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A Reliable Communication Scheme for VANET Communication Environments

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Abstract

In VANET, the most important applications are safety applications, public infotainment and internet service to vehicles participating in it. To enable such applications efficiently communication methodologies need to prevail. Despite of its dynamic nature, VANET offers stability to some extent if identified can be useful to create efficient network communication. One of the main problems observed in VANET are loss of network connectivity. These problems could be eliminated by creating and maintaining an efficient network environment that offers wide range of connectivity, regardless of the dynamic nature of VANET. In this paper, a proposal for designing an efficient protocol to improve VANET communication using Node Velocity based Hierarchical Clustering of Nodes (NVHCN) is made. By NVHCN, cluster formation is regulated such that each cluster lives for a longer duration. Through inter-cluster communication, a reliable communication network is formed.

Keywords: Communication Network, Hierarchical Clustering, Inter-cluster

1. Introduction

The research interest in VANET has been evolving due to the continuous exploration of possibilities by introducing newer techniques and technologies for enabling vehicular communication for developing various applications for several purposes.

A typical VANET scenario can be represented in terms of the location in which the VANET has been implemented. Two distinct scenarios with respect to VANET infrastructure based environment are Urban and Rural. In an urban scenario, the possibility of the deployment of RSU or other networks facilitating V2I communication is comparatively more when compared to a rural scenario. Hence the probability of vehicle density and connection probability enabling vehicular communication in an urban scenario is comparatively high. Hence in a rural scenario, such as long highways, the deployments of RSUs are limited and are scarcely found.

Recently VANET proposals have started to consider the mobile communication networks such as GSM, CDMA, UMTS, LTE and WiMAX as a substitute for the previous infrastructure based vehicular networking techniques. It is because of their wide connectivity in most of the places. Also, utilizing such existing connectivity infrastructure for vehicular networking would eliminate the cost of establishing VANET specific infrastructures along roadside through RSUs.

The need mainly arises from the measures to develop applications for enabling Intelligent Transportation Systems (ITS). ITS deals with solving the increasing difficulties in road transportation and exploit the available resources in the communicating vehicles in order to develop innovative applications.

Traffic information system[6], accident avoidance system[7], cruise control[8], traffic control, traffic congestion detection[9], and commercial ad dissemination system[10], internet connectivity for multimedia content streaming[11],

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secure connectivity schemes[12] are the recent applications in the field of VANET.

Regardless of what network is being deployed for vehicular networking, since the access medium for all the participating vehicles is wireless there are higher probabilities for problems while connectivity. Such problems may be the based on network unavailability or high demand for network channels by a large number of participating vehicles to establish connectivity with the VANET infrastructure.

Such situations can cause undesirable and unexpected network overload in some places where the need for infrastructure based connectivity increases rapidly and thus providing a lesser throughput.

Although several techniques such as cooperative MIMO would help in solving these issues, they are dependent on the nature of the network involved in the infrastructure. It cannot be suitable where the particular network type offering such advanced features for reducing network overload are not available.

To some extent clustering of vehicles through Inter Vehicular Communication (IVC) would be a solution for this problem to help reduce situations which cause undesirable and unexpected network overload. Most of the clustering techniques become unsuitable due to the different mobility patterns observed in different vehicles. Such clusters formed are not stable for a longer duration. The lack of understanding about the observations in vehicular behaviour is the major source of such problems.

In such a context, this paper proposes a technique in which the node velocities are the major consideration. Exploiting the node properties completely before forming a cluster can increase the cluster lifetime. Thus it is forming a reliable communication backbone using the participating vehicles within the effective communication range of the clusters.

The proposed technique shows its importance over others in the ways such that mobility which is a ban in majority of the cases for vehicular communication is taken as a boon. The cluster once formed retains a longer duration than in any other existing methods.

2. Related Works

The major problem in performing communication between the moving vehicles is that the vehicles are of different mobility. This problem affects any communication, either it be a short communication, emergency message broadcasting or long communication, or multimedia content like video broadcasting. Therefore, finding out a reliable path before starting communication is essential.

In order to overcome the inabilities caused due to frequent topology modifications several protocols have been proposed[13–17]. There are also certain path predictions algorithms[1] in which the vehicles' position, velocity, acceleration of all connected vehicles are obtained and a communication path is gathered using Differential GPS and map data. In addition, clustering based proposals[2–5] exist in the literature in which certain criteria are assumed in order to express their suitability according to situations specified in their proposals.

Clustering can be made on identifying the interests of the participating vehicles. This type of clustering is made based on user interest over several multimedia contents[2]. Based on which the clustering is made and a cluster head is elected such that it offers high stability of multimedia content distribution among the cluster members. It relies on absolute distance between the vehicles by obtaining their position through GPS. All vehicles moving in a particular direction are considered with equal importance so that there were no distinct differences between the vehicles moving with different mobility. Since there would be a longer communication time during multimedia content transmission, there are chances for an attacker to make use of this duration and perform attacking strategies. Thus although it is a multimedia content delivering cluster it offers less reliability for the participating vehicles.

Hierarchical clustering algorithm[3] is implemented with varying status of the participating vehicles. Also clustering of vehicles is done with up to three hierarchies of vehicles connected in an agglomerative passion. Thus the distance between any members in a cluster is measured in terms of the number of hops required for a signal to reach an intended node. It is independent of the participating vehicles' position, velocity and thus proposes an analytical model which is dynamic to all roles of a vehicle participating in a cluster. Hence the stability of the roles of the cluster members is highly dynamic which is unsuitable for long duration of communication.

There are multiple agents[4] involved in the estimation for the formation of clusters. The mobile agents are the assumed software agents preinstalled in each participating vehicle. Those agents are for information collection, information dissemination and managing the information based on a knowledge base. The cluster head carries information in its knowledge base even after it loses its cluster members on crossing an intersection. This information in knowledge base would be helpful if the knowledge base is frequently updated irrelevant of previous experiences. Like in most cases, the vehicle positioning is done using GPS and map data. The validity of a cluster head to manage the cluster members is limited between shortly arriving intersections.

The vehicles are equipped with GPS[5] and map data so that it can find the position of the source and destinations. Cluster management is done autonomously, in case of any intersections have been passed. Additionally, the vehicles are informed about the cluster member's position and direction of motion. By using the direction, a cluster head decides whether to transmit data to the nearby member or not.

Thus in the previous works, the absolute positioning of vehicles have mostly been performed. Also longer cluster duration has not been ensured since the possibility of a node from getting out of the cluster.

In this paper, these problems have been addressed by employing a Node Velocity based Hierarchical Clustering of Nodes technique (NVHCN) in which relative positioning of vehicles based on the coverage offered by each of the vehicles is used. Thus the dependence over GPS and other position finding systems is eliminated by determining vehicle positions in a fully ad hoc mode.

3. The Proposed Approach

In VANET, one of the main problems is loss of network connectivity. A durable connectivity strategy is needed to reduce or eliminate this problem. In order to attain such a robust and durable connectivity, Node Velocity based Hierarchical Clustering technique (NVHCN) for designing a clustering network among vehicles participating in a VANET is proposed in this paper.

Therefore, amongst the cluster members in a cluster, the cluster head for each and every cluster is determined by an election technique based mainly on Node Link Weightage and Least Relative Mobility. The cluster head thus elected is assigned to each member belonging to the appropriate cluster.

3.1 System Model

Assumptions considered in this proposal are as follows:

- A multilane one way highway scenario with each lane possessing vehicles moving in low, medium and high speeds.
- Since it is a highway VANET scenario, the variability of velocities of the participating vehicles will be considerably less.
- Classify clustering into three ranges as LMC, MMC and HMC.
- The relative mobility between any two vehicles can be taken as a measure of nearness of participating vehicles.

3.2 Computations

Computations required for this proposal are as follows:

- Duration of connectivity of a vehicle A with respect to vehicle B can be represented as, DAB. DAB is the ratio of total coverage distance offered together by A and B at a particular instance to the relative speeds of A and B. i.e., DAB=(TCDAB)/(SA~SB).
- MAX duration of connectivity that a particular node A can offer to any other node X can be given by, MAX=∑DAX , for X= 0 to M, where M stands for the maximum number of nodes present in the cluster.
- CH selection criteria for a participating node can be represented as, CHcrit={Nodes with velocity of the node near to the Mean Mobility among cluster members} ∩ {Nodes with Maximum (∑Availability Duration for each vehicle)} ∩ {Nodes with maximum number of members within coverage}. Table 1 lists the used abbreviations.

Table 1. List of abbreviations

Abbreviation	Description
TCD_{AB}	Total Coverage Distance offered together by A and B at a particular instance
S_A,S_B	Speed of nodes A and B respectively
LMC	Low Mobility Cluster
MMC	Medium Mobility Cluster
HMC	High Mobility Cluster
LRM	Least Relative Mobility
V_i	Set of vehicles located in the transmission scope of vehicle 'i' within C
V_i'	Set of vehicles located in the transmission scope of vehicle 'i' within C'
CH	Cluster Head
CM	Cluster Member
GW	Gateway node
C	Current Cluster
C'	Neighbouring Cluster

4. Node Velocity based Hierarchical Clustering Technique

The algorithm used in this paper for cluster formation, cluster head selection and maintenance of cluster throughout the persistence of VANET clusters is represented in Figure 1. Also a flowchart corresponding to the same is represented in Figure 3.

The cluster formation is limited to vehicles subject to the lease relative mobility such that the duration of connectivity offered by the vehicles to other vehicles is longer. The identification of vehicles or clusters by other vehicles is done using the broadcasting of message containing self-information. Self-information of each vehicle comprises of node id, cluster id (if it is in cluster), cluster mobility range, coverage distance, and velocity. In any cluster, regardless of which mobility range it belongs to, a cluster head in any cluster is selected based on CHcrit. It is done in one of the nodes in the cluster which is termed as

Algorithm 1: Cluster Formation & Cluster Head Selection Algorithm

1. Let the new vehicle be A, send ADV message.
2. Identify vehicles V_i.
3. If there are no vehicles in communication range then
   3.1. Assign itself as Cluster Head and set a time for CHTimeOut.
   3.2. Assign its ID as Cluster ID.
   3.3. After CHTimeOut, repeat from step 1.
4. Else Broadcast self-information of A to V_i.
5. Select the vehicle with the LRM and send request for connectivity.
6. After receiving an ACK from the LRM node, establish connectivity.
7. If LRM is in any other cluster then
   7.1. get the cluster ID from the GW node or the CM of that cluster

Figure 1. Cluster formation and cluster head selection algorithm.

Algorithm 2: Inter-Cluster Communication Algorithm

1. If any node i in C receives a communication request message from a node i' among V_i' belonging to C' then i will send GW REQ to its CH.
2. After receiving GW ACK from its CH become the GW node for C'.
3. Depending on the message size and mobility of i' (in V_i'), the GW node i will reserve appropriate timeslots for communication in i and mutual neighbor/s of i and V_i' through CH in C.

Figure 2. Inter-cluster communication algorithm.

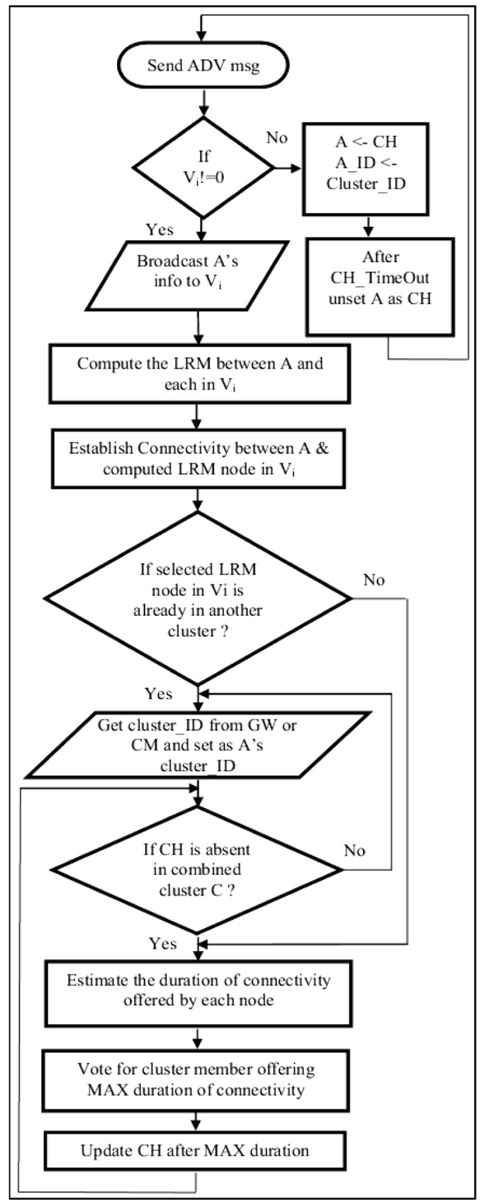

Figure 3. Flowchart representation of cluster formation and cluster head selection algorithm.

PseudoCH. CHcrit selection is made by maintaining different stacks for getting node priority for each like mean velocity, maximum availability duration and maximum nodes under coverage. In the PseudoCH, the voting for CH is conducted between all nodes in the cluster. Thus through voting a node which offers long duration of connectivity for most of the nodes in the cluster C is elected as CH.

Along with CH selection, a CH TimeOut is set which enables conducting re-election at the end of maximum duration of connectivity which could be offered by the then CH. This concept of forming a cluster based on least relative mobility is applicable in highway road environments and other less dense road ways where the velocity of each vehicle seems to be varying infrequently.

In addition, such a clustering technique will enhance the stability of the clusters formed by avoiding clustering with vehicles belonging to an entirely different velocity range. Thus it ensures the durability of the cluster formed which, in turn, increases the lifetime of the communication path established using the cluster. Similar to the general clustering techniques, the communication procedure employed is Time Division Multiple Access (TDMA). But this proposal is distinct from others by enabling formation of clusters strictly with vehicles belonging to the same category of mobility. Thus, it is favouring a reliable cluster formation to enable better intra cluster communication.

The inter cluster communication is opportunistic to happen in between two nodes of different clusters. If those two nodes belong to the same mobility range, then the clusters that they belong to is combined into a single cluster. Else, one of the two nodes requesting for communication is made as the gateway node to yield the request of the other.

Figure 2 represents the algorithm corresponding to inter cluster communication strategy which is defined in this paper. It is to be noted that, there is a facility for reserving the timeslots of the nearby CM (of the same cluster), by a currently communicating GW node to facilitate uninterrupted communication for a non-CM node (or node belonging to other cluster) of different mobility without forming clusters with them, which is analogous to soft handover in the existing mobile cellular telecommunication networks. Thus, inter cluster communication can be processed effectively even without including them in the cluster.

5. Conclusion

We have proposed a connectivity scheme in which maximum cluster duration is ensured by utilizing the practical factor; it plays a key role in determining the validity of a cluster, which is the mobility of each individual vehicle with respect to other vehicles to which it is connected with. Further, we are planning to extend our proposal to a scenario of road intersections in our future work.

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