Vehicle to Vehicle Cluster-Based Auto-Configuration for Vehicular adhoc Networks

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Abstract

The auto-configuration for Vehicular adhoc networks remains a challenging issue, where the traveling vehicles (nodes) are not bound to travel only in restricted regions like MANET. The application of auto-configuration in infrastructure-based seems to be easier issue as compare to network ad hoc mode. In the ad hoc network, configuration of IP address in advance is not considered a practical method. Nodes need to be configured on fly or at run time. In VANET the Vehicular Address Configuration (VAC) protocols, claimed to be first protocol to consider auto-configuration protocol to reflect on the ad-hoc mode of VANET, but the VAC remained victim to frequent re-configuration request of IP address. This paper introduces Cluster-Based Auto-Configuration (C-BAC) protocol for VANET in ad hoc mode environment. The C-BAC applies lane and speed based grouping algorithm in order to achieve better result. The traveling vehicles on highways adjust to traveling group according to their traveling cluster. This clustering of vehicle according to speed and lane grouping stabilizes the network and reduces request re-configuration requests immensely. In simulation result C-BAC outperforms the VAC protocol, as C-BAC stabilizes the network and reduces the frequent re-configuration of IP requests.

Keywords: Cluster, C-BAC, Member Vehicle, Group, Vehicle to Vehicle (V2V).

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INTRODUCTION

The designed application of C-BAC follows the auto-configuration mechanism for the highway network topology. Due to intermittent connectivity of vehicles on highway network and variation in speed, the availability of network services can be irregular and fragmentation of network become inevitable. One way to counter this problem is, to place or install RSUs with required distance or to avail UTMS mobile network services (Benslimane et al., 2011), but lack of bandwidth availability of UTMS, on other hand if RSUs are placed they lack transmission penetration issue. Installation or placement of RSUs everywhere is not ideally possible, keeping in view infinite VANET network topology (Fazio et al., 2009). The author in (Sou and Tonguz, 2011) has proposed connectivity enhancement with respect to carry and forward mechanism to resolve the connectivity issue, but again getting help from stationary RSU does not seem to be an ideal deploy for VANET .

The attempts to convene the intermittent connectivity problem with help of cluster based application with respect to equivalent speed based mechanism applied in (Ibrahim and Weigle, 2008) . The moving vehicles join moving clusters group with respect to their own speed equivalent criterion. The selection and grouping of vehicles has been carried out with help of *Lane Speed Based Group* (LSBG). The accumulation of vehicles in to clustering group is laid out by fuzzy rules. The fuzzy based grouping and selection of cluster group by ordinary vehicle helps vehicle to join their respective speed group and lane group on the highway. This optioned selection in return becomes the reason of prolonged network connectivity and reduces the intermittent connectivity.

The fuzzy based selection of clustering group by joining vehicle demonstrates better results with respect to auto-configuration as compare to Vehicular Address Configuration (VAC) protocol. The VAC claims to be the first auto-configuration protocol for VANET. The basic problems with VAC protocol remained; it does not follow any particular criteria in order to join the leader vehicle. The uncorroborated joining by ordinary vehicles result in frequent re-configuration requests, because keep in view esurient desires of drivers to obtain better network service from leader vehicles. The ordinary vehicles may frequently change their point of attachment to obtain better connectivity. In the following section LSBG algorithm is discussed.

Lane and Speed Based Grouping (LSBG)

The possibility of frequent changes in the attachment points of vehicles by the ordinary vehicles needs to be dealt with smartly. The C-BAC applies the LSBG in order to create best option for joining vehicle with respect to lane and speed grouping. The detailed information about the LSBG algorithm is presented with help of (Table 1).

Table 1: LSBG Table

Speed km/h	Lane	Clustering Group
0-20	1	0
30-45	1	1
45-60	1	2
60-75	2	3
75-90	2	4
90-110	3	5
110- 120+	3	6

The Table-1 introduces the three columns with respect to vehicle movement on the highway, on the respective highway, there are three lanes and every lane has its own speed limitations. The speed and lane combination with respect to cluster grouping is organized very carefully in order to meet every participating vehicle's need.

The speed criterion from 0-60 has been covered in lane I and there are three clustering groups with respect to speed parameters. Same application is applied for all three lanes with their speed groups as demonstrated in Table I. The scenario of the speed, land and cluster grouping is demonstrated in (Figure 1) for prolonged network connectivity.

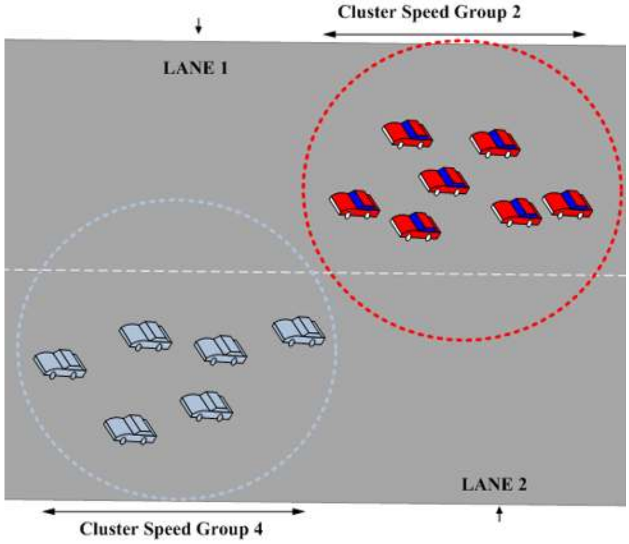


Figure 1: LSBG

As the network connectivity enhances, the re-configuration IP requests reduce automatically. This is where C-BAC outperforms VAC with respect to network connectivity and reduces network overhead in form of less amount of re-configuration requests by ordinary vehicle. In the following section we intend to introduce member entities of C-BAC protocol in order to comprehend protocol application easier.

The C-BAC Member Entities

The introduction of member entities paves the way to develop an understanding with C-BAC protocol. The participating vehicles are introduced with respect to their intended terminologies.

Undecided Vehicle (UV)

The UV is a vehicle, this is a state of vehicle where desired vehicle switches on and starts moving along the road and waiting for any signal or response from any existing vehicles along the road. This state of vehicle is termed as UV in C-BAC protocol. The vehicle at the start may or may not find any vehicle advertisement as they start to move along the road. The said vehicle may remain in this stage until it finds any vehicle to join or any vehicle may find this vehicle to join.

Non Participating Vehicles (Non NPV)

The designed protocol tries to follow the real traffic situation and understands that the every vehicle moving along the road may not be interested to join network, or it may not be equipped with desired communication devices in order to develop communication with moving network. The vehicle which is stand alone not connected to any network. These types of vehicles in the designed protocol are termed as Non Participating Vehicles (NPV).

Cluster Member Vehicle (CMV)

Member vehicle is used for those vehicles, which have developed the communication environment with the moving clustering group along the road. After joining the cluster, a vehicle's status changes from UV into member vehicle CMV. This CMV will become an active member of cluster after receiving an IP address from CH and remains able to communicate with other member vehicle in the vicinity of same cluster group directly.

Cluster Head (CH)

The cluster head is the backbone of small network called cluster. It maintains two tables one for member vehicles and other for neighboring cluster heads. The MV table is used to provide unique IP address to its members and keeps track of the assigned IP addresses. The Neighbor Cluster Head table is used to update the information about the neighboring cluster heads, in order to organize assigned IP address set of neighboring CHs.

Clusters Gateway (CGW)

The gateway plays important part in stability of network, it maintains its position between two CHs in order to keep cluster heads connected with the other. The criterion to become a CGW seems simple as a vehicle receiving signals from two clustering heads. One CH moving ahead of CGW and second cluster group following CGW, this type of vehicle is considered as a potential candidate. The selection criterion for CGW is discussed in more detail for the coming section.

The C-BAC Cluster Formation with help of LSBG

This applies a speed based grouping of vehicle to form the clusters on highways in order to have better inter-communication in the VANET.(Acarman Division, 2007) The Lane and Speed-Based Grouping (LSBG) of vehicles has been designed after understanding the short comings of VAC protocol. The LSBG provides an option to the moving vehicles on the highway to decide, their best matching speed group with respect to lane. The frequent lane changing has not been encouraged in the design of protocol, but changing lane is possible if the lack of SNR is received constantly from same lane. In Figure-2 the LSBG demonstrates a flow diagram, where vehicles with different speed check their relative lane with respect to speeds group and then join the group speed in the lane.

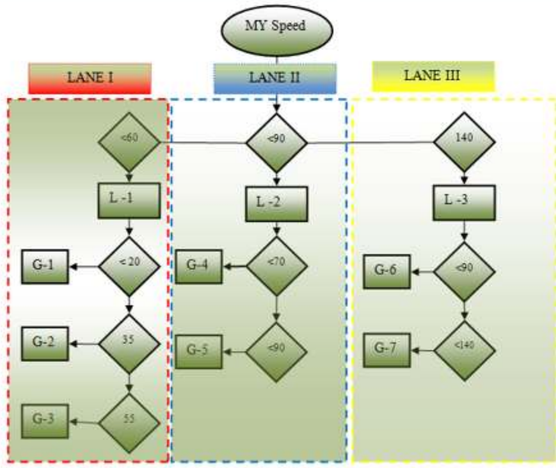


Figure -2 LSBG of Vehicles

After having decided the LSBG the vehicle starts moving along the highway, in this phase cluster formation the C-BAC protocol introduces different vehicle on the highway appearing with different time pauses, following the Poisson distribution mechanism. The Cluster formation for the C-BAC is depicted in Figure-3 with the help of flow chart.

At the start of the cluster formation a vehicle finds itself in an undecided situation, let that vehicle be termed as X, when X switches on. It may or may not find itself among the vehicles. If the X finds itself alone, it waits for signal or hello message from other vehicle and keeps its timer on. After due time duration, if X does not find any vehicle nearby it may consider itself as an alone vehicle and considers itself a Cluster Head. Let's elucidate the cluster formation in all three phases with respect to different phases one by one.

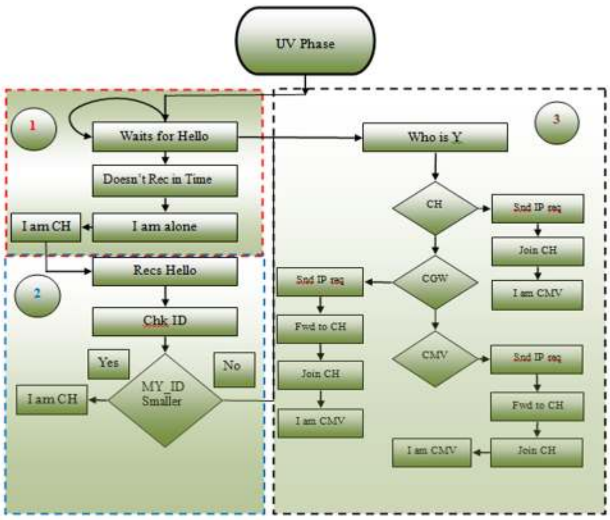


Figure -3 C-BAC Cluster Formation Using LSBG

Cluster Formation

In the formation phases, the introduction of every step with respect to process is described.

Phase I Undecided state to CH

The red rectangle in Figure-3 introduces phase 1. When the vehicle switches on it finds itself's alone and waits for hello message from neighbor vehicles. If vehicle X does not receive any hello message, then X waits for response and keep its timer on. When the time expires and X does not receive any response during this time, it changes its status cluster head, and the vehicle X becomes the CH.

Phase II CH vs. New Hello

In the blue rectangle here X becomes CH after not receiving any response from neighbor vehicles it declares it as CH. In blue rectangle Phase II X receives Hello packet from a vehicle nearby i.e. Y. Now X checks its ID with Y's ID. If Y's ID is greater than IP of X, then X tells Y to join X, as X is CH.

Phase III Joining as Member Vehicle (MV)

In the Phase III, when X checks the ID of Y and finds the ID of Y is smaller than the ID of X, then X comes to know that Y is on the road before me. (Note) The term ID is used in to indicate IP address of vehicles. The joining or configuration of new vehicle as MV could fall into three main stages, such as direction configuration from CH, configuration via CGW and configuration via MV.

Direction Configuration from CH

In the direction configuration from CH the said vehicle X, may find direct vehicle Y as CH. The X then sends IP request to Y, after receiving IP request from X, the CH Y replies back to X with a new IP address, after receiving IP address from Y. The X sends joining acknowledgement to Y and Y after receiving acknowledgement form X, registers IP address of X to its MVT, the process of direct configuration from CH is demonstrated in (Figure-4).

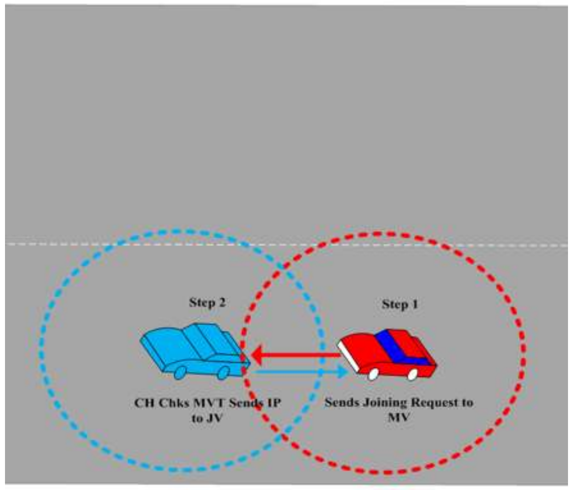
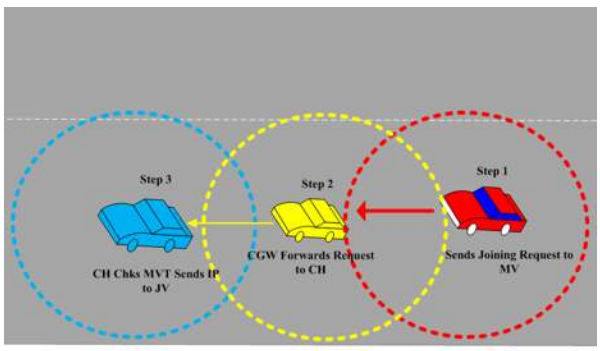


Figure 4: Direction Joining to CH

Configuration via Cluster Gateway (CGW)

In this scenario the vehicle Y is CGW, the vehicle X sends IP request to Y, and Y forwards the IP request to CH, the CH after receiving IP request through Y, replies back to vehicle X. after receiving IP address from CH, the X sends joining acknowledgement to CH. After receiving acknowledgement form X, the CH registers IP address of X to its MVT, the process is known as indirection configuration via relay vehicle, that is demonstrated in (Figure-5).



Configuration via Member Vehicle (MV)
Y is MV, then X sends IP request to Y, and Y forwards the IP request to CH, the CH after receiving IP request through Y, replies back to vehicle X. After receiving IP address from CH, the X joins CH and replies back with Acknowledgement to CH as demonstrated in (Figure-6).

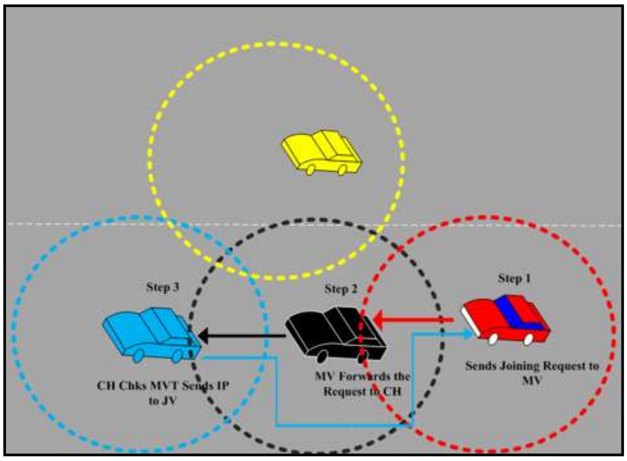


Figure 6: Joining Through Member Vehicle

BAC CH Practicality

Having understood the basic layout of C-BAC protocol, it's now time to turn to core issue of C-BAC protocol that is auto-configuration of VANET with respect to V2V application. The auto-configuration on highway with clustering approach for VANET has not been covered before as for as the knowledge of author and available Internet material is concerned. The VAC protocol has applied an auto-configuration protocol with leader vehicles, but it never meant to be cluster-based application. There is a cluster-based auto-configuration protocol for MANET in the literature (Joung and Kim, 2007). The cluster-based application for ad hoc network needs to cover three main aspects.

1. There should be one Cluster Head (CH) that is responsible for all IP address assigned in the vicinity of that cluster.

2. CH should maintain uniqueness IP address intact, before assigning IP to new joining vehicle. Otherwise there is high possibility that joining vehicle may assign already exiting IP address that would be problem known as DAD.

3. The member vehicle should have default link developed to cluster head in order to update its assigned IP address.

The CHs maintain their pool if IP addresses with communication with neighboring CHs in order to avoid assignment of duplicate address. Each CH owns disjoint sorted block of IP addresses. They are designed to be sequential, allocated to every CH with respect to their arrival on the highway. The CH assigns IP address to any joint vehicle (JV) from the allocated pool of IP addresses. The CH remains responsible of uniqueness of IP address in its respective vicinity and keeps itself updated with neighboring CHs in order to avoided duplicated address assignment.

IP address Management

IP address management is one of the basic operations of any host auto-configuration protocol (Perkins. 1999). In order to achieve address uniqueness the CHs are required to perform address synchronization periodically. To achieve this CHs maintain two tables to update information about member vehicle and neighboring CHs. The two tables that are updated by CHs are termed as Member Vehicle Table (MVT) and Neighbor Cluster Head Table (NCHT).

Member Vehicle Table (MVT)

The MVT demonstrated in Table-2 is used to update information about the MV in the vicinity of said CH. This table is updated periodically by CH in order to maintain the status of MV intact. The MVT provides complete information about the MV. The complete description of MVT is elaborated in Table-2.

Table-2 MVT Table

IP Address	Location	Prev_Speed	Cur_Speed	Status	Role
12AB:0:0:CD10::1010	F	70	70	1	1
12AB:0:0:CD20::1011	R	60	70	1	2
12AB:0:0:CD30::1012	M	70	70	1	1
12AB:0:0:CD40::1013	X	60	X	X	X
12AB:0:0:CD40::1013	F	65	66	1	1

Table -3 MVT Table Detail

Name	Data	Description
IP Address	12AB:0:0:CD10::1010	The Assigned IP address to MV by CH
Location	F	The Current Location of MV is in front of CH
Prev_Speed	70	The Previously Noticed Speed of this MV
Cur_Speed	72 X	Present Speed of MV Present No information about Speed is available
Status	1 X	1 indicates Active Connectivity of MV and X indicates Inactive status of MV
Role	1 2 X	indicates MV, indicates CGW present indicates UV

The communication between the member vehicle is supposed to be active and every MV remains aware of their cluster fellow with respect to IP address similarity bits. As any new vehicle with different IP pattern is introduced, the CH gets its information from its members i.e. MVs or CGWs. The new vehicle is always recognized with different CH IP address pattern, which indicates different address pool of different CH.

Table 4: NCHT

Table -4 NCHT Table

IP Address	AddSet	Status	Location
12AB:0:0::CD10::0120	1-50	1	F
12AB:0:0::CD10::1272	51-100	1	R
12AB:0:0::CD10::1230	101-150	2	F
12AB:0:0::CD10::1234	151-200	2	R
12AB:0:0::CD10::1243	201-255	X	X

Table -5 NCHT Table Detail

Name	Information	Description
IP Address	12AB:0:0::CD10::0120	IP address of Neighbor CH
Addset	1-50	Can Assign IP address from 1-50 Address pool
Status	1 2 X	1 One Hope Connectivity to Neighbor CH 2 Two Hope Connectivity to Neighbor CH via CGW X indicates present no Connectivity that CH
Location	F R X	F indicates the location of Neighbor CH is ahead R indicates the Location of Neighbor CH is rear Present No information of this Neighbor CH is available

Neighbor Cluster Head Table (NCHT)

In order to keep updated information about the neighboring CHs, every CH maintains (NCHT-5). The NCHT is updated periodically by CHs, to keep neighbors CHs' information updated. The benefit of this NCHT is, the duplication in IP address configuration is minimized, and overhead on the network is reduced.

The NCHT-5 is maintained to keep complete information about neighboring CHs. The information such as IP address of CHs and their allocated IP address pool, their respective location.

RESULTS AND DISCUSSION

The LSBG adopted approach by C-BAC proves better connectivity of vehicles with the CHs as compared to leader based connectivity of VAC protocol. In main problem with VAC protocol remained it has not considered the prolonged connectivity of individual vehicles, where vehicle may possible frequent change their point of attachment in order to have better signals from leader vehicles. The better connectivity of individual vehicle in return proves better auto-configuration protocol performance in terms of reduces amount of churn rates (frequent leaving and joining of vehicle or nodes). The main idea of C-BAC is to reduce churn rates, because earlier designed protocols have not paid due attention to this part of auto-configuration, which caused heavy amount of overheads on the network. The VAC claims to have lesser configuration time, but due to increase in churn rate, the saved amount of time during auto-configuration can lead to zilch (Rossberg and Schaefer, 2012).

In the auto-configuration protocol design, particularly for ad-hoc networks the cost of individual node is calculated carefully. In the network initialization cost, when a new vehicle joins the network by sending Address Request (AR) and till it receives address confirmation acknowledgement (ACK) (Nazeeruddin et al., 2006), can be expressed as followed.

$$N_{JV} = 2 * U_C + S_U \quad (1)$$

Where N_{JV} is the new joining vehicle U_C denotes the Unicast Message from joining vehicle and S_U denotes the single hope Unicast message, if there exists a direct communication link between the J_{NV} and the CH/ leader vehicle. We have simulated both protocols in matlab environment following the macro simulator (Saleet et al., 2008) for mobility pattern.

Table 6 Simulation Table of LSBG

Parameter Name	Simulating Values
Simulation Area	10 km X 10 km
Number Vehicles	10000
Velocity of All Vehicles	0-120
Maximum Transmission Range CH	600m
Minimum Transmission Range CH	600m
Maximum Transmission Range OV	600m
Minimum Transmission Range OV	600m
Max Connectivity Time	36000

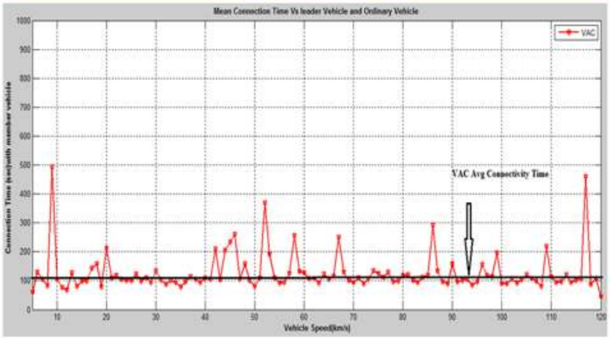
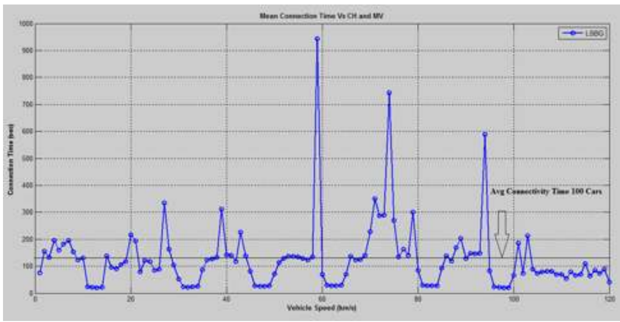


Figure 7: The VAC simulation Graph with 100 cars



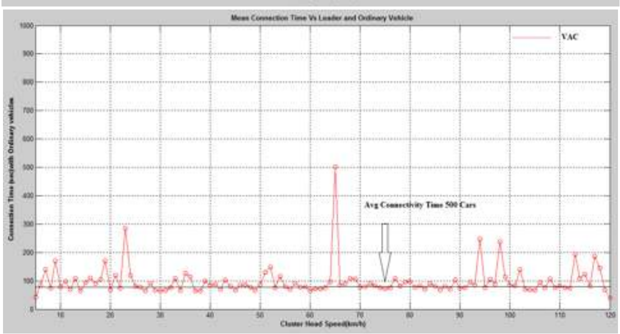


Figure 9: VAC simulation Graph with 500 cars

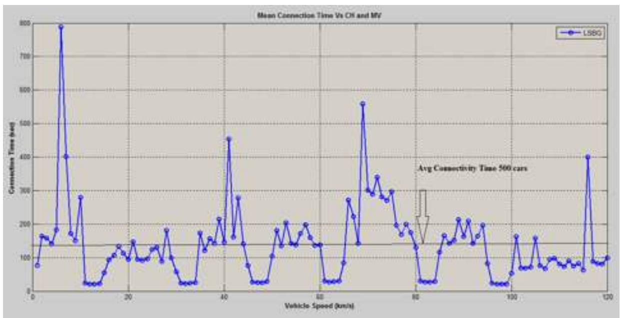


Figure 10: C-BAC simulation Graph with 500 cars

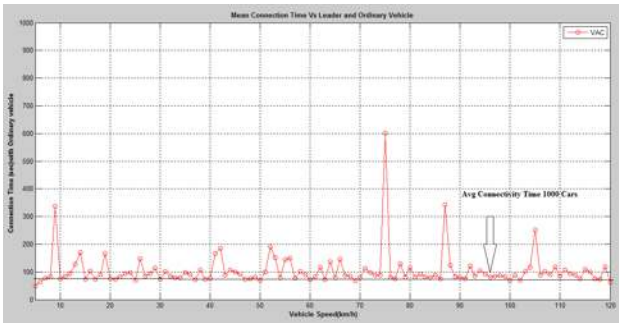


Figure 11: VAC simulation Graph with 1000 cars

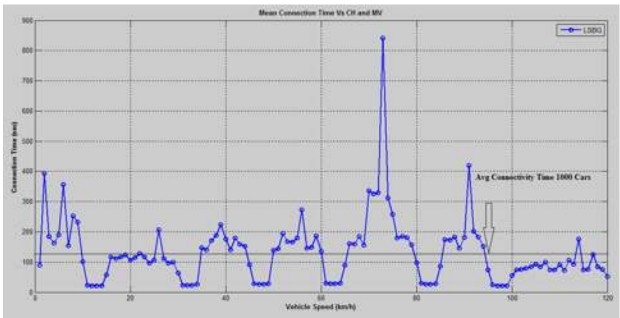


Figure 12: C-BAC simulation Graph with 1000 cars

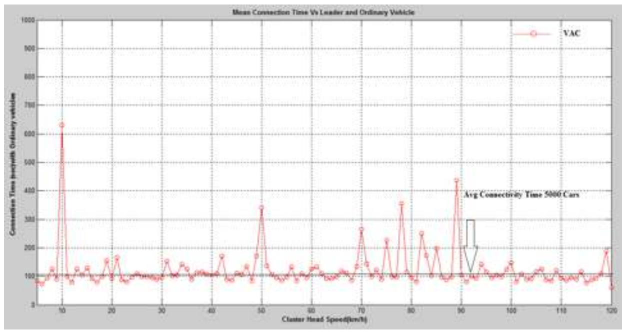


Figure 13: VAC simulation Graph with 5000 cars

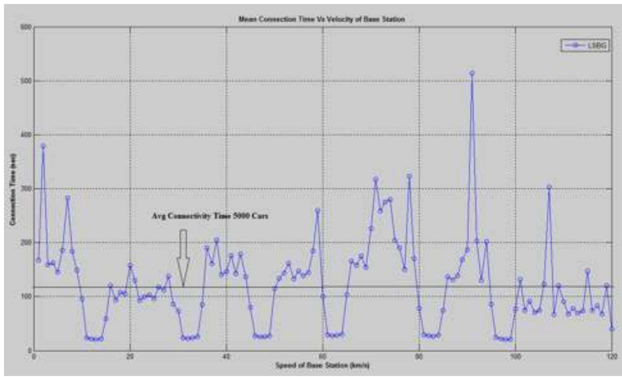


Figure 14: C-BAC simulation Graph with 5000 cars

The simulation results in figure-7 demonstrate the frequent intermittent connectivity among the traveling vehicles. The graph demonstrates connectivity amount the vehicle remains for very little time and vehicle keeps on changing their point of attachment. On other hand in figure -8 demonstrates stable and better result. In first simulation only 50 vehicles were simulated, but we kept on increasing the number of vehicles in the rest of demonstrated graphs as followed by number of increased vehicles. The results clearly demonstrate better as number of vehicle are increased.

CONCLUSION

The designed auto-configuration protocol C-BAC has been introduced in this paper. The application of C-BAC is meant to be built for highway traffic traveling scenario. In this paper three main things were considered to be achieved successfully. The organization of vehicles in some sort of traveling pattern that was achieved by the introduction of LSBG algorithm. The LSBG organized the traveling vehicles in groups and clusters with respect to lane and speed-based traveling scenario.The auto-configuration of traveling vehicles on the highway was achieved with help of cluster-based application. The CHs in C-BAC maintain distributed IP address pool to assign IP address to the join vehicles. The CH maintained two tables in order to keep IP address pool updated, (i) the NCHT and (ii) the MVT respectively. The connectivity maintenance of traveling vehicles on the highway in order to reduce churning rate effects of the protocol. The churn rates reduction is achieved through selective joining of CHs. The churn rate (frequently reconfiguration) of vehicles with their leader vehicles remained one of major issues of earlier designed standard VANET ACPs. The simulation results demonstrated that the C-BAC provides better results for the VANET auto-configuration on the highway scenario as compare to VAC protocol.

REFERENCES

- Acarman Tand Division C, .Clustering Formation for Inter-Vehicle Communication. pp. 636-641.

- Benslimane A, Taleb T and Sivaraj R.(2011). Dynamic Clustering-Based Adaptive Mobile Gateway Management in Integrated VANET – 3G Heterogeneous Wireless Networks. 559-570.

- Fazio M, Das S, Palazzi CE, Gerla M and Matematica D.(2009) Vehicular Address Configuration pp. 1-20.

- Ibrahim K and Weigle MC. (2008). CASCADE: Cluster-Based Accurate Syntactic Compression of Aggregated Data in Vanet. pp. 1-10.

- Joung U and Kim D.(2007). 2-Level Hierarchical Cluster-Based Address Auto-configuration Technique in Mobile Ad-Hoc Networks. pp. 309-320.

- Nazeeruddin M, Parr G, and Scotney B.(2006). DHAPM : A New Host Auto-configuration Protocol for Highly Dynamic MANETs. pp. 1-14

- Perkins C.(1999). Ad-hoc On-Demand Distance Vector Routing. p. 1-11.

- Rossberg M and Schaefer G, Survey A.(2012). on Automatic Configuration of Virtual Private Networks. pp. 1-16

- Saleet H, Langar R, Basir O, and Boutaba R. (2008). Proposal and Analysis of Region-Based Location Service Management Protocol for Vanet. pp. 1-6.

- Sou SI and Tonguz OK. (2011). Enhancing VANET Connectivity Through Roadside Units on Highways. pp. 3586-3602.