic value. The same equation can be used to evaluate the complete traversal and also find the heuristic values of incomplete traversals. Incomplete traversals are those situations in which vertices are still left to be added to the traversal. In such a situation, the vertex that met the constraints are added to the traversal one by one. They are also evaluated using equation (3). Based on the evaluation thus carried out, the vertices are assigned heuristic values.

Pheromone Updating in the Search Space

The pheromone values associated with the edges serve as guiding factor the ants during their traversal. The quality of the traversal performed by the ants is employed in order to determine the values of the pheromones in an efficient manner. The update of the pheromone values on the edges that make up the trail are carried out in proportion to the quality of the trail. The entire swarm carries out their traversal based on this. With the help of equation (7) the pheromone value associated with the edges is updated. The edges connect the vertices that constitute the trail of the ants.

$$\tau_{ij}(t+1) = (1-e)\tau_{ij}(t) + (1 - \frac{1}{1+tra_t}\tau_{ij}(t)) \qquad (7)$$

Here, τ_{ij}(t) is value of pheromone between i^{th} and j^{th} at t^{th} iteration of the outer while loop.

e represents the evaporation rate of the pheromone.

tra_t denotes the quality of the traversal performed by the n^{th} ant.

From the pheromone update equation, it can be observed that first a percentage of the previous pheromone is evaporated. Thereafter, based on the quality of the traversal quality of the n^{th} ant, a percentage of the pheromone is added. For every traversal carried out by all the ants in the swarm the pheromone update is carried out. Based on equation (3) if the traversal is found suitable with respect to the requirements of the clustering process, then greater percentage of pheromone is added compared to the percentage of pheromone evaporated. In such a situation the ants get more attracted to the vertices that make up the traversal in the forthcoming traversals.

The exploration is significantly improved during the introduction of evaporation. On the other hand, if a static heuristic function is used then ants tend to converge very quickly [27].

Stop Criteria of the algorithm

The algorithm stops executing if the total number of iterations as specified by the network user is completed. It will also stop executing if the number of stall iterations reaches its maximum count. In the proposed algorithm iteration is designated as stall iteration in case there is no improvement in the current traversal compared to the previous traversal that has been performed in the outermost while loop. Once the algorithm stops, the best traversal carried out so far is used to cluster the vehicles in VANET.

The detailed cluster formation algorithm has been shown in table 3. The algorithm depicts the cluster formation for a single lane. Similarly, the algorithm executes for the other lane also.

Table 3. Cluster Formation Algorithm

Algorithm 2: Cluster Formation
Input Consideration $V_{d1} = \{v_{11}, v_{12}, v_{13} \dots v_{1n}\}$ be the sets of vehicles. Output consideration $H_{d1} = \{h_{11}, h_{12}, h_{13} \dots h_{1k}\}$ be the sets of vehicles to be chosen as cluster centers from set V_{d1} Here swarm size is number of vehicles in set v_{d1}

Step 1: A mesh topology is created among the vertices or nodes. A vehicle ID is represented by every vertex.
Step 2: Equivalent pheromone values are assigned to every edge of the mesh topology formed above.
Step 3: The distances of each vehicle from one another is calculated. These values are normalized and associated with respective edges of the mesh topology.
Step 4: /*Traversal*/
while (iterations = as defined by the network administrator OR stall iterations =15)
for v_{1i}=1 to swarm size
v_{1i}.traversal=empty
v_{1i}. cost=infinity
nodes or vertices remaining for clustering = all vertices
while(there are nodes left for clustering)
end while
v_{1i}.cost<Best v.cost


```
        Best v= v1i
        v1i++
   end for
Step 5: /*Pheromone Update*/
for v1i=1 to swarm size
    pheromone update (v1i.traversal, v1i.cost)
    evaporate
    if (Best v.cost==last Best v.cost)
     stall iteration++
   else
     stall iteration=0
  endif
iteration ++
end while
```

Output: H_{d1}=Best v_{1i}.traversal

B. Cluster head selection

To generate efficient clusters proper cluster head selection is required. This is because the member nodes communicate with the MAGs through the cluster heads. The cluster head selection is done based on the following mobility parameters.

Trust Value - The trust value of a vehicle is an important parameter for cluster head selection. The vehicle having higher trust value ensures better connectivity with other members of the cluster. Each vehicle calculates its trust value with all other vehicles. This makes a vehicle an eligible candidate for cluster head selection. Trust value is calculated to find out the level of confidence a vehicle designated as vi has on a neighbouring vehicle designated as vj. The level of confidence is dependent on how the assigned tasks have been performed. To evaluate the trust, two things can be taken into consideration, the transaction history with the concerned node and recommendations obtained from the neighbour nodes [reference]. Each vehicle has to keep a record of the behaviour of their neighbouring vehicles in order to evaluate the trust. The record is made up of a number of different parameters known as trust metrics. The trust metrics along with their trust value for various successful transactions are stored in data records.

At the very beginning when a vehicle v enters a VANET, the vehicle is assumed to be a trustworthy one. An initial trust value is assigned to every vehicle as soon as it enters the network. For example, the initial trust value has been assumed to be 0.5 in this case. The trust value of the vehicle will vary with time as more and more transactions are performed with time. For every transaction successfully taking place between vi and vj, there will be an increase in the trust metric value of the corresponding vehicle. The value can go up to maximum 1. In the opposite situation the value of the trust metric will decrease till -1. The various trust metrics that have been considered are Control Packet/Message Precession, Data Packet/Message Precession, Traffic Rule Obey, Control Packet Forwarded and Data Packets Forwarded.

It is possible to calculate the Direct Trust (DT) on vehicles using the record containing trust data metrics of the various neighbouring vehicles [reference]. The process of calculating Direct Trust of node X on node Y has been shown in equation (8).

$$DT_X(Y) = [\prod_\alpha (m_\alpha)]^{\frac{1}{\alpha}}] \quad (8)$$

Here, the direct trust of node X on Y is denoted by $DT_X(Y)$.

m_α represents the set of ‘α’ different trust metrics.

Once vehicle X has calculated the direct trust on Y it reports the value to the MAG.

There are also situations in a VANET when the node X will again meet Y. In such a case X uses the past direct trust to calculate its present direct trust on Y.

The historical trust is an important factor because a node might not behave in the way it behaved in the past. In case the node was a malicious node in the past and at present it behaves in a trustworthy manner, the current trust value can be calculated in a much precise manner taking the historical reputation of the vehicle into consideration.

The historical trust for ‘kth’ interaction can be calculated using equation (9)

$$HT_X(Y)_k = HT_X Y_{k-1} + \frac{DT_X(Y)_k - DT_X(Y)_{k-1}}{|DT_X(Y)_k + DT_X(Y)_{k-1}|} * \omega \quad (9)$$

While calculating the historical trust the difference between the trust for ‘kth’ and ‘k-1th’ interaction has been calculated in order to evaluate the increase or decrease in trust value during two consecutive interactions.

Here, ω is a coefficient whose value is equal to the total trust value of vehicle Y.

Again, for ‘k’ number of interactions we can calculate the average historical trust value using equation (10)

$$\overline{HT_X(Y)} = \frac{1}{k-1} \sum_{k=1}^{k=m} HT_X(Y) \quad (10)$$

Upon calculation of the historical trust vehicle X reports the trust value to the MAG. The MAG stores it for the final trust value calculation.

Lastly, the indirect trust of a node on another node is taken into consideration. In this case three nodes X, Y and Z are taken into consideration. In this situation, node X and Y have already interacted with each other. However, X and Z have never interacted with each other earlier. An attempt has been made to calculate the indirect trust of X on Z based on the recommendations of Y. It has been assumed that X trusts the recommendations that Y makes. In other words, it can be said that X believes that Y make correct recommendations all the time.

The recommendation value from Y to X about Z is denoted by RecX(Y). X obtains the recommendation trust whenever it requires. This is done by sending multicast messages to a selected set of nodes that can provide recommendation value about the target node. The multicast request can be sent using a recommendation value requisition message to the selected set of vehicles. The information about the vehicle about which the recommended trust is to be obtained is sent along with the message. The recommendation trust of X on Z can be calculated using equation (11)

$$\mathrm{REC}_{X(Y)}(Z) = \frac{\mathrm{Rec}_X(Y) * \mathrm{DT}_Y(Z)}{\gamma} \quad (11)$$

Here, γ is the maximum trust state between X and Y.

$\mathrm{REC}_{X(Y)}(Z)$ means the indirect trust of X on Z based on the recommendation of Y.

After calculating the recommended trust from every member of the multicast group from which X has requested recommendation value for Z, the mean recommendation trust of X on Z can be calculated using the formula in equation (12)

$$\overline{\mathrm{REC}_X(Z)} = \sum_{t=1}^{n} \mathrm{REC}_{X(t)}(Z) \quad (12)$$

After the X has calculated the indirect trust of Y, it reports the value to the MAG. the MAG stores this value for final trust value calculation.

Vehicle X on calculating the direct, historical and indirect trust value of Y reports the value to the MAG. The MAG maintains three matrices to store the trust values. The first stores the direct trust of every node and is denoted by MATDT. The second matrix stores the historical trust value of X on Y and is denoted by MATHT. The third matrix stores the indirect trust value X on Y and is denoted by MATIT. The matrices are nxn matrices, where n is the number of vehicles under the coverage area of the MAG. If i=j, where i and j denotes vehicles, the trust value in both the cases is 1.

Structure of MATDT, MATHT and MATIT matrices has been given below:

ith column stores all the trust values associated with the ith node.

Vehicle	V1	V2	V3	V4	Vn
V1	1				
V2		1			
V3			1		
V4				1	
Vn					1

Finally, the total trust on a particular vehicle by the neighbouring vehicles by considering Direct Trust, historical trust and indirect trust is calculated. This trust value calculation is done at the MAG. The total trust on a vehicle 'Vtar' can be calculated using the equation (13)

$$\mathrm{TVAL}_{V_{tar}} = \tanh\left(\sum_{j=1}^{n}\left(\mathrm{DT}_{V_j}(V_{tar}) + \overline{\mathrm{HT}_{V_j}(V_{tar})} + \overline{\mathrm{REC}_{V_j}(V_{tar})}\right)\right) \quad (13)$$

Here, the total trust on a particular vehicle 'Vtar' has been denoted by $\mathrm{TVAL}_{V_{tar}}$.

The Direct Trust of the neighbouring vehicles V1, V2, V3,…, Vn on Vtar is represented by $\mathrm{DT}_{V_j}(V_{tar})$.

After every predefined time 't' the MAG sends the updated trust value of a vehicle to it.

Table 4. Trust Value Calculation

Algorithm 3 : Trust value calculation Algorithm
Input Consideration: $\mathbf{m_\alpha}$= set of 'α' different trust metrics k = interaction count **γ** is the maximum trust state between X and Y

if node X and node Z are directly connected then
compute DTX(Z) and update MATDT
compute HTX(Z) and update MATHT
else if node X and node Z are not directly connected
node X requests recommendation about Z from trusted node Y
computes RECX(Y)(Z) and update MATIT
end if
MAG computes $\mathbf{TVAL_{V_{tar}}}$
After every 't' time MAG sends updated $\mathbf{TVAL_{V_{tar}}}$ to Vtar

Output : $\mathbf{TVAL_{V_{tar}}}$

- Speed of the node (V) – Mean speed of the vehicles belonging to a particular cluster is calculated denoted by Vmean. The speed of every vehicle is compared with Vmean and the vehicles having speed closest to this mean speed becomes a probable candidate to be elected as the cluster head.
- Signal strength received from the MAG(S) – The received signal strength must be high for a cluster head. As it is responsible for cluster management and act as a communication medium between member nodes and MAG.
- Load on the resources (L) – The load on the computing resources such as CPU and memory of the candidate node must be taken into consideration. The one having the lowest load is the most probable candidate for becoming the cluster head.

Each parameter is assigned a weight which are adjusted based on various conditions for selecting the cluster head. Four weight calculation factors are f1, f2, f3 and f4 are used. They are varied depending on the amount of traffic on the road and the time of the day. In the proposed scheme the whole day is divided into two sessions, viz., day time and night time. Three scenarios during both the sessions, viz., High Traffic Scenario, Medium Traffic and Low Traffic Scenario are considered. The high, mid and low traffic scenario are determined by the number of vehicles in a MAG.

During the day time (0900 hrs to 2100 hrs), if the average density of vehicles in the transmission area of an MAG, is more than 1050 per km, then it is considered to be a high traffic scenario. On the other hand, if the number of vehicles is in between 650 per km and 1050 per km then it is considered to be a medium traffic scenario. If the number of vehicles is below 650 per km then it is considered to be a low traffic scenario. The night time scenarios are considered between 2100 hrs to 0900 hrs. The boundary value estimation of the number of vehicles is done based on a report on Kolkata traffic in 2011 [24] which states that the average vehicle density of Kolkata is 823 per kilometres. Table 3 shows the weight factors based on time of the day and traffic. The weights used are normalized weights that sum up to 1 as shown in equation (6) where f_jis the j^{th} weight factor.

$$\sum_{j=1}^{4} f_j = 1 \quad (14)$$

Justification of assignment of values to various factors

During the start of each new day the trust worthiness of every vehicle will not be a determining factor as vehicles just start interacting with each other. While, at night the vehicles have already interacted a lot throughout the day. As a result, higher value is assigned to this factor at night compared to day time.

In high traffic most of the vehicles will be moving slowly. Thus, the speed factor is not that important during such situations. The factor has been assigned increasing weight as the traffic becomes less dense.

Signal strength received by a vehicle from the MAG is an important factor during dense traffic. Vehicles receiving better signal have increasing chance of becoming cluster head. So, this factor has been given greater importance during high traffic. The value has been decreased as the traffic has become rare.

During high traffic load is much greater on the computing resources of the vehicles. It is also higher during day compared to night time. Due to this reason greater emphasis has been given on this factor during day. Additionally, it has been varied according to traffic density during day time. With increase in traffic greater emphasis is given on the load on computing resources.

Table 5.Weight calculation factor determination based on scenario

Factors	Day (if time>=0900 hrs&& time<=2100 hrs)			Night (if time>2100 hrs&& time<0900)		
	High Traffic (if d_vehicles>1050)	Medium Traffic (if d_vehicles<=1050 &&d_vehicles>=650)	Low Traffic (if d_vehicles<650)	High Traffic (if d_vehicles>1050)	Medium Traffic (if d_vehicles<=1050&&d_vehicles>=650)	Low Traffic (if d_vehicles<650)
f_1	0.3	0.3	0.3	0.4	0.4	0.4
f_2	0.2	0.25	0.3	0.2	0.25	0.3
f_3	0.3	0.2	0.1	0.2	0.15	0.1
f_4	0.2	0.25	0.3	0.2	0.2	0.2

The vehicular node in a network sends an INFO_MSG packet as referred in Figure 4(e) at regular interval to a MAG to inform about its presence. This packet contains the following fields- a) MAC_ID, b) TVAL, c) Speed (V), d) Signal strength (S), e) Load (L) and f) position obtained using GPS. On getting the information the respective mobile access gateway needs to store the received information in theNODE_INFO table.The value of C_ID,C_No, C_flag and IP_ADDR fields of NODE_INFO are initially empty. The fitness for every vehicle in a cluster is calculated using equation (15) where fit_i denotes the fitness of the i^{th} vehicle in a cluster and f1, f2, f3 and f4 are the weight calculation factors

$$fit_i = TVAL * f_1 + \frac{1}{|V_{mean} - V|} * f_2 + S * f_3 + \frac{1}{L} * f_4 \quad (15)$$

The cluster head selection and member node registration procedure is illustrated in Table 6. The algorithm is executed in two scenarios. Firstly, after a predefined time period to find better candidate to be elected as Cluster head. Secondly, if the nodes belonging to particular region fail to connect to any Cluster head for a defined time period, the nodes send an INFO_MSG packet to the nearby MAG. The MAG checks whether it has received multiple INFO_MSG packet from the same region. If there are multiple INFO_MSG packets the MAG triggers the cluster formation and cluster head selection one after the other. Else it declares the node as Cluster head if there is only one node. Each cluster head maintains a M_INFO table to keep track of the cluster members under it.

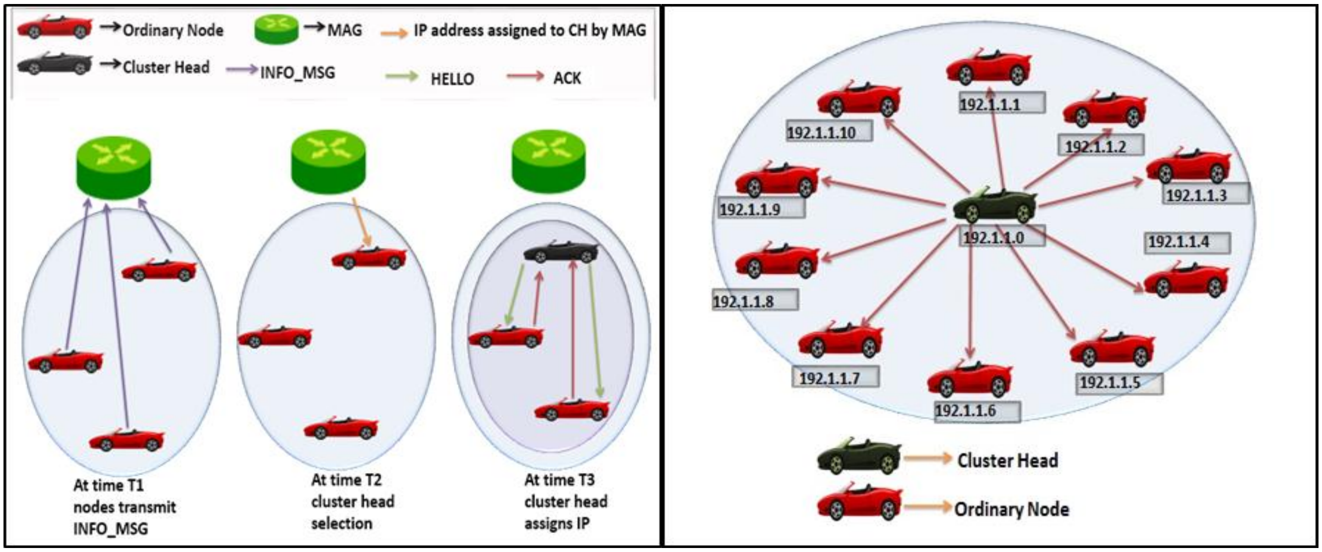


Figure 6(a). Cluster Head Selection, (b). IP address assignment

Table 6: Algorithm for cluster head selection

Algorithm 4 : Cluster head selection
Step1. Every node transmits an INFO_MSG packet containing its MAC id along with TVAL, V, S, L and its position obtained using GPS to the MAG after a regular time interval t. The MAG updates the NODE_INFO table with information received via the INFO_MSG packet.
*Step2.*MAGs on receiving the INFO_MSG from all the vehicles triggers the cluster formation algorithm mentioned in Table 1. The cluster formation algorithm forms the particular clusters and fills the C_NO field with the respective cluster numbers for each vehicle.
*Step3.*The vehicles are grouped according to their C_NO and the fitness (fit)for each vehicle entryin its respective cluster is calculated using equation (5).
*Step4.*The vehicle with the maximum fit is chosen as the cluster head. The C_flag entry for the corresponding node chosen as cluster head is set to 1.Also the C_ID field of all the vehicles falling under the same cluster in NODE_INFO is set with the MAC address of the Cluster head.
Step5. The MAG assigns IP address to the node that has been selected as the cluster head and notifies it that it has been selected as the cluster head. For example: 192.1.1.0 is the IP of the CH in Figure 6(b). The IP address for the cluster head contains only the MAG_ID and the CH_ID. The O_ID field of the address is kept all 0's waiting to be assigned to ordinary vehicles under the cluster head.
Step6. On getting the IP address the CH starts broadcasting HELLO messages which contains its MAC address. After getting the id of the cluster head, each node sends ACK message to the cluster head to register as a member of the cluster. The ACK message contains MAC_ID of the node.
Step7: Once the CH receives ACK message from a particular node, it assigns a unique IP address to the node which is a subnet of its own IP address, as shown in Figure 6(b) and updates the M_INFO table thus registering the node in the cluster.
Step 8: The Cluster head also sends a V_ADD message to the MAG to notify it that a new node has joined it. The MAG after receiving the V_ADD message updates the IP_ADDR field of the Node_Info table.

C. Proposed Handoff model

Managing handoff is one of the most important issues that must be addressed in VANET. This is due to the fact that nodes in VANET are vehicles that move at a very high speed. Thus, there is frequent change of cluster head and MAG. To carry out handoff and reduce packet loss during the process, the concept of proactive caching is used in CBVH. In proactive caching the packets intended for the victim vehicle are stored in the MAG during the handoff process of the vehicle. This reduces the packet loss during the handoff process. Once the vehicle gets attached to some Cluster head (CH) or enters the area of a new MAG the information is deleted.

In the proposed scheme the handoff is considered in two different scenarios.

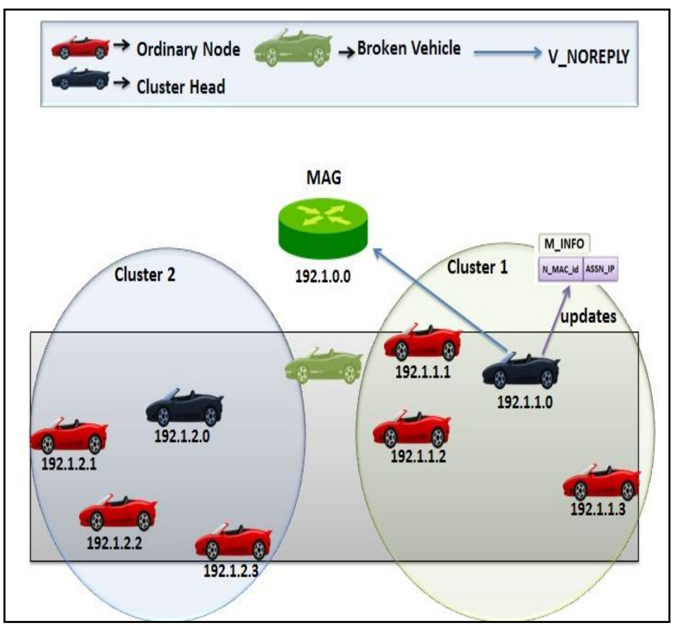
- Vehicles performing handoff in between different cluster heads belonging to the same MAG (Intra-MAG handoff).
- Vehicles performing handoff between two different MAGs (Inter-MAG handoff).

Event 1 : Member nodesmove from one cluster to other within the same MAG

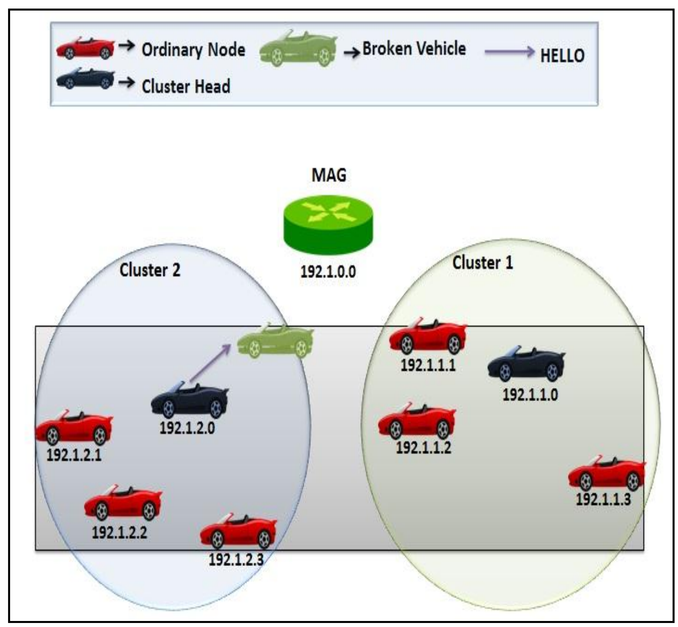
The cluster heads and the member nodes keep on exchanging HELLO and ACK messages at regular time intervals. Whenever a cluster head doesn't receive ACK message from a particular member of the cluster it understands that the particular node has left the cluster. Similarly, when a particular node does not receive the HELLO message for a prolonged time period it apprehends that it has detached from the previous CH and requires to get attached to a new cluster head. So, it waits for a HELLO message from some new CH. On detecting that a particular node has left the cluster the CH sends a V_NOREPLY message to the MAG containing the MAC_ID and IP_ADDR of the node. The payload of both V_NOREPLY and V_ADD message discussed in algorithm 2 are the same. So, there must be some bit indicator to differentiate between the two. Figure 4 (d) shows the structure of both V_NOREPLY and V_ADD message with a two-bit Bit indicator. 00 signifies V_NOREPLY and 11 denotes V_ADD message. On receiving the V_NOREPLY message the MAG proactively caches the packets meant for the detached node until the it gets attached to another cluster head. The process of Inter cluster handoff is shown in Table 7. Figure 7 (a-f) shows the various stages of intra-MAG handoff and Figure 8 shows the timing diagram.

Table 7. Algorithm for Intra-MAG Handoff

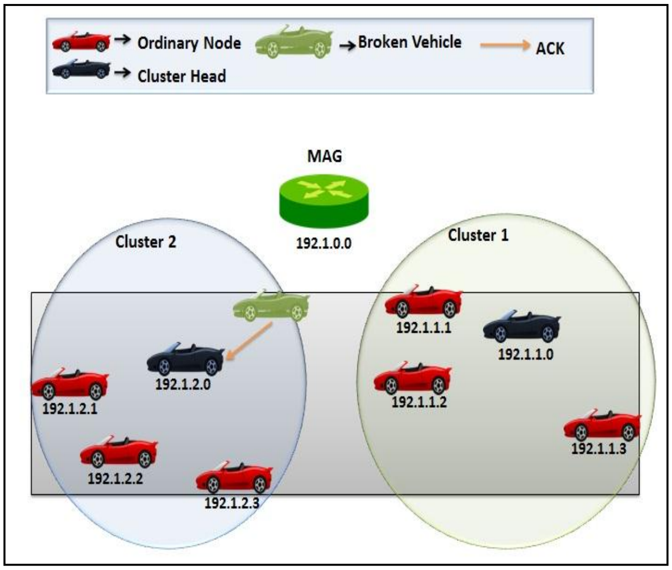
Algorithm 5 : Member nodes move from one cluster to other within the same MAG
Step 1. The CH on not receiving HELLO message from a node send the V_NOREPLY message to the MAG. On receiving the V_NOREPLY message the MAG updates the NODE_INFO table by clearing the values stored in IP_ADDR, C_ID, C_NO associated with the particular node. The MAG also proactively caches the data packets meant for the node till it joins some other CH. *Step2.* The previous CH then deletes the entry of the particular node from its M_INFO table. *Step3.* Once the node enters a new cluster, it receives the HELLO message that the CH of that cluster is broadcasting. On receiving the HELLO message the node replies with the ACK message. Once the CH receives the ACK message it associates the node with the cluster, updates its M_INFO table with the information of the new node, assigns it an IP address and sends a V_ADD message containing the MAC_ID and IP address (IP_ADDR) of the vehicle. *Step4.* The MAG on receiving the V_ADD message updates the C_ID and C_No field of the NODE_INFO table with the corresponding information of the cluster head to which the node has attached. *Step5.* The MAG sends the cached packets intended for the node to the CH to which the node has attached. The CH then delivers the packets to the particular node.



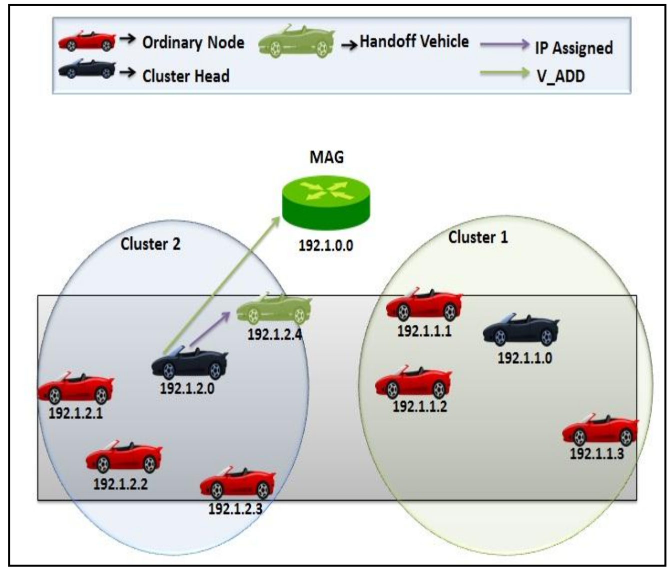
(a) Current CH sends V_NOREPLY to MAG and updates M_INFO



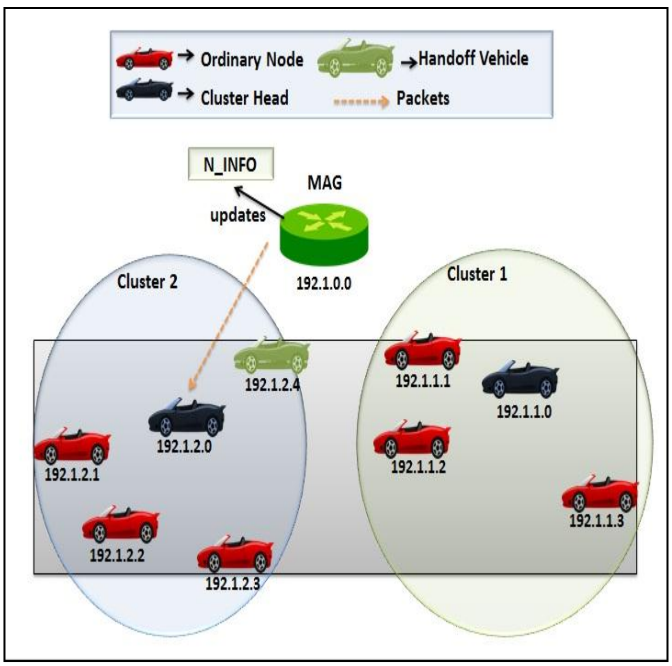
(b) Broken Vehicle receives HELLO from new CH



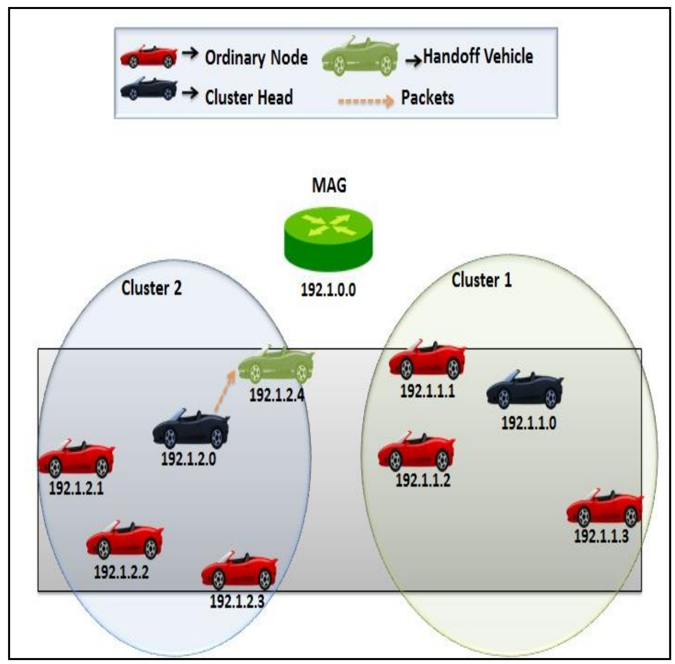
(c) Broken vehicle sends ACK to new CH



(d) New CH assigns IP to handoff vehicle and sends V_ADD to MAG



(e) MAG updates N_INFO and sends packets of the vehicle to CH



(f) CH forwards the packets to the vehicle

Figure 7. Intra MAG handoff of the proposed scheme

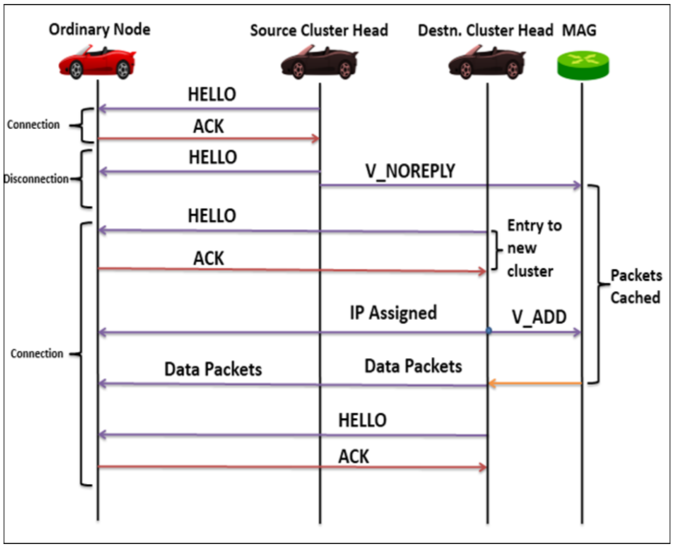


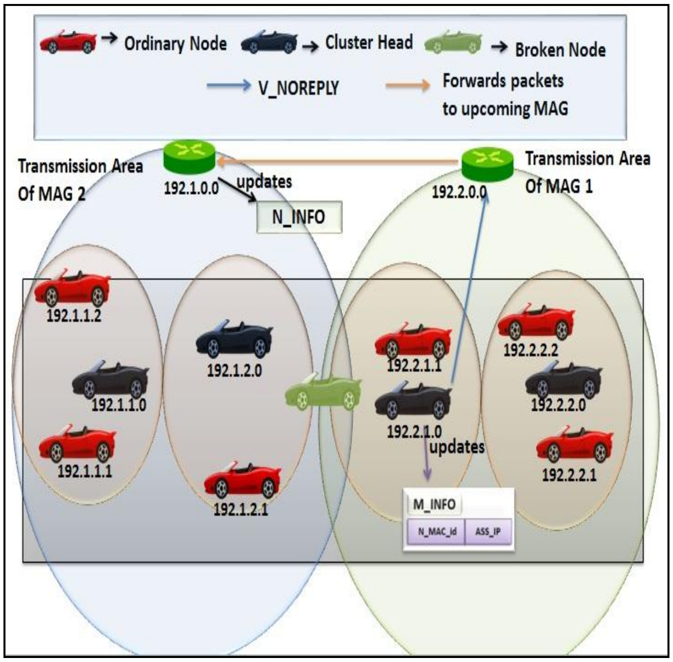
Figure 8. Timing Diagram for the Intra-MAG Handoff of the proposed scheme

Event 2 : Member nodes move from one cluster to other belonging to different MAG

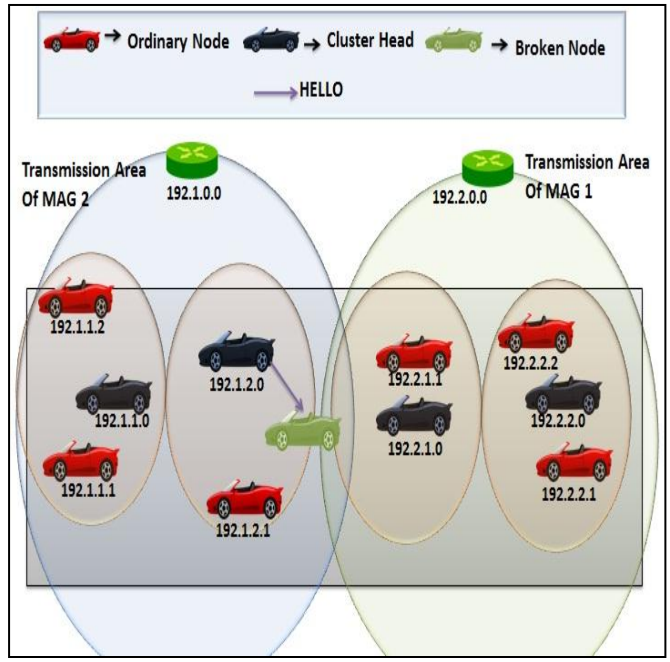
Every MAG maintains a table that contains the information about the neighbouring MAGs. This table is denoted by NBR_INFO as shown in Figure 4 (c). A node belonging to the clusters near the boundary of a MAG has to perform Inter MAG handoff. The CH and nodes keep on exchanging HELLO and ACK messages continuously. Whenever a CH does not receive the ACK against a HELLO from a particular node within a predefined time period it understands that the node has left its transmission area. Similarly, when a node does not receive the HELLO message from a CH for a particular time period it understands that it has detached from the particular cluster and need to associate itself with another cluster thus performing Inter-MAG handoff. Table 8 shows the entire Inter- MAG handoff process. Figure 9 (a-f) shows the various stages of Inter MAG handoff and Figure 10 shows the timing diagram of the proposed Inter MAG handoff.

Table 8. Algorithm for Inter-MAG Handoff

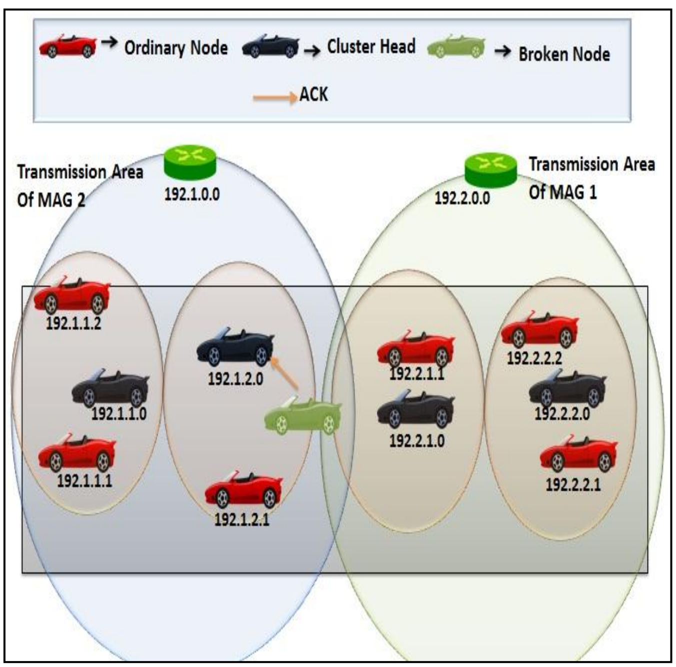
Algorithm 6 : Member nodes move from one cluster to other belonging to different MAG
Step1. The CH sends V_NOREPLY message to its MAG and deletes the entry of the node from its M_INFO table. *Step2*. On receiving the V_NOREPLY message the MAG caches the packets meant for the particular node for a given time period. The MAG waits for the node to get attached to some CH belonging to its own transmission area. It waits for a V_ADD message having the MAC address of the detached vehicle during this time span. *Step3*. In case the source MAG does not receive any V_ADD message from any CH belonging to its transmission area it understands that the node has left its transmission area. Based on the NBR_INFO table and the last updated position of the car the current MAG transmits the MAC_ID and packets of the particular node to a neighbouring MAGs. The neighbouring MAGs that receive the packets intended for the victim node will proactively cache them. The previous MAG also deletes the entry of the victim node from its NODE_INFO table. *Step4*. The vehicle that has detached from the source MAG waits for HELLO message from the CH of the new cluster. Once the node receives the HELLO message broadcasted by the CH, it responds with the ACK message. *Step5*. The CH assigns IP address to the vehicle and updates its M_INFO table. The CH also sends a V_ADD message to the MAG notifying about the association of the particular node to it. *Step6*. On getting the V_ADD message the target MAG adds the vehicle to its NODE_INFO table along with the C_NO and C_ID field in the NODE_INFO with that of the cluster head which sent the V_ADD message. It also transmits the cached packets of the node to the CH to which the node has got attached. The CH then forwards the packets to the node. *Step7*. The handoff process is complete. The other neighbouring MAGs that have proactively cached the packets of the nodes wait for a certain time interval. The packets are dropped if they don't receive any V_ADD message.



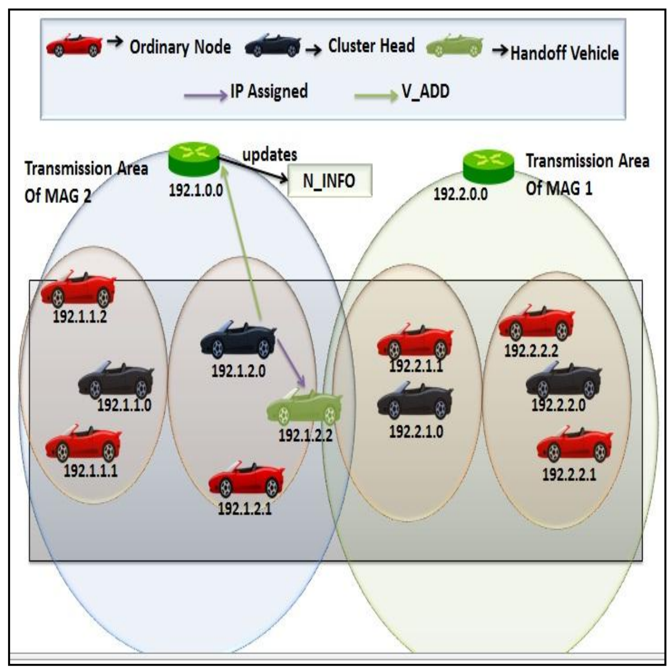
(a) CH sends V_NOREPLY, updates M_INFO. Current MAG sends data packets to neighbouring MAGs



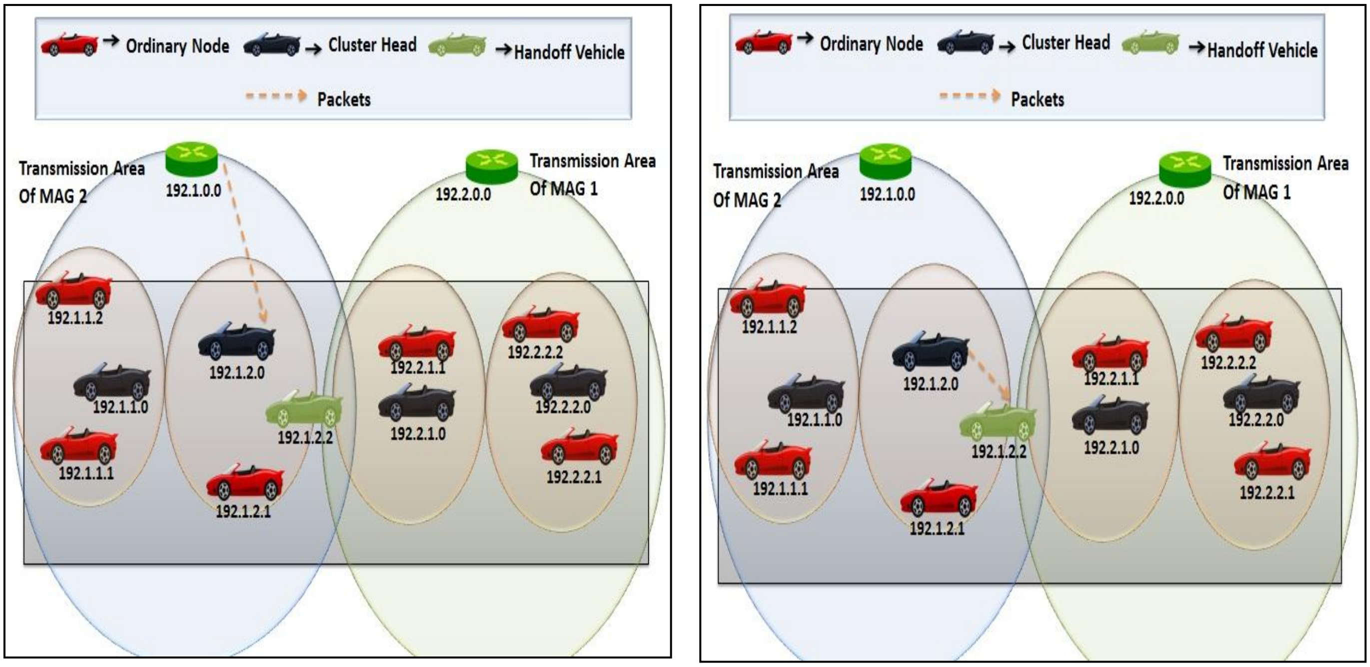
(b) Broken vehicle gets HELLO packets from new CH



(c) Broken vehicle sends ACK to new CH



(d) New CH assigns IP to handoff vehicle and sends V_ADD message to MAG



(e) MAG sends the packet of the handoff vehicle to the CH

(f) CH delivers the received packets to the handoff vehicle

Figure 9. Inter MAG handoff

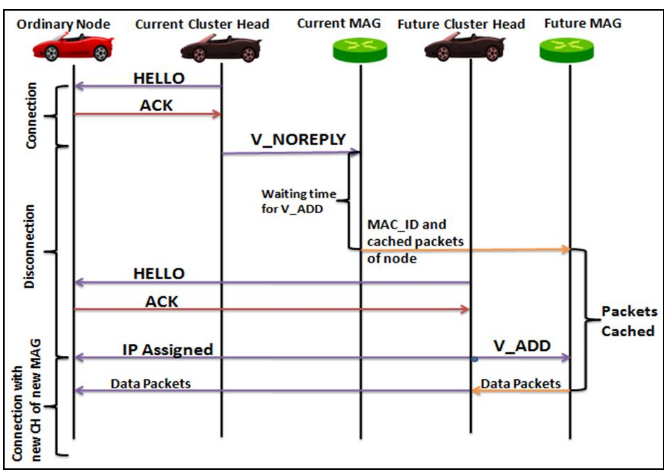


Figure 10. Timing diagram of the Inter-MAG Handoff process

Event 3 : Cluster Heads move from one MAG to other

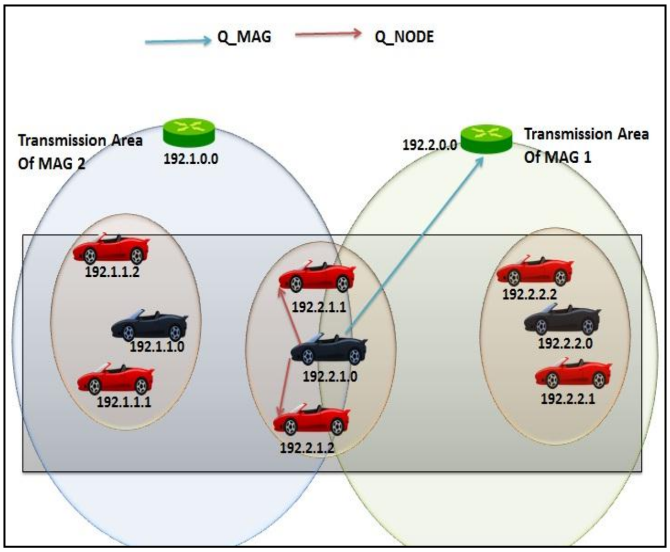
When a Cluster head leaves the transmission range of a MAG and enters the transmission range of another MAG, handoff need to be performed and cluster reformation is required. The CH understands that it is going to enter the transmission area of another MAG when the signal strength received by it goes down below a certain threshold value. Table 9 shows the cluster head handoff procedure. Figure 11 (a-f) shows the stages of handoff and Figure 12show the timing diagram of cluster head handoff.

Table 9. Algorithm for Cluster Reformation

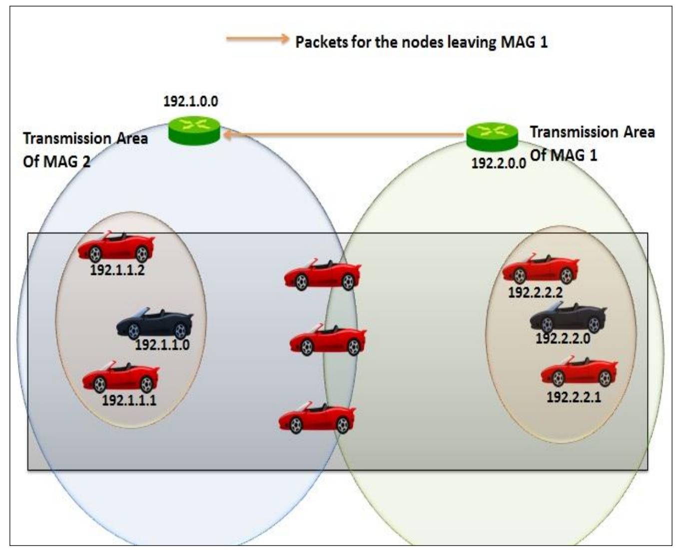
Algorithm 7 : Cluster reformation
Step1. The CH sends Q_MAG message to the current MAG to inform the MAG that it is leaving its coverage area. The Q_MAG message contains the MAC_ID of the CH. The CH also sends Q_NODE message (containing flag value in binary) to the ordinary member nodes notifying that the cluster is breaking. The structure of both Q_MAG and Q_NODE message is given in Figure 4(f). *Step2.* As soon as the MAG receives the Q_MAG message it stops transmitting the data packets intended for the CH and all its members. It forwards the packets intended for the cluster heads and all its members to the neighbouring MAGs using the information in the NBR_INFO table. The probable future MAGs proactively caches the packets of all the nodes along with their MAC addresses that might enter their transmission area. The current MAG also deletes the entry of the victim nodes from its NODE_INFO table. *Step3.* Once the ordinary nodes receive the Q_NODE message it breaks the cluster. The vehicles then re-transmit the INFO_MSG. *Step4.* The target MAG on receiving the INFO_MSG triggers the cluster formation and head selection algorithm. Once the new clusters are formed and CH for every cluster is selected the IP_ADDR, C_ID, C_NO and C_Flag fields corresponding to every MAC_ID is updated. Also the packets meant for each vehicle are forwarded to them preventing any packet loss through their respective cluster

heads.

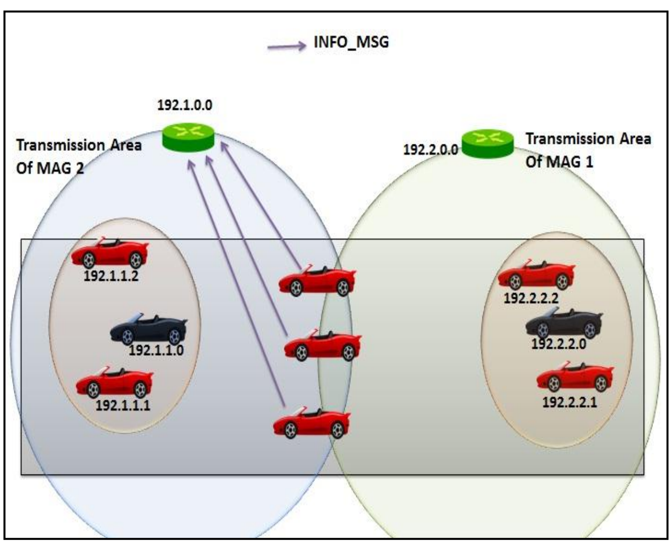
Step5. The other neighbouring MAGs that have proactively cached the packets of the nodes wait for a certain time interval. The packets are dropped if they don't receive any INFO_MSG.



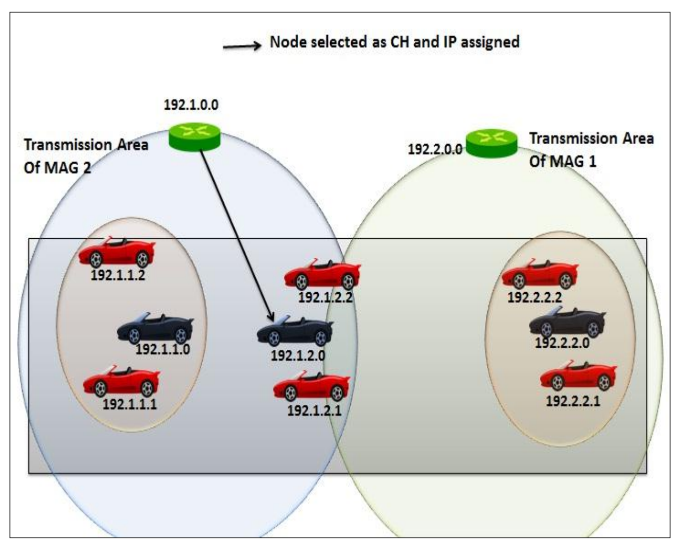
(a) CH sends Q_MAG message to current MAG and Q_NODE message to member nodes



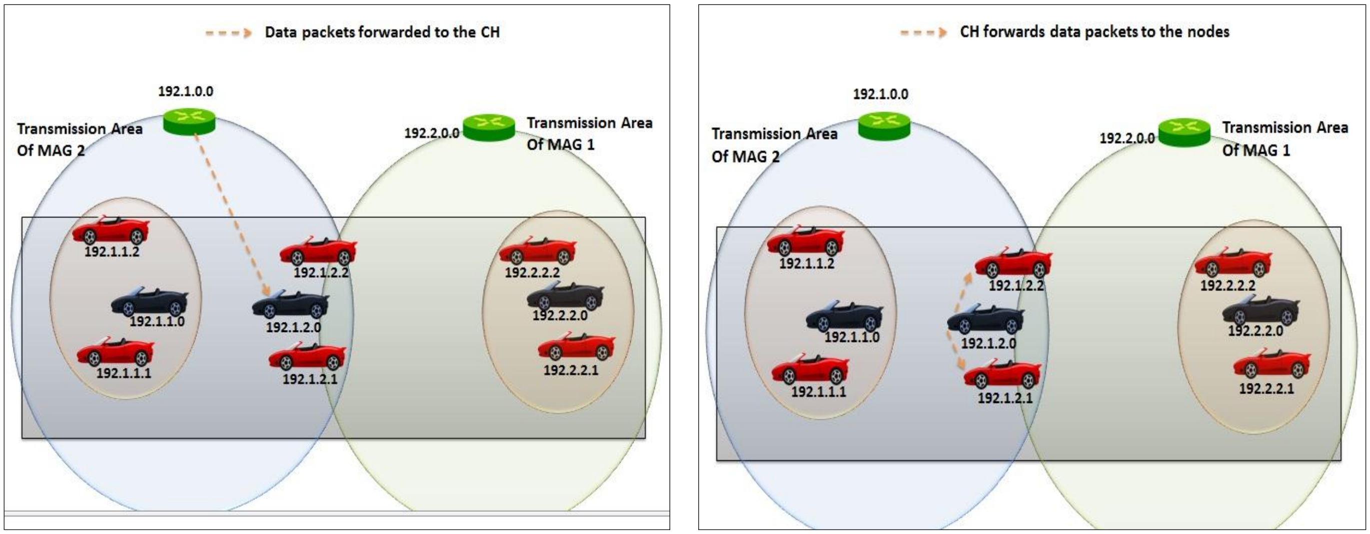
(b) Packets of the nodes are forwarded to neighbouring nodes



(c) Once the cluster is broken nodes send INFO_MSG to new MAG



(d) New CH is selected and IP assigned to the nodes



(e) New MAG forwards data packets for intended nodes to CH

(f) CH forwards the packets to the nodes in its cluster

Figure 11. Cluster head handoff

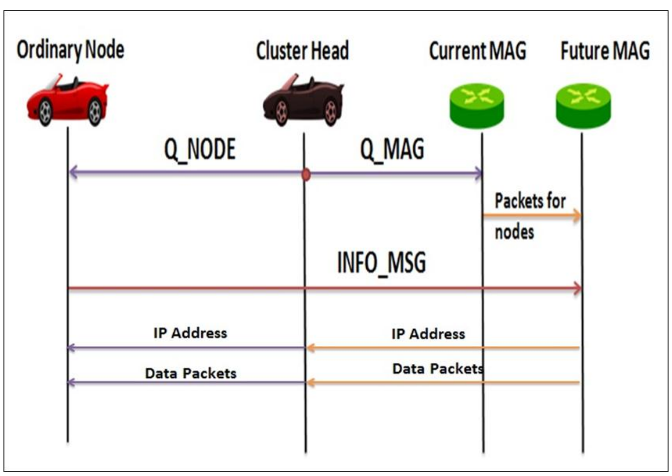


Figure 12. Timing diagram of Cluster head handoff

VI. LATENCY AND POWER CONSUMPTION OF THE PROPOSED HANDOFF MODEL

Latency for the proposed handoff model

Latency is an important parameter for any handoff model. It determines the time taken for a vehicular node to get associated with one MAG to the other. In this proposed cluster based handoff techniques two types of latency are evaluated. During the initial stage the network is forming a number of clusters and each member in the cluster is assigned an IP address. The time required to acquire IP addresses by vehicles is referred to as IP acquisition latency. The second type of latency incurred in the network is the time required to complete the handoff procedure referred to as Handoff latency.

A. IP acquisition latency

The vehicular nodes need to acquire IP every time it enters a network. The IP acquisition latency can be calculated using equation (6) where T_{IP} gives the IP acquisition latency for each member nodes. T_{INFO} is the time taken to transmit INFO_MSG. T_{CF} and T_{CH} is the time taken for carrying out cluster formation and cluster head selection procedure. T_{ACC} stands for the time taken by the cluster head to acquire IP from the DHCP server, while T_{DR} represents the time taken for distributing the IP addresses to the member nodes. N stands for the number of vehicles participating in the IP acquisition task at the same time interval.

$$T_{IP} = N1 * T_{INFO} + (T_{CF} + T_{CH}) + T_{ACC} + T_{DR} \quad (16)$$

B. Handoff latency

The handoff latency is the measure of time taken to complete the handoff procedure after a vehicle enters a network. The handoff latency for the proposed network is calculated using equation (17) where T_{HL} is the time required for handoff.T_{CNCT} denotes the time taken to connect with the new network. T_{VADD} is the time taken to add the vehicle to the NODE_INFO table. T_{IPACC} is the time required to acquire the IP address from the cluster head. N2 stands for the number of vehicles performing the handoff at the same time interval.

$$T_{HL} = N2 * (T_{CNCT} + T_{V_{ADD}} + T_{IPACC}) \quad (17)$$

VII. RESULT AND DISCUSSIONS

The proposed scheme is simulated using NS3.26 and sumo. The mobility patterns were generated using sumo while the algorithms is executed using NS3.26. For simulation purpose one lane in each direction is considered. The density of the vehicles is varied gradually based on three conditions, that is, low traffic, medium traffic and high traffic.)n an average we have observed 1050 vehicles in high traffic scenario, 850 vehicles in medium traffic scenario and 320 vehicles in low traffic scenario. The total length of the lane considered is 100 km which is the total coverage area of two consecutive MAGs. The total simulation is carried out in a time period of 1000 s. In the simulation we have determined the average speed of the vehicles based on statistical observations that have been carried out on Indian roads. To carry out communication between the various entities of the network the communication standards laid down in IEEE 802.16. For carrying out the road tests 6 Mbps data rate is considered. This data rate is being used by members of Vehicle Infra-Structure Integration (VII) Consortium [25].

A. Performance Evaluation

The IP Acquisition latencies for varying densities were compared and CBVH showed promising results. The Results obtained are shown in Figure. 13 where it shows a whopping ~80% reduction in IP acquisition latency for CBVH.

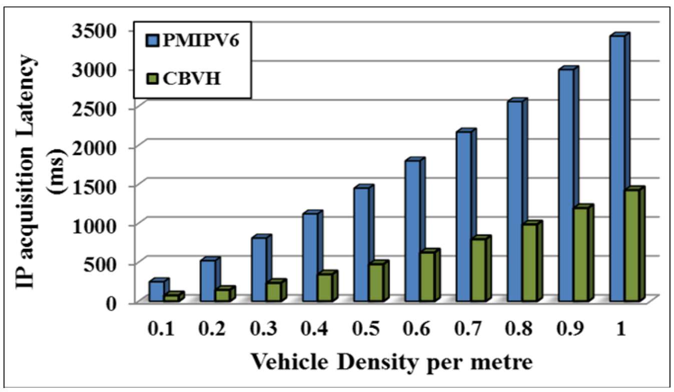


Figure 13. Comparison of IP acquisition latency between CBVH and PMIPv6

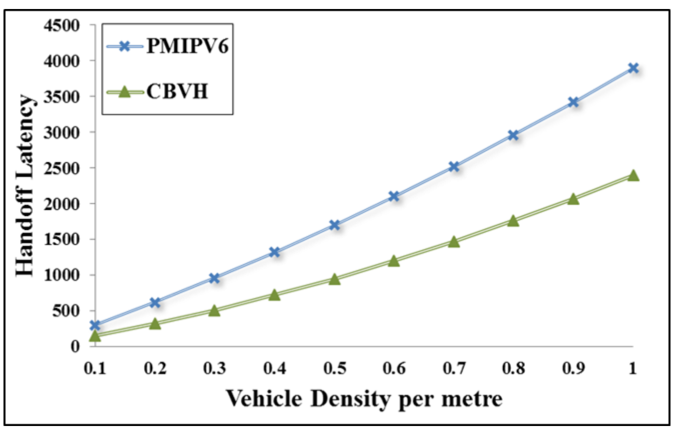


Figure 14. Comparison of handoff latency between CBVH and PMIPv6

B. Comparative Analysis

In this section a comparative analysis is done based on the proposed work and some existing techniques. Table 10 shows a comparative analysis highlighting some important parameters which needs to be considered for developing an efficient seamless handoff technique.

Clustering reduces load on the Mobile Access Gateways (MAGs) as the cluster head will take up responsibility of managing the members within its cluster. This work aims to reduce the load of the MAGs and time required in carrying out the handoff. As the CH and member nodes continuously exchanges HELLO and ACK messages, a broken node is detected without any delay. This not only reduces the handoff delay but also reduces the overhead associated with handoff process. A proactive caching mechanism is proposed in this work in which the packet of the intended vehicle moving from one MAG to the other is stored. This reduces the number of dropped packets during the handoff process. The clustering approach also reduces the load on a single point by distributing the load among the cluster heads thus eliminating single point failure problem.

According to [9] the MAG has to assign IP addresses to vehicles that are entering its coverage area. This increases the load on the MAG whereas in this scheme the Cluster Head takes up the task of assigning the IP to the member nodes that are associated with it. This reduces the load on the MAG. It is also seen that in [10] the RSUs depends on a single backbone server. This dependency is avoided by dividing the network into a number of clusters. Though a strategy is proposed in [23] for the formation of a stable cluster, nothing has been done to reduce the load on the Road Side Unit (RSU) or MAG. Further, no handoff procedure for the vehicles has been proposed.

In [24] author proposed a network model for VANET that is based on clustering methodology. The scheme does not take into account the vehicle density at the time of cluster formation. Also, there is no handoff strategy mentioned in this paper.

CBVH takes into account various hours of the day at the time of assigning values to the weight calculation factors. This makes the network more adaptive at the time of selecting the cluster head.

The scheme also helps in forming a stable cluster as the vehicle having least difference with the average speed of all vehicles in the cluster is given preference at the time of cluster head choice. Additionally, the proposed method not only takes into account load on the resources into consideration at the MAG level but also at the level of the cluster head. A stable cluster is formed along with proper handoff strategy is mentioned.

Table 10. Comparison of the proposed scheme with some existing schemes

	Existing Schemes				Proposed Scheme
	Algorithm to form stable clusters in vehicular ad hoc networks on highways [13]	Proxy MIPv6 Handover Scheme [9]	Handoff Using Multi-Way Proactive Caching [10]	CBVANET [14]	CBVH
Scenario	Clustering method for VANET to form more stable clusters in highway scenarios	MAG maintains pool of IP addresses which are assigned to the vehicles on arrival	Current MAG multicasts the packets intended for a vehicle to all neighbouring MAGs. These packets are cached until the vehicle the area of a MAG.	A VANET network model based on cluster formation	Cluster heads assist in the handoff of the vehicle. Packets are proactively cached in the MAGs until the handoff process for a particular vehicle is complete
Features					
Reduction of load on MAG	X	X	X	X	√
Consideration of vehicle density	√	X	X	X	√
Clustering of nodes	√	X	X	√	√
Handoff of Nodes	X	√	√	X	√
Assistance of cluster head in the handoff process	X	X	X	X	√
Proactive Caching of data packets during handoff	X	X	√	X	√
Scalability	√	X	X	X	√

VIII. Conclusion and Future Scope

In this paper we have presented a novel approach using which it is possible to reduce the load on the MAG. This has been possible by breaking the whole network into clusters. Each cluster has been assigned a cluster head that has to take the responsibility of serving nodes that are at an optimal distance. Thus, failure of the network due to single point failure has been completely avoided as the cluster head performs the functions of the MAG. Additionally, the amount of packet loss during the handoff process will be lessened as the packets are proactively cached in the MAG. The continuous exchange of HELLO and ACK messages between the cluster head and the nodes ensure that handoff latency is reduced. Whenever the cluster head will discover a node with broken link it will start initiating the handoff process. The node will also start searching for a new cluster head as soon as it discovers that it has broken from its previous cluster head. This scheme considers both QoS and load reduction on the backbone device, that is, MAG. Thus, the quality of service will enhance. Additionally, we have taken into consideration the road condition during the various hours of the day. The weighing factors have been varied depending on road condition to make the cluster head choice fair. Our simulation results show that IP acquisition time for nodes have been drastically reduced. It can be also observed that the handoff latency has decreased significantly. From the results it can be concluded that our scheme performs well irrespective of the speed and density of the vehicles, which is far better compared to many of the existing schemes. We will take into account the security of the network for further improvement of the scheme.

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