A New Two Level Cluster-based Routing Protocol for Vehicular Ad hoc NETwork (VANET)

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***Abstract* — Vehicular ad hoc networks (VANETs) are a subset of mobile ad hoc networks (MANETs). These networks do not have a specific structure, in which network-forming nodes are moving vehicles. Therefore, routing is essential for data dissemination in these networks. The problem of the link failure between vehicles is one of the principal challenges in these networks. In this paper, a reliable two-layer cluster-based algorithm has been introduced in VANETs to mitigate the link failure problem. Using two-layer routing makes route maintaining and the possibility of self-organization easier when topology does not have a steady shape. At the first level of new method, selecting the strong link and at the second level, the greedy algorithm is used in order to select the best route. Velocity, direction, S_T and location are all effective parameters involved in this new algorithm. The proposed protocol that was simulated by NS-2.35 improves the network parameters such as end-to-end delay and packet delivery ratio compared with two similar measured protocols. Increased packet delivery ratio and decreased end to end delay compared with previous protocols showed better performance of the new method.**

Keywords - VANET, greedy algorithm, routing protocol, ad hoc network

I. Introduction

VANET is one of the categories of mobile ad hoc networks. There are not any centralized nodes such as base stations or access points in this network for the purpose of management control, thus VANET is an infrastructure-free network, but there are some constant network nodes as Road Side Unit (RSU) [1]. VANET utilizes two kinds of communications including V2I and V2V. V2I is Vehicle to Infrastructure communication and V2V is Vehicle to Vehicle communication. The second communication is helpful when no infrastructure is available. Dedicated Short Range Communication (DSRC) is a fast, short-to-medium term wireless technology that VANET uses for V2V and V2I communication [2]. Researchers are interested in VANET due to some great advantages such as the deployment of Intelligent Transportation Systems (ITS), collision avoidance, payment services, reaching to the Internet and using online service while on the road and improving road safety [3].

Every vehicle has a communication range that is limited. therefore, if the distance between source and destination is more than communication range, they need to use some intermediate nodes to send messages to the destination and due to the suffering from ink failure problem, routing is a significant task for VANET. Providing a constant and reliable routing is essential in order to mitigate this issue [4].

In this paper, a two level cluster-based routing algorithm will be presented, taking into account metrics such as the distance of the node, the velocity of the node, the direction of the node and the transmission power of the transmitted signal (S_T). The purpose to use cluster based routing is the feasibility of self-organization and maintain routing if the topology of network keeps altering. The proposed method focuses on developing a reliable two-level routing protocol with a greedy algorithm in VANET. Furthermore, some important metrics were used to choose the best neighbor in the first level of routing between cluster members. At the second level of routing, a greedy method was used between clusterheads and destination. At this level, the greedy method was used in order to have high speed in deciding. Parameters such as distance and velocity were also considered in greedy approach routing in order to select the best path between clusterheads and destination; moreover.

The paper is organized as follows: section 2 is related work to the proposed technique. A brief review of preliminaries will be outlined in section 3; section 4 describes the first level of the proposed protocol. In section 5, the second level of the proposed protocol will be explained. Simulation results are discussed in section 6 and the last section reveals the conclusion.

II. Related work

When a node is about to send a packet to another node and they are not succeeded to communicate with each other directly, or in other words, if they are not in the same radio range, the source should use middle nodes to send packets to the destination. Thus, routing is a necessity to find a route between source and destination. Due to the movement of vehicles at different velocities, topology changes constantly; therefore, routing is one of the principal challenges in VANET. Hence, routing has a high significance rule in these networks and it is subjected to research, There are two classes for routing protocols in VANET which are called position and topology based routing protocol [1]. In the first class, routing is done based on the location of the source and destination nodes and also neighbor nodes. In another class, network information is used for routing. In [6], a QoS-based

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unicast routing protocol is proposed. This protocol uses two techniques: a clustering algorithm and an artificial bee colony algorithm based on QoS criteria to find the best route from a source to a destination. Available bandwidth, end-to-end delay, jitter, and link expiration time are all used criteria in this method.

RMRPTS in [1] is a multi-level cluster based routing protocol. This algorithm has two levels. At the first level, an improved AODV routing protocol with fuzzy logic is used in order to create reliable routing between cluster members. At the second level, tabu search is used for routing between cluster heads and destination.

Selection of middle node or next hop is truly important to find a reliable route. In [2], selection of next node is done according to several metrics in VANETs. There are two categories of metrics which are the link and node based metrics to select the best neighbor as the next hop in this method.

VTARA protocol in [4] uses waiting time as a metric to select next step. Waiting time means the farthermost neighbor of sending node is much closer to the destination, thus it gets the lowest waiting time. After choosing the best neighbor with the lowest waiting time, the packet will be delivered to it. If there is not any suitable neighbor to get data packet from, then the data packet will be sent to RSU.

In [5], a position-based routing protocol is proposed for VANET that uses the greedy algorithm to find the best route between the source and the destination node which is by choosing the best neighbor in every step.

A routing protocol is proposed in [6], uses Ground Vehicle to Ground Vehicle, Flyover Vehicle to Flyover Vehicle and Flyover Vehicle to Ground Vehicle/Ground Vehicle to Flyover Vehicle communication to improve the routing performance. The urban road network information such as multi-lane and flyover helps to send the data to the destination with a minimum forwarding delay. After calculating path value for each path connected to an intersection by the Road Side Unit the next path for data sending is selected.

III. A BRIEF REVIEW OF PRELIMINARIES

A. *Greedy algorithm*

The greedy algorithm performs the best choice according to the problem conditions and determined criteria. It hopes optimization is done with continuing the same procedure in every step. In a greedy way, the element that is best based on a certain criterion is selected at each step. It selects the element, regardless of choices that have already been made or will be made in the future. The greedy algorithm starts its procedure with an empty set and step by step some elements are added to this set. Finally, the complete set is used as a solution. This algorithm makes its choices based on local information [7].

IV. PROPOSED PROTOCOL

Vehicular ad hoc network (VANET) is a type of mobile ad hoc network (MANET) that provides communication between vehicles on the road, also the connection between vehicles and infrastructure units that are usually installed alongside the roads. Due to the massive movement of vehicles, electing the next vehicle and therefore electing the best route to send packets is rather difficult. So the problem of link breakage between vehicles is considered as one of the primary challenges of VANET.

In this paper, a two level cluster-based routing protocol is presented in VANET. The main reason for the creation of routing based on clustering is that in VANET, the possibility of self-organizing and sustaining the path across the cluster increases. At the first level, routing is performed between cluster members by dividing nodes into two groups with strong and weak links. At this level, several metrics are used to select links and high quality reliable paths. At this level of routing, when a node intends to send a data packet, first it evaluates its link to the clusterhead to realize if it is strong or weak therewith it decides how to send the packet to the clusterhead. If the node has a strong link to the clusterhead, it sends the packet to the clusterhead frequently in an instantaneous step. Otherwise, according to the metric feasibility condition, it chooses the best neighbor from the corresponding neighborhood, which has a strong link to the clusterhead thereafter sends the packet to it. The reason for splitting the nodes inside the cluster into two groups is to ensure that the data packet is received by the clusterhead. Here are several effective measures such as velocity, distance, S_T and direction have been used to select the reliable link.

In the second level of this method, the greedy algorithm is used to find the proper path between clusterheads. At this level, after getting data packet to the clusterhead of the source node, greedy routing is done between clusterheads and destination accordingly.

The purpose of this study is to provide a new two level cluster-based routing algorithm called NTLCRP in vehicular ad hoc network.

In the following, the proposed method is fully covered in detail. In figure 5, the general flowchart of the proposed method is illustrated.

A. *The first level of proposed routing method*

In the following, the first level of the proposed method that is the routing inside the cluster described in detail. At the first level of proposed routing, the cluster nodes send data packets through nodes with a high quality link to the clusterhead. The steps for the first level of routing are explained below.

1) First, the source node sends a REQ packet to the clusterhead, and collects the required information including velocity, direction, and location from clusterhead. The REQ packet format is shown in figure 1.

2) After obtaining the required information by the source node, the distance between the source node and clusterhead is calculated by (1).

$$D = \sqrt{(X_2 - X_1)^2 + (Y_2 - Y_1)^2} \tag{1}$$

So that (X_1, Y_1) and (X_2, Y_2) are the coordinates of the first and second nodes respectively, and D represents the distance between two nodes.

3) The source node calculates its quality of link (QoL) to the clusterhead by having the information that it received from the clusterhead. To calculate QoL, by having the required information such as direction, velocity, and distance, then node uses (3).

$$DIR = |\, Direction_{source} - Direction_{clusterhead} | \quad (2)$$

$$QoL = \left(1-\frac{Distance}{Max\ Range}\right)\times\left(1-\frac{Velocity}{Max\ Velocity}\right)\times\left(1-\frac{DIR}{180}\right) \quad (3)$$

So that Distance represents distance between node and the clusterhead, Velocity represents the velocity of node ، Max Velocity represents the highest velocity of node, Max Range represents the highest radio range of node, Direction source represents the direction of the source node, Direction clusterhead indicates the direction of the clusterhead, both of which are of the interval [-90, 90], and QoL represents the quality of link between node and clusterhead. The greatest difference is assumed to be 180.

4) If the quality of the link is greater than a defined threshold value of QoL (QoLth), then that node would be considered as a strong node. The strong node sends the packet directly to the clusterhead with a strong link.

5) Otherwise, this node is considered as a weak node or node with a weak link. The node sends its data packet with a weak link through a strong node to the clusterhead. For this purpose, the source node sends a REQ_L1 packet containing its location to its neighbors, requesting them to send back their quality of the link to clusterhead and distance to the source node. Fiqure 2 is the REQ_L1 packet format.

The node who receives the REQ_L1 packet first calculates their distance to the source node by (1) and their QoL to the clusterhead by (3), then send them through the REP_L1 packet to the source node. The REP_L1 packet format is shown in figure 3.

6) After receiving REP_L1 packets by the source node from its neighbors, it buffers their quality of the link to clusterhead and distance between the source node and its neighbors in a table. Then, the source node selects the best node using (5), to send its information. Each of neighbors that has the best value of optimal path (OP) is selected as the best node to deliver data packet to it.

$$Scope = \frac{1}{S_T} \quad (4)$$

$$OP = CV \times \left(\frac{QoL}{D \times Scope}\right) \quad (5)$$

Where CV is a constant value that is between 0 and 1.

7) A neighbor has a high quality of the link, less distance and high value of St is selected and the source node delivers its data packet to it.

8) The neighbor selected in step 7, sends the received data packet to the clusterhead.

The flowchart of the first level of the proposed method is shown in figure 6.

Base fields	Location	Direction	Velocity

Figure 1. REQ packet

Base fields	Location

Figure 2. REQ_L1 packet

Base fields	QoL	Distance

Figure 3. REP_L1 packet

Base fields	Velocity	Location	Check

Figure 4. REP_L2 packet

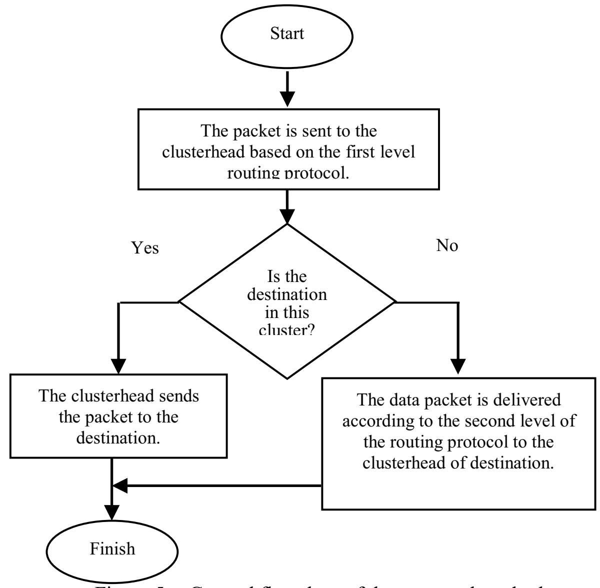

Figure 5. General flowchart of the proposed method

B. *The second level of the proposed routing method*

In this section, the second level of the proposed method is described. When the destination is in another cluster, the data packet must forward between clusterheads to reach the clusterhead of the destination. The second level of the proposed method is used for routing between clusterheads. At this point, the clusterhead utilizes a greedy algorithm to find the best next step or the best next clusterhead. The steps of the second level of routing will be detailed down below:

1) The clusterhead sends a REQ_L2 packet to its identical clusterhead neighbors to get the information it requires.

2) The containing packet requests the velocity and location of its neighbor clusterhead.

3) If the clusterhead that received REQ_L2 packet is happened to be the destination: the clusterhead set the check field as one to indicate that it is the destination and returns the REP_L2 packet to the source node. The clusterhead of the source node then sends the data packet without the intermediary to the destination node.

4) If the clusterhead that is received REQ_L2 packet knows that the destination is within its cluster: The clusterhead set the check field of the REP_L2 packet as one

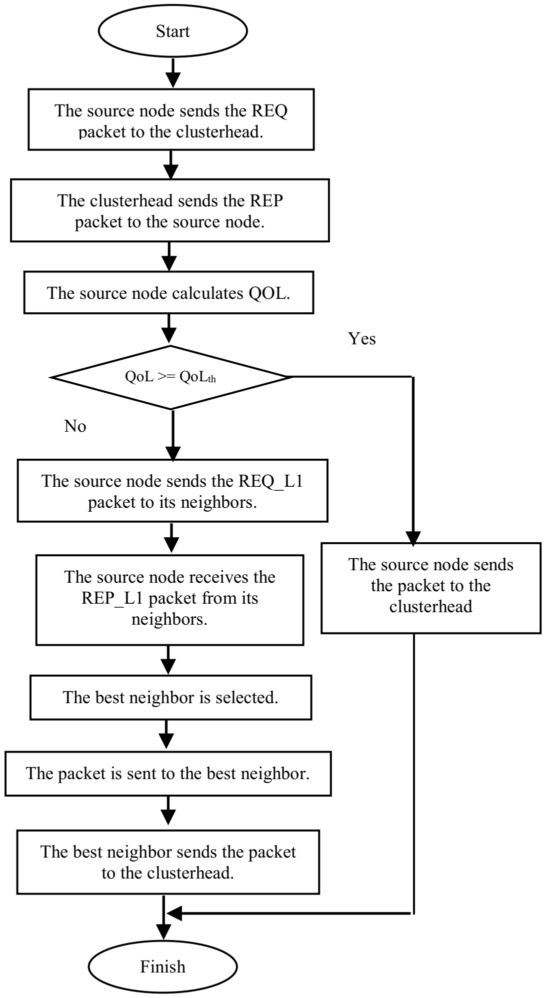

Figure 6. The first level flowchart of the proposed method

which indicates that the destination is within the cluster and return it back to the source node. The clusterhead of source node by receiving REP_L2 packet sends the data packet to the clusterhead of the destination. Then the clusterhead of destination node sends the data packet to the destination node within its cluster.

5) If the clusterhead that is received REQ_L2 packet is not the destination: The clusterhead set, check field as zero to declare that it is not the destination or the destination is not within its cluster and returns the REP_L2 packet to the source node. The clusterhead of source node make decision based on the information received from its neighbor clusterhead in a greedy way, to deliver the data packet to the desired clusterhead. At that time, the data packet is sent to the selected clusterhead.

6) The clusterhead selected by step 4 will repeat the steps for selecting the next step from step 1. And this process continues until the delivery to the destination is done. The steps in the greedy algorithm to select the best neighbor are as follows.

In a greedy method, in each step, the element selection is based on a certain criterion, regardless of the choices already made or will be considered in future. In the following, the function of the greedy algorithm in the proposed method is described. When the packet is delivered to the clusterhead that is neither the destination nor the destination within the cluster, this clusterhead gives source node information including the velocity and location by returning the REP_L2 packet. Then, the source node, according to the REP_L2 packets received from neighboring clusterheads, chooses the best suitable next clusterhead using the greedy algorithm. Equation (6) is evaluation function that is used in the greedy algorithm for evaluating clusterheads.

$$F = (\alpha \times |V_{source} - V_{selected}|) + ((1- \alpha) \times D) \qquad (6)$$

Where: D is a distance between the source node and selected node. (X_{source}, Y_{source}) and ($X_{selected}$, $Y_{selected}$) are coordinates of the source node and selected node and V_{source} and $V_{selected}$ represents the speed of the source node and node selected. α represents the weighting factor (1 = α). This step is repeated for each clusterhead to reach the data packet to the clusterhead of the destination node.

The second level of the proposed method is shown in detail in figure 7.

V. SIMULATION

This section focuses on simulation and evaluating of proposed routing method (NTLCRP) using NS-2.35 simulator. The proposed routing protocol is compared with AODV [12] and ACO [13], by taking into account different parameters such as packet delivery ratio and end-to-end delay. In table ɪ, the simulation parameters are described for the proposed technique. In order to fairly compare the protocols, the new method must be compared with protocols in the same environmental conditions. The movement of nodes is assumed in different directions, velocities and locations.

A. Evaluation of simulation results

In this part, important parameters such as packet delivery ratio and end-to-end delay are in two different perspectives, among different velocities and the numbers of vehicles are considered. The main reason for considering different velocity and number of vehicles factors in the simulation is that the link failure among vehicles or the disappearance of links between vehicles is due to the unpredicted velocity and number of vehicles in VANET. These two factors have a profound impact on the lifecycle of communication links and the quality of routing between vehicles indeed. As it is evident in table ɪ, the minimum velocity of the node is 60 km / h and the maximum velocity of the node is 120 km/h. The minimum and the maximum number of nodes in an environment are considered with 100 and 300 nodes respectively. Here are the simulation results for the different criteria of the proposed routing protocol that are shown and evaluated. In order to calculate the packet delivery ratio (PDR), the number of packets received at the destination is divided by the total number of packets sent from the source.

TABLE I. SIMULATION PARAMETERS

Value	Parameters
Velocity	60-120 km/h
Simulation area	1000*1000M2
Number of nodes	100-300
source/destination	Random
MAC type	IEEE 802.11
Data packet size	500-3000 bytes
Channel type	Wireless channel
QoLth	0.7

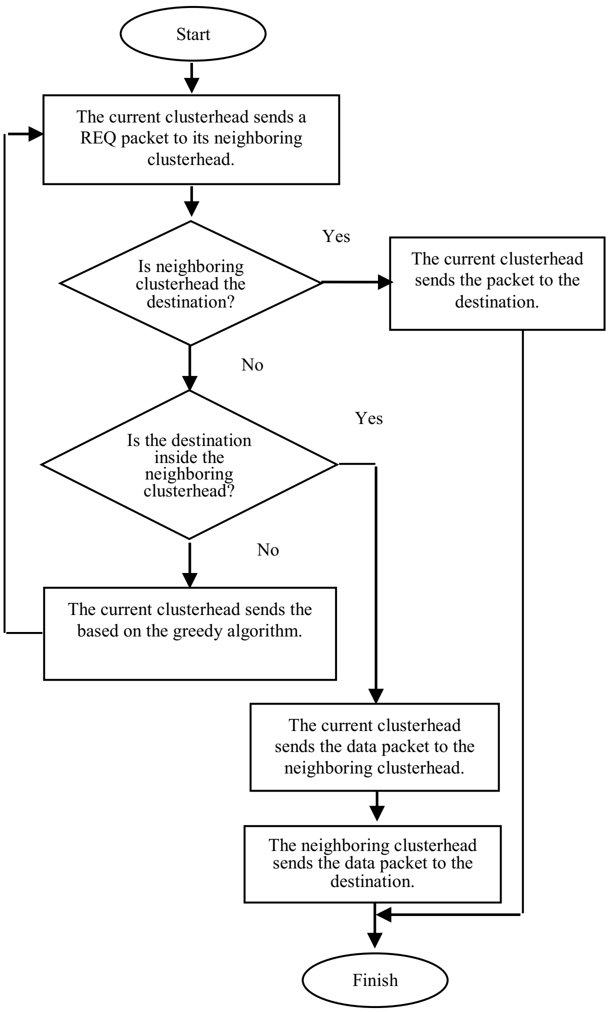

Figure 7. The second level flowchart of the proposed method

The packet delivery ratio reflects the accurate and proper routing protocol.

According to figure 8, the packet delivery ratio has decreased slightly by increasing velocity. The packet delivery ratio decreases with raising velocity because at high velocities the link failure can be increased. Due to the fact that it does not support multi-routing method in ACO, packet delivery ratio is decreasing with raising velocity. In the proposed routing protocol, since the most reliable links are

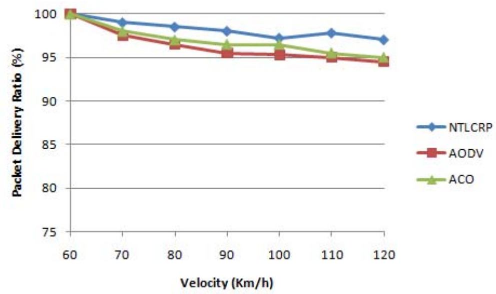

Figure 8. Comparison of packet delivery ratio at different velocities

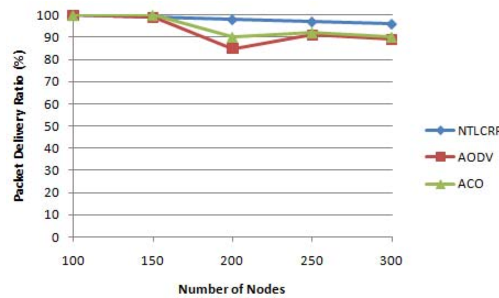

Figure 9. Comparison of packet delivery ratio in different number of nodes

selected between members of cluster and between clusterheads, the node will be selected at the lowest cost (better velocity, closer distance with the current node), hence the probability of a link failure is reduced and the packet delivery ratio in the destination is increased.

In figure 9, the changing in packet delivery ratio in the different number of nodes indicates the dependency of routing protocols on the number of vehicles. The new presented protocol has a higher priority prior to other two protocols per say. Some of the causes which lead to the decrease in packet delivery ratio are defined as insufficient bandwidth, the overhead of buffer and problems due to the propagation of corrupted and tampered packets. AODV suffers from more delay since the number of hops increases due to broken links or establishing entirely new routes to destinations.

The time taken by the data packet to arrive from the source to the destination node is called average end-to-end delay. The average end-to-end delay represents the time consumed for all buffering delays, path discovery, connection lines, retransmission process, and propagation time. In VANET, with increasing the velocity or increasing the density of the nodes, as soon as the loss of the communication link increases, therefore, the delay rises. In the new technique, as more stable paths are selected, thus fewer links are broken, so decreasing in average end-to-end delay are shown. As it is illustrated in figure 10, at high velocities, ACO routing algorithm has more delay than AODV and the proposed method. Because in choosing the shortest route, there should be ants as the backward ants for increasing the pheromone, so the delay will augment accordingly. But AODV protocol has a low latency at low

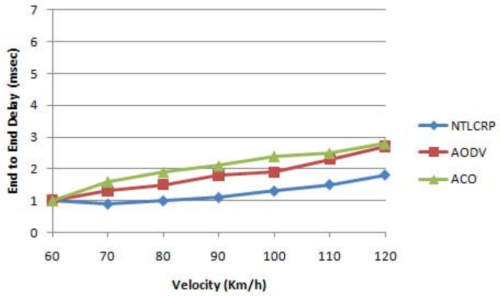

Figure 10. Comparison of end-to-end delay at different velocities

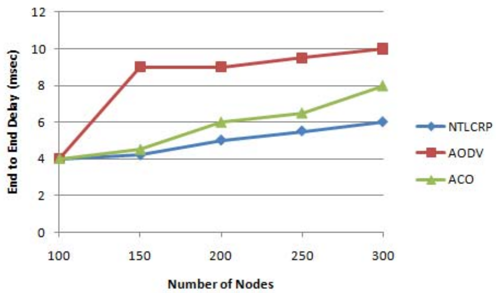

Figure 11. Comparison of end-to-end delay in different number of nodes

velocities, the reason for this is that, on shorter paths, the length of the links were also shorter and sending data packets between nodes requires less time, therefore latency is far less than long paths. In the proposed method, due to the consideration of multiple criteria for selecting the link, the delay is significantly reduced compared to the other two protocols.

According to figure 11 at the different number of vehicles, the end-to-end delay is highest in AODV routing algorithm. In the proposed method, the significant improvement in the end to end delay has been observed taking into account different criteria. As it is known, with increasing in the number of vehicles, the end to end delay raises but in the proposed method, with consideration of several parameters, there is a considerable decrease in the end to end delay.

VI. CONCLUSION

In this paper, a new reliable cluster based routing protocol that has two levels has been proposed. The reliable routing protocol ensures that high packet delivery ratio and less end to end delay are achieved. The proposed method is compared with AODV and ACO in NS-2.35 network simulator. In the first level, routing was done among members of the cluster. Data packet was sent to the clusterhead directly if source node has a strong link to the clusterhead; if not then the data packet was sent to the best neighbor of the source node. Two metrics such as QoL and distance are used in order to elect the best neighbor of the source node to choose favorable paths. After selecting the best neighbor, data packet was delivered to it, and then the best neighbor sent the data packet to clusterhead.

Afterward, the data packet was reached to clusterhead, and then routing entered its second level. At this level, routing was performed between clusterheads. For choosing the best path, the best link was selected between clusterheads via a greedy algorithm. The parameters of distance, direction and velocity were considered here to select links. The impressive results of the proposed method exhibit reducing end to end delay and increasing packets delivery ratio in the network. To select the best neighbor, QoL and distance are used. It is possible to achieve better performance by changing these parameters. In choosing the best neighbor of the clusterhead, a greedy algorithm is used. The greedy algorithm determines based on local information. It can be enhanced by replacing other protocols.

REFERENCES

[1] E.Moridi and B.Hamid, "RMRPTS: a reliable multi-level routing protocol with tabu search in VANET, "Telecommunication Systems, vol. 65, no. 1, 2017, pp. 127-137.

[2] R.Kasana, and K.Sushil, "Multimetric Next Hop Vehicle Selection for Geocasting in Vehicular Ad-Hoc Networks," International Conference on Computational Intelligence & Communication Technology (CICT), IEEE, Feb. 2015, pp. 400-405.

[3] M .Fekair, A.Lakas, and A.Korichi, "CBQoS-VANET: Cluster-based artificial bee colony algorithm for QoS routing protocol in VANET, " International Conference on Selected Topics in Mobile & Wireless Networking (MoWNeT), Apr. 2016, pp. 1-8.

[4] [4] R.Shukla, N.Tyagi, A.Gupta and K. Dubey,"A new position based routing algorithm for vehicular ad hoc networks,"Telecommunication Systems, 2015, pp. 1-16, doi:10.1007/s11235-015-0130-6.

[5] S.Boussoufa-Lahlah, F.Semchedine, and L.Bouallouche-Medjkoune,"A position-based routing protocol for vehicular ad hoc networks in a city environment, " Procedia Computer Science, Vol. 73, Jan. 2015, pp. 102-108.

[6] M.Fathian, G.Shiran and A.Jafarian-Moghaddam,"Two new clustering algorithms for vehicular ad-hoc network based on ant colony system,"Wireless Personal Communications, 2015, Vol. 83, No.1, pp. 473-491.

[7] M.Hatamian, H.Barati and A.Movaghar, "A new greedy geographical routing in wireless sensor networks, " Journal of Advances in Computer Research, Vol. 6, No. 1, Feb. 2015, pp. 9-18.

[8] S.Bhoi, P.Khilar and M.Singh,"A path selection based routing protocol for urban vehicular ad hoc network (UVAN) environment, "Wireless Networks, Vol. 23, Feb. 2017, No. 2, pp. 1-12.

[9] S.Harrabi , I.Jaffar and K.Ghedira, "Novel Optimized Routing Scheme for VANETs," Procedia Computer Science, Dec. 2016, Vol. 98, pp. 32-39

[10] [10] S.Chang and S.Lee,"A Routing Protocol for Urban Vehicular Multi-hop Data Delivery," Chinese Journal of Electronics, Feb. 2016, Vol. 25, No. 2, pp. 348-356.

[11] A.Joshi and R.Kaur, "A novel multi-cast routing protocol for VANET," IEEE International Advance Computing Conference (IACC), Jun. 2015, pp. 41-45.

[12] B.Ding, Z.Chen, Y.Wang and H.Yu, "An improved AODV routing protocol for VANETs,"International Conference on Wireless Communications and Signal Processing (WCSP), 2011, pp. 1-5.

[13] H.Rana, P.Thulasiraman and R.Thulasiram, "MAZACORNET: Mobility aware zone based ant colony optimization routing for VANET," IEEE Congress on Evolutionary Computation (CEC), Jun. 2013, pp. 2948-2955.