A TRUST BASED CLUSTERING WITH ANT COLONY ROUTING IN VANET

Rashmi Ranjan Sahoo[a], Rameswar Panda[a], Dhiren Kumar Behera[b], Mrinal Kanti Naskar[c]
[a,c]ADES Lab, Department of ETCE, Jadavpur University, Kolkata-700032, India
[b]Department of mechanical Engineering, IGIT, Sarang, Odisha-759143,India
[a]{rashmi.cs2005,rameswar183}@gmail.com, [b]dkb_igit@rediffmail.com,[c]mrinalnaskar@yahoo.co.in

Abstract-Inter-vehicle communication is a promising way to share and disseminate real-time and nearby safety information on the road. Scalability of vehicular ad hoc network is one of the decisive matters for a network designer, which can be solved by clustering. In this paper, as our first algorithm an attempt has been made to create clusters by considering direction, position and relative speed of the vehicle for managing the scalability issue. Moreover, we have proposed a new algorithm for selecting the most appropriate cluster head (CH) by considering the real time updated position and trust value of vehicles. As, evolutionary based routing is a predominant research theme thus we have used the most efficient ant colony routing technique based on trust for the simple highway scenario based VANET. Finally simulation result shows our proposed Trust dependent Ant Colony Routing (TACR) has outperformed the Mobility-aware Ant Colony Optimization Routing (MAR-DYMO) algorithm in terms of routing overhead.

Keywords: **VANET, Clustering, Direct Trust, Indirect Trust, Dynamic transmission Range, Ant colony Routing.**

1. INTRODUCTION

VANET is a subset or class of Mobile Ad Hoc Networks (MANETs) in which vehicles are considered as nodes [1], which move either with high or low speed. Due to the high mobility nature of nodes in VANET, the network formation is dynamic in nature. The vehicles of a VANET are equipped with the Dedicated Short Range Communication (DSRC). Most of the existing VANET models [2] assume VANET model as a collection of vehicles and fixed units called Roadside Units (RSU). In a VANET model communication at any point between the VANET nodes is done through Fixed Roadside Units only [3]. This scenario is valid inside a city only where the vehicles move slowly and more number of RSUs are available in the network. If the vehicles move with high speed as on a highway -outside the city where there are less number of Road Side Units, the city model of the VANET is difficult to implement [4]. Hence there is a requirement to propose a VANET model which is best suited for highway scenario-outside the city as well as within the city. Scalability of vehicular ad hoc network is also one of the critical issues for the network designers. Therefore, clustering based model is one of the ideal choices for network designers.

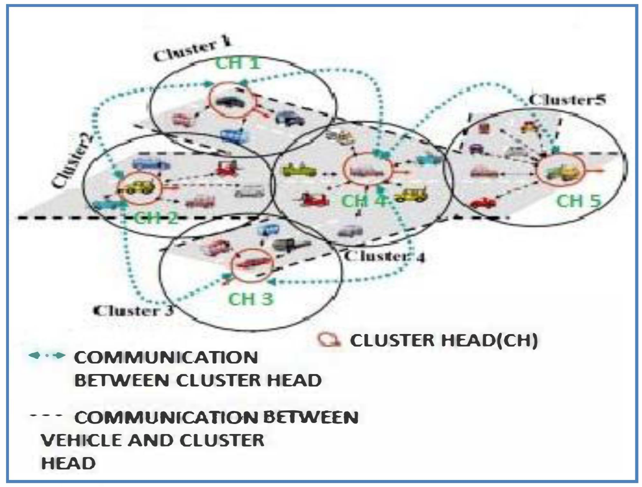

Fig. 1. Architecture of a highway scenario based VANET.

Routing based on clustering is appropriate for vehicular networks as vehicles may form clusters on road. The advantages of clustering can be summarized as follows [6]: (i) clustering can facilitate the reuse of resources and then can improve the capacity of VANET, (ii) clustering can decrease the amount of information that is used to store the network state, (iii) the amount of routing information propagated in the network can be reduced in cluster- based routing, (iv) a cluster-head (CH) can gather the status of its members and build an overview of its cluster condition, and (v) distant vehicles outside a cluster usually do not need to know the details of specific events occurring inside the cluster. In the clustering algorithm each cluster consists of cluster head (CH) and some members. The cluster head keeps all the relevant information about its members like real time position, trust value, speed and radio range of each vehicle in the cluster along with the information about the other cluster heads of the neighboring clusters for message communication. Cluster-head operates on two different frequencies for avoiding the intra and inter clustering message communication.

Selection of most appropriate cluster-head has great impact on clustering based message communication in VANET. So, for selecting the cluster-head we need to consider the re-affiliation energy, velocity and trust value of vehicle for increasing the stability and efficient message communication in inter and intra cluster. Transmission range is a very critical factor to maintain the connectivity in VANETs. A static transmission range cannot maintain the network's connectivity because of the non-uniform distribution of vehicles and rapid change of traffic conditions [5]. Therefore, a dynamic transmission range is required to maintain a good connectivity in non-uniform networks. A bio-inspired ant colony routing procedure has been considered to establish the proper route between source and destination node via cluster-head, as meta-heuristic ant colony has proved its credential for routing in ad-hoc network [8]. Ant colony routing along with the concept of trust helps to detect malicious vehicles present within the network, as a result it prevents unnecessary message transmission through the network.

The remainder of the paper is organized as follows: An overview of related work found in literature is presented in section 2. Section 3 depicts cluster creation mechanism and cluster-head selection method. A bio-inspired ant colony routing mechanism based on Trust is presented in section 4. Experimental results are presented in section 5. Finally section 6 concludes the paper along with the direction of future work.

2. RELATED WORK

A Clustering for Open inter-vehicle communication Network (COIN) [9] is proposed, which selects the cluster-head on the basis of driver intention and vehicular dynamics. This algorithm improves stability of networks but its disadvantage is, it does not consider the vehicle behavior, whether the selected cluster-head is a normal or abnormal vehicle. A direction based clustering algorithm [10] has been proposed, here the moving direction and leadership of cluster-head has been taken into consideration.

In order to evaluate trust among vehicle and to maintain proper connectivity in VANET several algorithms have been proposed. Some of the related existing works on VANET Counter measure uncooperative behaviors with dynamic trust-token in VANETs [11], this algorithm improves cooperation among vehicles by assuming that there are successor nodes in transmission range of each vehicle but the disadvantage is consideration of static transmission range whereas VANET requires dynamic transmission range.

There are several traditional ad-hoc routing procedures such as Ad-hoc On Demand Distance Vector (AOVD), Destination Sequenced Distance-Vector Routing (DSVD), Destination Sequenced Distance Vector (DSR), Position based routing algorithm, but by extensive research it has been already shown that these algorithms are not suitable for highly dynamic environment. Ad-hoc On Demand Distance Vector (AODV) is an on demand algorithm [13] i.e. this algorithm establishes the route only when required by source node. Due to dynamic nature and high mobility of network the route establishment breaks very frequently. As this algorithm create the routes on the basis of request/ reply query cycle hence it increases delay time of delivering data and control messages. Mobility-aware Ant Colony Optimization Routing (MAR-DYMO) [12] has been proposed which uses Dynamic MANET on-demand (DYMO) routing protocol along with ant colony technique.

3. CLUSTERING PROCESS

3.1 Cluster formation process

The proposed cluster formation procedure for a VANET is a distributed algorithm based on direction and relative speed of a vehicle. In the clustering method, the size of cluster plays an important role for network stability. The size of cluster can neither be very small nor very large, as very small size cluster decreases the stability of network because of the re-affiliation of network. Vehicles which are in the same direction will remain in relatively stable state. Hence vehicles moving in same direction are only considered as a member of cluster. Moreover, the average speed of a vehicle within a network also has great influence for determining the size of cluster. In this proposed clustering method we are considering the vehicles which are moving in the same direction and their speed is less than or equal to the given threshold value (S_{TH}) as members in the same cluster, since the vehicle which moves in high speed will leave the cluster of slow moving vehicle very frequently. Hence our proposed mechanism ensures a stable cluster with less frequency of re-affiliation. The entire cluster creation procedure is described as follows.

i) Select a vehicle V from the network, which does not belong to any other clusters;

ii) Vehicle V broadcast hello message to all the neighbors present within its maximum transmission range (I.e. 1000m as per DSRC);

iii) Recipient of hello message reply back to V with its own position and average speed, if the recipient does not belong to any other clusters

iv) Vehicle V finds the direction of each vehicle ***find_direction()***;

v) Vehicle V also compares the average speed of each vehicle with the supplied threshold value of speed (S_{TH}).

vi) If the neighbor of V has same direction of movement as V and average speed is less than or equal to S_{TH} then V announces that neighbor vehicle as cluster member depending on the size of the cluster.

vii) If the vehicle V finds that the vehicular movements of neighbor vehicles are slow, density is high, and traffic is heavy then creates a cluster of small size. On the other hand when the density of vehicle is less and the speed of vehicle will be high then create large size clusters. When neighbor vehicles are moving slowly and vehicle density is high then V creates a medium size cluster.

Note that we can get number of clusters by setting the different value of speed threshold (S_{TH}).

Procedure to find direction

When vehicle V receives a beacon message from its neighbors, it can estimate the distance between itself and its neighbors. Vehicle V calculates this distance in two consecutively received beacon messages from each neighbor, and then V can determine the direction of its neighbor. More over vehicle V applies this technique only for its neighbors that have the same movement with V.

Algorithm 1:

Procedure find_direction( )

{

$(X_V, Y_V)_T \leftarrow$ position of vehicle V at time instant T;

$(X_U, Y_U)_T \leftarrow$ position of vehicle U at time instant T;

$W \leftarrow T+5;$

$(X_V, Y_V)_W \leftarrow$ position of vehicle V at time instant W;

$(X_U, Y_U)_W \leftarrow$ position of vehicle U at time instant W;

/* calculate the City block distance between vehicle V and U at time instant T and W */

$D(V,U)_T \leftarrow |(X_V - X_U)_T| + |(Y_V - Y_U)_T|;$

$D(V,U)_W \leftarrow |(X_V - X_U)_W| + |(Y_V - Y_U)_W|$;

if ($D(V,U)_T \leq D(V,U)_W$)

Vehicle V and U are moving in same direction;

else

Vehicle V and U are moving in opposite direction ;

}

3.2 Cluster head selection process with cluster boundary formation

If the proposed algorithm finds a Road Side Unit (RSU) within the cluster then the algorithm selects it as the cluster-head, because it is obvious that RSU has more processing capabilities as well as it is immovable and static. If the algorithm fails to find the RSU within the cluster, then the selection of cluster-head along with cluster boundary formation are carried out according to the following steps:

i) Find the slowest moving vehicle (S_{mv}) from the cluster because this vehicle ensures that it will remain in its own cluster coverage area for a maximum period of time than the high speed vehicles: ***slowest_ vehicle ().***

ii) Calculate the total Trust value on slowest moving vehicle (T_{smv}) in order to ensure whether the selected S_{mv} is a normal or a malicious vehicle: ***trust _slowest _vehicle ().***

iii) If T_{smv} > threshold trust value of the network (TN_{th}) then select that vehicle as cluster-head (CH) otherwise find the subsequent slowest moving vehicle and repeat step (ii) through step (iii).

iv) If the algorithm finds any two or more vehicles satisfies the above conditions then it selects the vehicle which has more trust value (i.e. Most Trust worthy) as the cluster-head.

v) If two or more vehicles have same displacement and same trust value then repeat step (i) through step (iv).

vi) The slowest moving trust worthy vehicle will announce itself as CH among all the members present within that cluster through beacon message.

vii) CH broadcasts get_positon request message to all of its member nodes. All member nodes in turn unicast about their position to CH. CH receive position of all the member nodes and calculate the maximum X and Y limiting coordinates values to define its boundary. CH broadcasts the message about cluster boundary to all members such that all the members become alerted about the cluster boundary information which can be verified while changing their position.

viii) If the speed of the CH increases then there is high chance that CH may leave the Boundary. For this situation the system has to do the following steps.

ix) Repeat steps (i) through step (vii) excluding current CH. Transfer all information from old CH to the new CH.

Procedure to find slowest moving vehicle (S_{mv})

Algorithm 2:

Procedure slowest_ vehicle ( )

{

node _count ← Available nodes in the Cluster;

for i ← 0 to node _count

{

$T_i(x, y)$ ← X, Y position of node i at time T by using GPS;

U ← $T+5$;

$U_i(x, y)$ ← X, Y position of node i at time V by using GPS;

$diff_i(x, y)$ ← | $T_i(x, y) - U_i(x, y)$ |;

$dist\ (i)$ ← $diff_i(x, y)$;

/* Compares the distance of each node and chooses a particular node as the slowest moving whose distance is very small due to low node velocity*/

find_min_dist_vehicle(dist, node_count);

} }

Procedure find_min_dist_vehicle(dist, node_count){

min_dist ← *dist* (0); /*Distance of first vehicle*/

for i ← 0 to node_count

{

if (*dist* (*i*) < *min_dist*)

min_dist(*i*)=*dist*(*i*);

}

return (i); }

3.2.1 Trust evaluation of S_{mv}

The trust value of S_{mv} is being calculated in order to ensure whether the selected S_{mv} is a normal or malicious vehicle. Trust value defines the level of confidence of a vehicle V_i on neighbor vehicle V_j depending on the performance evaluation of the assigned task. The trust can be evaluated from the history of transactions with the node and from the recommendations given by other neighbor node inside the cluster [7]. For evaluation of trust each vehicle keeps track of the behavior of their neighbor vehicles and maintains record called as Certificate Authentication (CA). The record is comprised of various parameters called as trust metrics. These trust metrics with their trust value for different successful transactions are kept in data records. Initially, whenever a vehicle V joins to VANET, it is assumed that the vehicle V is a Trustworthy (Normal) vehicle i.e. some trust value will be allocated to the vehicle depending upon the threshold trust value (T_{th}). For example in our proposed scheme we have assumed that the threshold trust value (T_{th}) is 0.5. The trust value of vehicle is time dependent i.e. trust value of vehicle will vary based on transaction performed, as time goes on. For each of the successful transaction in between vehicle V_i and V_j the trust metrics value of corresponding vehicle will increase up to maximum 1, otherwise trust metrics value will decrease up to as minimum as 0. Table 1 shows different trust metrics.

Table 1. Different Trust metrics

Traffic Rule Obey (**TRO**)
Data Packets Forwarded (**DPF**)
Data Packet/message Precession(**DPP**)
Control Packet Forwarded (**CPF**)
Control Packet/message Precession(**CPP**)

Trust metrics data record of different neighbor vehicles will be helpful for calculating the trust on them, called as Direct Trust (DT) [7]. Direct Trust (DT) of any node is geometric mean of all the trust metrics i.e. DT of node A on node B can be calculated as shown in equation (1).

$$DT_A(B) = [\prod_k (m_k)]^{1/k} \tag{1}$$

Where $DT_A(B)$ represents the direct trust of node A on node B and m_k is set of K different trust metrics.

In our proposed algorithm we have calculated the total trust on S_{mv} which is experienced by individual neighbor vehicles by taking the Direct Trust into consideration. The total Trust on S_{mv} can be calculated by using equation (2).

$$T_{smv} = \sum_{i=1}^{n} DT_{vi}(S_{mv}) \tag{2}$$

Where T_{smv} is the total trust on S_{mv} and $DT_{vi}(S_{mv})$ represents the Direct Trust of neighbor vehicles $v_1, v_2, v_3 \ldots v_n$ on S_{mv} . Fig. 2 depicts Direct Trust on S_{mv} given by other neighbor vehicles expect S_{mv}.

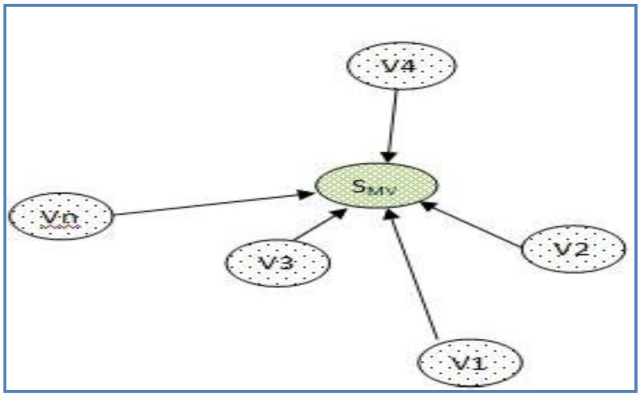

Fig. 2. Direct Trust calculation of a vehicle (Slowest moving vehicle S_{mv})

The threshold trust value of network (TN_{th}) can be calculated by using equation (3).

$$TN_{th}=\sum_{i=1}^{n}(Tvi)/n \quad (3)$$

Where Tvi represents the total trust value of each vehicle v_1, v_2, v_3 ... v_n, which is experienced by individual's neighbors.

Algorithm 3:

Procedure trust_of_S $_{mv}$

{

Calculate the total trust value on S_{mv} i.e. T_{smv} by using equation 2

if ($T_{smv} > TN_{th}$)

S_{mv} is the trust worthy node /*Normal vehicle*/

else

Not a trust worthy vehicle /*Malicious or Selfish vehicle*/

}

3.3. Dynamic Transmission Range

In vehicular ad-hoc network each vehicle can communicate among them only if they are located within the transmission range of one another. In order to establish an efficient communication between the vehicles the consideration of dynamic transmission range is more effective than static transmission range as the topology of the network changes rapidly. It is also shown in [14] that a dynamic transmission range is needed to maintain the connectivity in non-homogeneous networks to take advantage of power savings and increased capacity. According to the theory of traffic flow, the transmission range is a function of local density of vehicle, which is determined by vehicle movement and speed [5]. The dynamic transmission range (TR) is determined by equation (4).

$$TR=min\ (L*K\ (1-L),\ \sqrt{L*\frac{ln(L)}{K}}+a*L) \quad (4)$$

Where L is the Maximum transmission range (DSRC standard), K is the estimated local density of vehicle, 'a' is the traffic constant from traffic flow theory. The estimation of local density K is carried according to method proposed in [5].

4. ANT COLONY ROUTING PROCESS

In order to perform efficient routing, effect of malicious vehicles are considered because if the message generated by vehicle is a malicious one then there will be unnecessary propagation of message through network. Therefore, in order to ensure that the message generated by the malicious vehicle should not travel through network we have calculated the trust value of message generating vehicle using Indirect Trust (ID) [7] as follows.

Whenever the message is generated by the source node (S), it will transfer the message to its cluster-head (CH) provided the cluster-head is present within the transmission range of the source node(S). The cluster-head will send a beacon message to all the members within its transmission range present inside the cluster except source node (S) for calculating indirect trust value on source node S. The node who has received the beacon message will respond with the trust value of source node S. Cluster-head can calculate the indirect trust on source node S by using equation (5). Figure 3 shows the Indirect Trust (IT) calculation by CH on S, gathered by other neighbor vehicles.

$$IT_{CH}\ (S) = [\prod_{n} (DT_{n} (S)]^{1/n} \quad \textbf{(5)}$$

IT_{CH} (S) is the indirect trust of cluster-head(CH) on source node S, calculated from indirectly given information(i.e. Direct Trust(DT) on S) by n neighbor nodes on node S and given to cluster-head (CH). Whenever the Indirect Trust (IT) on S is found below the network threshold value of indirect trust (ITN_{th}), the node S will be regarded as abnormal vehicle. The network threshold of indirect trust (ITN_{th}) can be calculated by using equation (6).

$$ITN_{th}=[\sum_{i=1}^{n-1}(IT_{vi})]/n\text{-}1 \quad (6)$$

Where IT_{vi} represents the indirect trust of cluster-head on node i and n-1 is the number of nodes within the transmission range of cluster-head except CH.

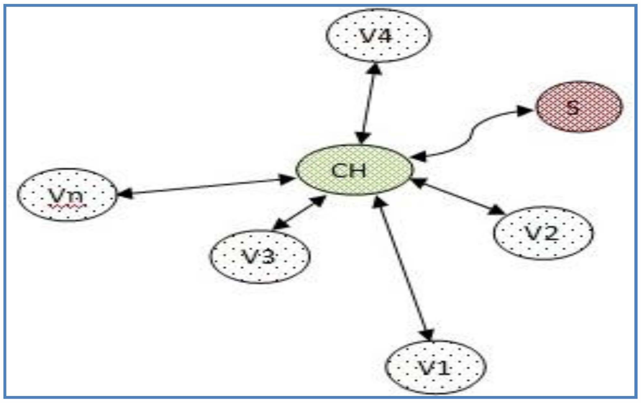

Fig. 3. Indirect Trust calculation of Cluster head (CH) on source(s)

If the cluster-head found that the source node (S) is an abnormal vehicle then it will send a beacon message to S as reply and discard the message otherwise route establishment process will occur. The route establishment process can be conducted for two different scenarios.

- Route establishment for intra-cluster
- Route establishment for inter-cluster

Route establishment for intra cluster

Whenever both the source (S) and Destination (D) are present inside the cluster, the intra cluster route establishment will take place as follows:

i) The source 'S' unicasts data packet (DP) to the cluster head (CH);

ii) CH(S) searches D within its Member List Table (MLT_{CH});

iii) If D is present then deliver DP to D and send feedback to S, otherwise go to step (iv);

Route establishment for inter cluster

i) Generate (n-1) forward ants (by CH) with unique sequence numbers and send them to n-1 reachable Cluster heads through multi-hop paths;

ii) Forward each ant towards boundary nodes of cluster(S), from these boundary nodes sent the forward ants to those neighbor nodes which are boundary nodes of other clusters;

iii) When forward ant comes to a cluster-head, the cluster-head stores the sequence number to track duplicate entry;

iv) When any of CH finds that D is its member, kill the forward ant and generate backward ant with same sequence number, deliver DP to D;

v) Send back backward ant to S as a feedback;

vi) Otherwise kill the forward ant as D is not present within the Member list table (MLT_{CH}).

Fig. 4 and Fig. 5 depict the intra and inter cluster route establishment respectively.

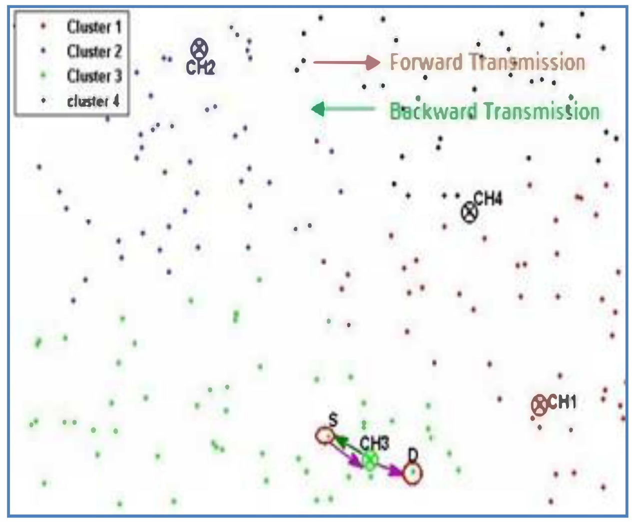

Fig. 4. Route establishment where both Source(S) and Destination (D) are in same cluster

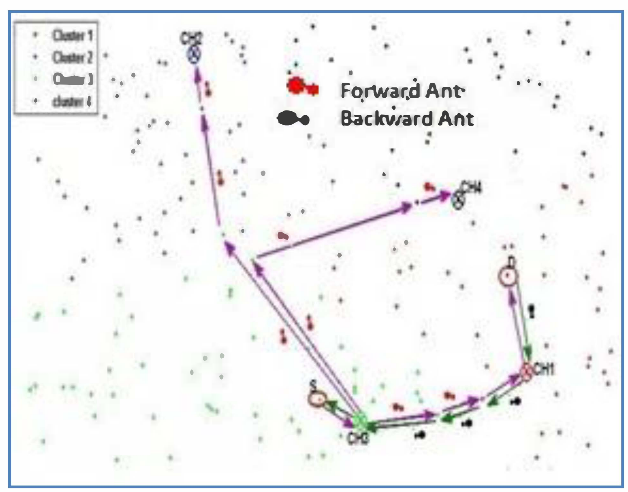

Fig. 5. Route establishment where both Source(S) and Destination (D) are in different cluster

5. RESULT AND DISCUSSION

A. Cluster Creation Time

Fig. 6 depicts the cluster creation time is directly proportional to the number of clusters i.e. when the number of cluster is less, the proposed algorithm also takes less time for cluster creation and vice versa. However there is no major change in cluster creation time for different cluster size.

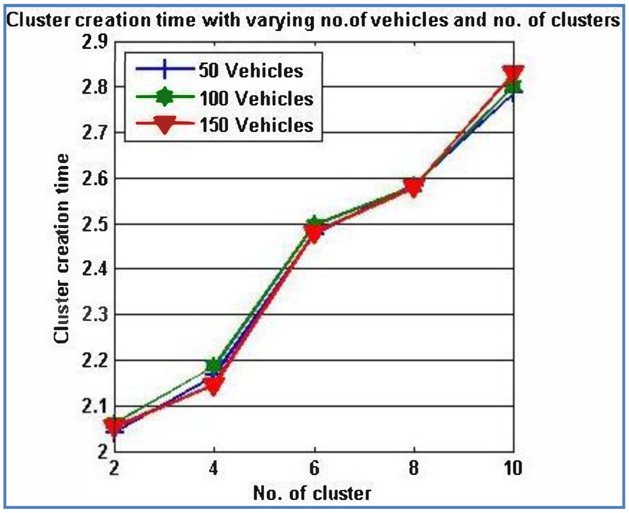

Fig. 6. Cluster creation time versus Number of cluster

B. Cluster-Head Selection Time

The Cluster Head Selection Time is estimated for different cluster size by varying the number of clusters as shown in fig. 7, it is noticed that when the no of clusters is low it yields a high head selection time irrespective of the number of nodes. It is also observed that the optimal number of cluster is between 6 and 8; it yields a low head selection time.

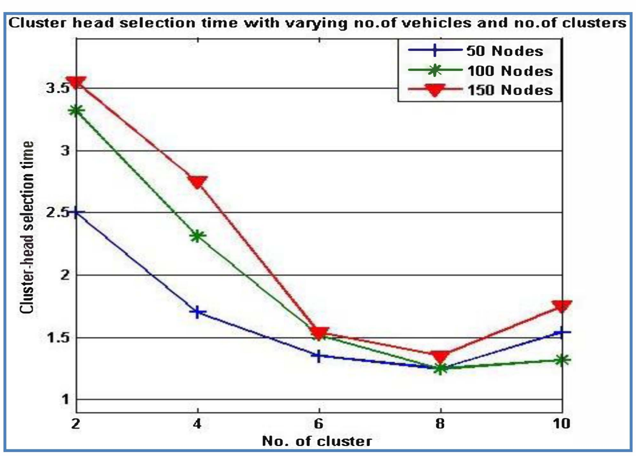

Fig. 7. Cluster head selection time versus Number of cluster

C. Probability of message Transmission (pr_{trans})

Fig. 8 shows ten number of vehicles present in the network and the horizontal axis represents the number of each vehicle. At transmission range of 250m, vehicles with number 6, 7, 9 have pr_{trans}=0 because there is no neighbor around them, and therefore, they cannot transmit the message through any other vehicle. But for dynamic transmission range there exists finite pr_{trans} which depicts improved reliability of the network on using the concept of dynamic transmission range for message transmission.

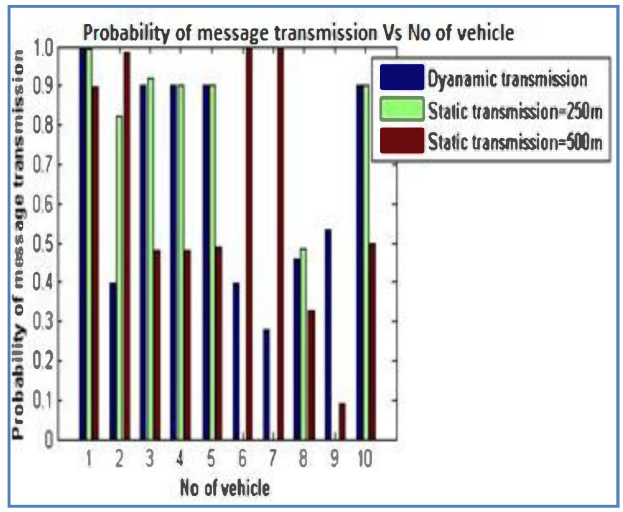

Fig. 8. Probability of message Transmission under Dynamic and Static Range over 10 numbers of vehicles.

D. Routing Overhead

The routing overhead is defined as being the number of routing packets, such as the control messages – per number of data packets successfully received at the destinations. This metric tells about the extra traffic generated by the routing protocol in order to successfully deliver data packets. Fig. 9 illustrates the comparison of traditional routing algorithms used in VANET such as AODV, MAR-DYMO with the proposed Trust Dependent Ant Colony Routing (TACR). Here the simulation shows that AODV routing overhead increases when number of vehicle increases. MAR-DYMO and TACR routing overhead also increases with the increment in number of vehicles, but the rate of increment is very less as compared to AODV. The Performance of MAR-DYMO routing closely resembles TACR for less number of vehicles but, on increase of vehicles (125 and above) the overhead of MAR-DYMO increases rapidly as compared to TACR.

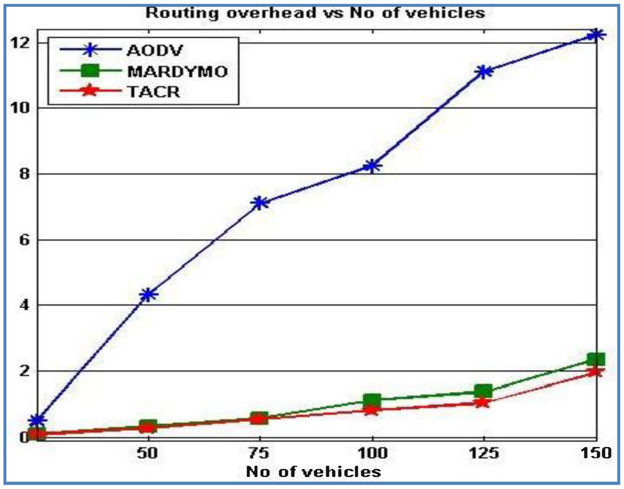

Fig. 9. Routing overhead comparison between AODV, MARDYMO and TACR

6. CONCLUSION AND FUTURE WORK

Efficient modeling of VANET is a most challenging task due to its rapid variation in topology particularly in Highway scenario. In this paper we have proposed a new clustering model based on the concept of Trust mechanism and most prominent evolutionary computing algorithm-Ant colony routing in order to establish efficient communication between VANET nodes. The simulation result shows that the proposed Routing algorithm based on Trust has outperformed the existing routing algorithms in terms of routing overhead. For cluster creation time and cluster head selection time, VANET simulation has been done for 20 times. 20 random values are obtained for different number of VANET nodes and clusters and the average value is presented. Also in the context of efficient routing, the future work would focus on application of Trust mechanism to find out the best trusted route between two nodes of a VANET.

REFERENCES:

[1] Malik M. and Ali Ibrahim Khan.: "Performance analysis of Routing protocols for Vehicular Ad hoc Networks Literature," April 2008.

[2] Wenmao Liu Hongli Zhang, W.: "Autonomous road side infrastructur secure VANETs," *proc. of wireless communication mobile computing Beijing, 2009.*

[3] T.D.C Little and A.Agarwal: "An Information Propagation Scheme for VANETs," *proc. Intelligent Transportation Systems, Sept 2005, pp. 155-56.*

[4] Koabazian, M.Ali Concordia Univ and Montreal: "A Performance Modeling of Connectivity in Vehicular Ad Hoc networks," *Vehicular Technology IEEE Transactions, July 2008, Volume 57, Issue 4, pp. 2440-2450.*

[5] M. M. Artimy, W. Robertson, and W. J. Phillips.: "Assignment of dynamic transmission range based on estimation of vehicle density," *VANET'05, Cologne, Germany, September 2005, pp. 40 - 48.*

[6] Liu X, Fan Zh and Shi L.: "Securing vehicular ad hoc networks," *proc. second conf. on int. pervasive computing and applications, July 2007, pp.424–9.*

[7] Shaik Sahil Babu, Arnab Raha and Mrinal Kanti Naskar.: "Geometric Mean based Trust Management System for WSNS (GMTMS)," *IEEE WICT, 2011, pp.448-453.*

[8] Fernando and C. V.: "Simple ant routing algorithm," *Teresa, proc. Int. conf. on Information Networking, Busan, South Korea, 2008, pp.486-493.*

[9] Blum J, Eskandarian A and Hoffman L.: "Mobility management in IVC networks," *proc. IEEE intelligent vehicles symposium, 2003.*

[10] Fan P, Mohamadian A, Nelson P, Haran J and John Dillenburg.: "A novel direction-based clustering algorithm in vehicular ad hoc networks" *proc. of transportation research board 86th annual meeting, Washington DC, United States, 2007.*

[11] Wang Z, Chigan Ch.: "Countermeasure uncooperative behaviors with dynamic trust- token in VANETs." *proc. ICC, 2007, pp. 3959–64.*

[12] Sergio Luis O. B. Correia, Joaquim Celestino Junior and Omar Cherkaoui.: "Mobility-aware Ant Colony Optimization Routing for Vehicular Ad Hoc Networks," *IEEE WCNC 2011 – Network.*

[13] Park Sanghyun, Shin Jayounq, Baek Senuqmin and Kim Sungchun.: "AODV based Routing Protocol Considering Energy and Traffic in Ad-hoc networks," *proc. Int. Conf. on Wireless Networks, 2003, pp.356-361.*

[14] R. Ramanathan and R. Rosales Hain.: 'Topology control of multihop wireless networks using transmit power adjustment," *proc. 19th Annu. Joint conf. INFOCOM, 2000, vol. 2, pp. 404–413.*