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ENHANCEMENT OF AODV ROUTING PROTOCOL PERFORMANCE VIA MODIFYING ROUTE MAINTENANCE PHASE MECHANISM

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Abstract

Vehicular Network (VANET)) is facing a lot of considerable issues affecting the network's performance. Factors like the massive number of nodes lacking inherent organization, also fast and frequent topological changes, makes routing one of the challenging tasks in VANET. In this paper, a new routing mechanism is developed to modify the operation's technique of AODV routing protocol to be used effectively in VANETs. The new mechanism of the modified AODV protocol (UAODV) is based on the idea of reducing the overhead of the protocol through the prevention of the broken link's predecessor node from the initiation and sending of the RERR toward the source node and after that, begins the procedure of the generation of a new message of the RREQ for repairing broken link rather than source node. Our developed mechanism illustrates that the UAODV protocol outperforms the original AODV in vehicular network environments. The results, which are verified by comparison with available experimental data, demonstrated that the average overhead of the UAODV has been reduced by 11.72% compared to original AODV. In addition to that, the number of the lost packets has been reduced by 31.90% and the transmission time for the packets has been decreased by 42.28% compared to original AODV. The proposed mechanism effectiveness evaluation is confirmed by comparing the efficiency of UAODV to the efficiency of the original AODV under different nodes mobility speed as well as different network load. The updated protocol (UAODV) improves the efficiency of the network by decreasing bandwidth consumption by protocol overhead.

Keywords: Enhancement, MANET, Mobility, Routing, VANET, Vehicular.

1. Introduction

Wireless networks are one of the vital technologies by which information and services electronically accessed via users, irrespective of their geographical positions. One of the major wireless networks are Mobile Ad Hoc Networks (MANETs) [1, 2] , they might be used in many real world applications and Vehicular Ad Hoc Networks (VANETs) are one of the significant applications [3]. Today, VANETs identify an emerging technology that based on MANET, it inherits all the challenges of MANETs. VANETs are developed for providing communications between vehicles and close fixed equipment and among close vehicles for providing comfort and safety for passengers.

VANETs were self-organizing, distributed communication networks created through moving vehicles. Also, they are facing a lot of considerable issues affecting the network's performance [4]. They have some hundred meters as a limited coverage, also it has been specified via the extremely high node mobility with limited freedom degree in mobility patterns. At the same time, the conditions of traffic might be rapidly changing between sparse and congested because of accidents, road constraints and traffic jams due to the fact that the vehicle mobility is creating highly-dynamic topologies. The vehicles might be within couple of meters proximity of each other in terms of heavy traffic congestions, while the distance might be hundreds of meters in terms of sparsely-populated roads [5]. Therefore, factors like the massive number of nodes lacking inherent organization, also rapid and frequent topological changes, makes routing one of the challenging tasks in VANET either because of slow reactions to the quick topology changes, or because of the explicit route establishment phase which is rendering the reactive protocols unfeasible for the majority of applications related to intelligent transport technologies (ITS) which have low-latency requirements. With regard to VANETs, there isn't a fixed topology because of the vehicles' mobility. Also, the factor of mobility is resulting in path loss and link breakage [6]. Packet loss is caused by recurrent link breakage; thus, degrading the performance of the network. There should be fast and continuous adaptation of Ad Hoc routing protocols to such unethical and unreliable conditions.

There are many types of routing protocols used in MANETs and VANETs. Ad Hoc on- Demand Distance Vector Routing Protocols (AODVs) is one of the most important protocols used in this type of networks. AODV routing protocol can be defined as one of the IP protocols by which the nodes are finding and maintaining routes to other network nodes [7]. In addition, AODV is a reactive routing protocol, as the route was created just when required. AODV has the ability of dealing with any type of mobility rate and many data traffics. There are two major phases of routing used by AODV [8] :

i. Route Discovery phase.
ii. Route Maintenance phase.

AODV can respond very quickly to the topological changes that affect the active routes, because of its adaptability to highly dynamic networks. On the other hand, a large number of control packets are generated when a link breakage occurs. These control packets increase the congestion in the active route as well as increasing packet loss and packets transmission time delay, which represents the most important drawbacks that affect the routing efficiency of AODV.

In this work, the main aim is modifying the operation mechanisms related to Ad Hoc on- Demand Distance Vector Routing Protocols (AODVs) for the purpose of enhancing its performance over many applications of MANETs, like VANETs.

In the case when there is a path disconnection between the source and destination because of node mobility or other reasons, the AODV routing protocol attempts on repairing the broken path through initiating as well as sending RERR message to source node for the purpose of informing the source along with all intermediate nodes that the destination through such path was unreachable [9]. When RERR is received via the source node, in the case when it still has the data which should be sent to unreachable destination, then it will start rediscovering the route to unreachable destination through using RREQ messages to flood the network for locating new route to destination. In addition, the processes of sending RERR as well as RREQ control messages for maintaining broken path consumed channel bandwidth due to high protocol overhead which leads for an increment in the number of lost packets and packet transmission time delay, the VANET performance is degraded via such problems. The presented study majorly contributes in modifying the route maintenance phase of AODV for repairing broken link between source and destination by decreasing protocol overhead. Consequently, decreasing bandwidth consumption leads to improve its performance.

2. Related Work

A lot of researches were conducted for improving AODV performance. A study conducted by Abbas et al. [10] built a novel system on the basis of feeding a few parameters of nodes including node mobility, residual energy, the number of hop counts and node mobility, via a fuzzy inference system for the purpose of computing the node trust level value, that might be utilized as one of the metrics for constructing an optimum path between the source and the destination. In addition, the simulation results specified that the suggested method is performing better compared to conventional AODV and lowest battery cost routing protocol with regard to network throughput, packet delivery ration, average control overhead, and average end-to-end delay.

Yadav et al. [11] suggested an approach of signal strength-based link availability prediction which will be utilized in AODV. The researcher showed that the link breakage time is estimated via the nodes, also they are warning the other nodes regarding the link breaks in the route. According to such information, either new route discovery or local route repair starts earlier compared to route breakage. The researcher showed that the identified results are showing that there was no considerable decrease in average end-to-end delays, packets drop and the ratio of packet delivery with regard to modified AODV compared to traditional AODV.

Kabir et al. [12] suggested a Pro-AODV (Proactive AODV), which is a protocol which applies the information from routing table of AODV for minimizing VANETs congestion while sustaining other metrics of performance at reasonable levels. The Pro-AODV efficiency is due to the fact that it does not need the execution of further logic, it was enough for knowing just the routing table size at each one of the nodes.

Zhang et al. [13] suggested an Extended Ad hoc On-Demand Distance Vector (EAODV) routing approach on the basis of Distributed Minimum Transmission (DMT) multi-cast routing. Based on the causes related to WSN's uncertain information like data fusion, random load or other impact factors, DMT based EAODV selects the forwarding routes that might be connecting more multicast receivers for the purpose of solving the routing optimization problem. Also, the approach suggests a dynamic strategy for changing the multi-cast tree structure on the basis of the property of WSN's node mobility. Furthermore, the experimental results are showing that the approach is efficiently enhancing the multicast routing effectiveness.

Sharma et al. [14] demonstrated that in MANET's communication process, the packet may also be delayed due to various reasons like congestion, link failure, and power failure. This constant update of variables leads to development of routing algorithms that consider delay and hop count for routing decision. Therefore, an improvement of AODV routing algorithm using adaptive fuzzy logic system is proposed. In the presented algorithm, each node will calculate its cost value based on input parameters, i.e., hop count and delay. Further, with the routing decision, optimal path route is selected based on minimum cost value. This leads to better utilization of the network in terms of packet delivery ratio and end-to-end delay. NS2.35 is used for simulation process and results show the better performance of proposed AAODV algorithm than standard AODV.

Kandali et al. [15] proposed a new broadcast approach based on the neighbourhood broadcasting methods. Based on this solution, they presented an improving Ad-hoc On-Demand Distance Vector Routing (AODV) to reduce the number of dropped packets, and minimize network overhead. The simulation showed encouraging results of their proposed approach.

Bamhdi [16] proposed a method by adapting the standard Ad hoc On-Demand Distance Vector (AODV) protocol to dynamically adjust transmission power usage, which is titled Dynamic Power-Ad hoc On-Demand Distance Vector (DP-AODV). This method used the dependence of a transmission range on density to achieve this improvement. The results demonstrated that as density increases, DP-AODV shows decrease in delay than AODV and offering better performance for highly populated networks exceeding 200 nodes. The simulation results showed that DP-AODV increase network throughput whilst reducing the node interference in a dense region, as well as it enhanced the overall network performance with respect to the increased packet delivery fraction, reducing the control overheads and jitter, enhancing overall throughput, reducing interferences and finally, shortening end-to-end delay in medium to high density conditions.

3. Ad Hoc on Demand Distance Vector (AODV) Routing Protocol

AODV routing protocol can be defined as one of the IP protocols by which the nodes are finding and maintaining routes to other network nodes. AODV is a reactive routing protocol, as the route was created just when required. The routing decisions are made using distance vectors, i.e. distances measured in hops to all available routers. AODV has the ability of dealing with any type of mobility rate and many data traffics as well as it supports unicast, broadcast, and multicast [7]. There are two major phases of routing used by AODV [8] :

i. Route Discovery phase.

ii. Route Maintenance phase.

Figure 1 shows the operation mechanisms of the AODV routing protocol.

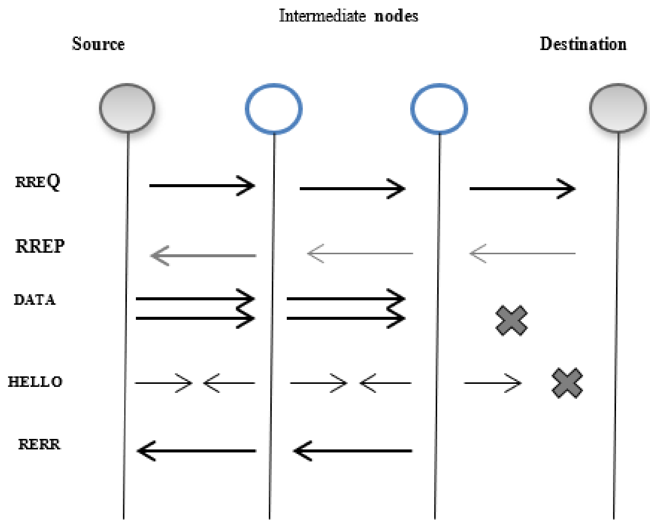

Fig. 1. AODV operation mechanism.

3.1. AODV route discovery phase

Route request (RREQ) message is broadcasted by the sender (i.e. the source node) for establishing a route to destination. A broadcast (id) is maintained by each node, such id is distinctively identifying RREQ when taken together with the IP address of originator [17]. Each time an RREQ is issued by the sender, it incrementally adds to its broadcast (id) as well as sequence number by one. When an RREQ message which isn't seen before by the received node, then it will setting up a reverse route back to the node in which RREQ came from, there is a lifetime value related to such reverse route. Also, the reverse route entry has been stored in addition to the information regarding the requested address of the destination. In the case when node receiving such message doesn't have a route to destination, then it will be rebroadcasting RREQ. In the case when the node has a route to destination, it will reply by unicast with RREP back to the node by which request was received. In addition, the reply will be sent back to sender through a reverse route that has been set by the RREQ, which is propagating back to source; nodes are setting up forward pointers to destination. As soon as RREP has been received by the source node, the route was established, then, the source starts sending data packets to destination [8].

3.2. AODV route maintenance phase

As mentioned in [8, 10] , the AODV route maintenance role is providing feedback to the source node when a link breakage occurs, for allowing the route to be re-discovered or modified. One of the most important drawbacks related to the design of original AODV is that a lot of control packets (overhead) were created with the occurrence of link breakage [18]. Consequently, the generated overhead consumes the bandwidth which leads to degrade the network performance. The route maintenance roles of original AODV starts in the case when the path between the destination and the source is disconnecting because of any reason, AODV attempts to repair the broken path through starting as well as sending ROUTE ERROR (RERR) message to source node for informing the intermediate nodes and the source that the destination through such path is unreachable. Then, the source nodes broadcasts RERR message with unreachable destination information to all network nodes. In addition, any host receiving RERR will invalidate the route and rebroadcast the RERR message. If the source node still has the data which should be sent to the unreachable destination following receiving the RERR message. It starts rediscover phase again to locate a new route to destination via using RREQ messages to flood the network. The process of flooding the network with RREQ and RERR control messages for maintaining the broken path increases the protocol overhead which leads to degrade the network performance [19].

4. Updated Protocol of AODV

The Updated AODV (UAODV) is different from original protocol of the AODV by the modification of original AODV route maintenance phase for the reduction of the overhead of the protocol through the prevention of the broken link's predecessor node from the initiation and sending of the RERR toward the source node and after that, begins the procedure of the generation of a new message of the RREQ for repairing broken link rather than source node. The UAODV has been based upon a system where the broken link's upstream node belonging to broken route (i.e., the old active one) is given the ability of re-discovering a new route from its location to unreachable destination. This has been shown to have feasibility due to the fact that the path between source node and any other node belonging to the old one (i.e., the broken path) doesn't change and could still be considered valid.

4.1. Operation mechanism of the UAODV protocol

As shown in Fig. 2, the operation mechanism of the proposed route maintenance phase of (UAODV) to rediscover and modify the broken path is done by any node sensing that the next hop link on active route has been damaged as a result of any reasons; it must perform the steps below:

i. Deactivates maintenance agent of UAODV from generating RERR message to prevent sending it to source node.
ii. Discontinue sending the received data packets to the following node.
iii. Buffered the packets that have been received from the sender node.
iv. Checks its routing table for whether or not there is another entry for a new path to unreachable destination.
v. Checks (TTL) parameter at IP header to compute the number of hops to unreachable destination.
vi. Incrementing the sequence number of the destination by one.
vii. Initiating a RREQ message.
viii. Increment RREQ id by one and broadcast it to every neighbour.
ix. Waiting for receiving an RREP from destination.

After receiving the RREP from destination or from any node that has a path to destination, the initiator of RREQ must perform the following operations:

i. Update the entry of the routing table for the path to destination, based upon new route.
ii. Begin to send the buffered data.
iii. Continue working like original AODV from this step on.

5. Modelling Scenarios

Two scenarios are modelled in this paper for the purpose of evaluating and analysing the efficiency of the suggested routing protocol (UAODV), these are:

i. Compare the efficiency of UAODV compared to the efficiency of the original AODV under different nodes mobility speed and fixed network load by fixing number of sources that generate packets to other destinations. In this scenario, the packet size and packet rate are kept with fixed value while the speed of the node is varied from 10 m/s to 50 m/s.

ii. Compare the performance of UAODV with the efficiency of original AODV at using different network load by varying number of sources that generate packets to other destinations and fixed nodes mobility speed.

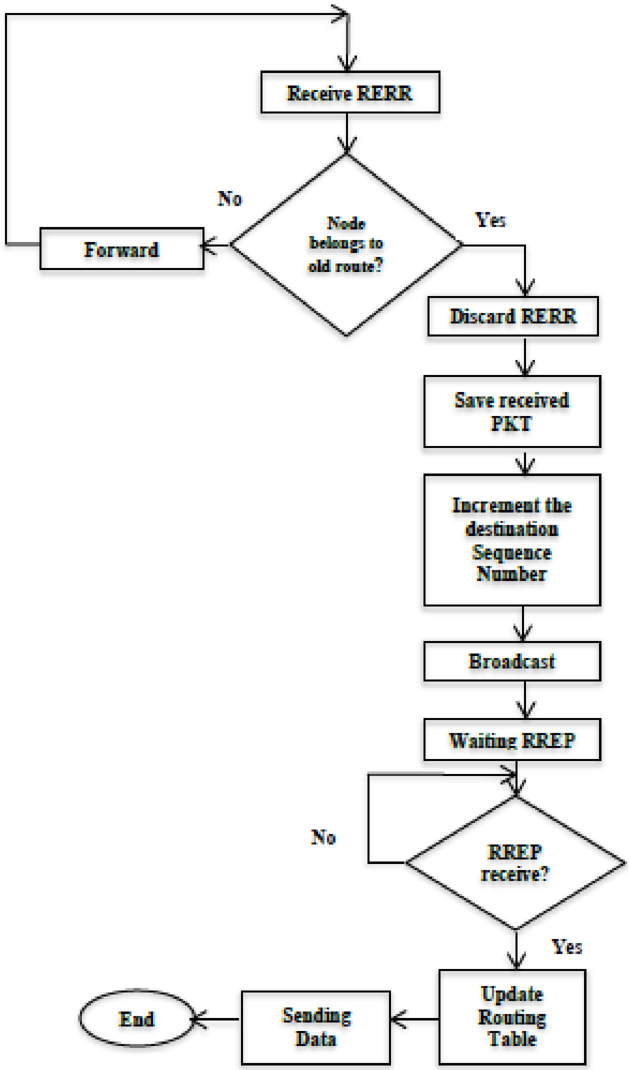

Fig. 2. UAODV Route maintenance phase performed by the upstream node to the link breakage.

6. Network Model Configuration

To evaluate the UAODV routing protocol, a network scenario with the following model specifications is modelled using OMNET++ network simulator:

i. The simulation time is set to be 500 seconds.
ii. The network area is set to be a (5000m x 1500m).
iii. Forty mobile nodes are distributed randomly as shown in Fig. 3.
iv. Six mobile nodes (sources) which have data must be sent are distributed randomly.
v. The nodes' speeds are distributed between 10m/s and 50 m/s.
vi. The node mobility is linear mobility pattern.
vii. Data packet size is set to be 0.5 Kbyte.
viii. The generation interval of data packets is set to be 0.05 second
ix. CBR traffic is considered at transport layer using UDP.
x. 802.11g is used as data link layer protocol.
xi. Channel bandwidth is set to be 54 Mbps.
xii. OMNET++ default parameters as explained in Table 1.
xiii. Routing protocols' parameters setting are set as shown in Table 2.

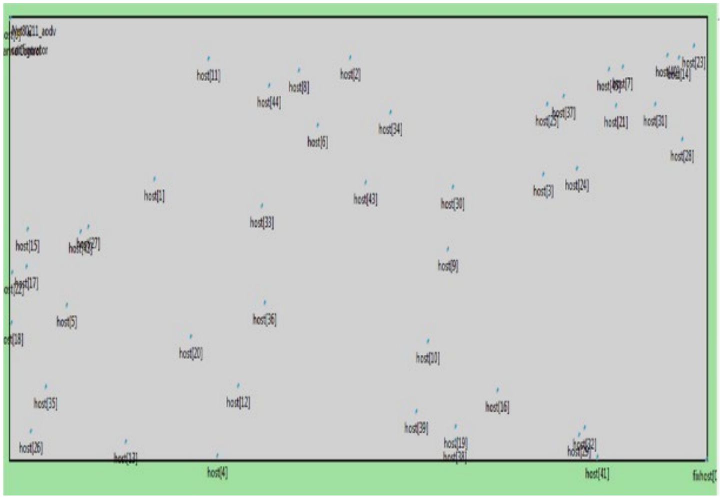

Fig. 3. Simulation area.

Table 1. Model parameters configuration.

Parameter name	Value
Playground	5000 m×100 m
Number of camera nodes	40
Distance between camera nodes	250 m
Packet size	0.5 kB
Packet rate	20 packet/s
Simulation time	500 s
Routing protocol	AODV,MAODV
MAC protocol	802.11 g
Radio bit rate	54 Mbps
Vehicle speed (meter/second)	10, 20, 30, 40 and 50

Table 2. Routing protocols parameters setting.

Parameter name	Value
Hello interval	1000 ms
Active Route Timeout	6000 ms
Allowed Hello Loss	2
Net Diameter	35 hops
Time between retransmitted request	3 s

7. Evaluation Metrics

The metrics that have been utilized for the evaluation of the performance of UAODV in comparison with the original AODV are:

i. Average Throughput of the Network: which is the mean rate of the successful packet delivery per unit time throughout a channel of communication [20].
ii. Lost Packets: which is the number of lost packets due to any reason.
iii. Packet Delivery ratio (PDR): which is the ratio between total number of the packets that have been received by the receivers and total number of the packets that have been sent by source [21].
iv. Average Packet Transmission Time (i.e., the delay) – which may be defined as average time delay that is needed by packets for reaching its destinations [21].
v. Protocol overhead: represents size of control message which are utilized by routing protocol for the discovery and maintenance of the route between source and destination during the simulation [12].

8. Result and Discussion

According to evaluation scenarios, two experiment types are implemented for the purpose of evaluating and comparing the effects of offered load and node speed variations on the performance of the MANET network uses UAODV protocol as a routing protocol as suggested in Fig. 2. The obtained results scope falls into showing that the (UAODV) routing protocol is suitable to be used in vehicular network applications, since it decreases the amount of protocol overhead generated to maintain the broken path as shown in Table 2.

8.1. Speed variation scenario

Figures 4(a) to (e) exhibit a comparison between the performance of the updated protocol (UAODV) and the performance of the traditional AODV under varying node speeds and fixed network load. The figures show that there are enhancements in UAODV performance according to the throughput of the network, ratio of packet delivery, number of lost packets, protocol overhead, and average transmission time delay. This is because, UAODV reduce the protocol overhead by pushing the broken link’s upstream node, belonging to the broken route (i.e. the old active one) for re-discovering a new route from its location to unreachable destination rather than the source node. The new alteration on the AODV routing protocol reduce the bandwidth consume by the protocol to send the control messages which leads to improve the network performance.

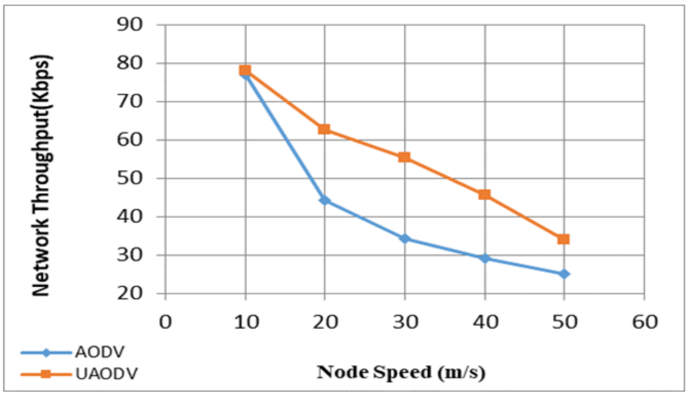

Fig. 4(a). Network throughput versus node speed.

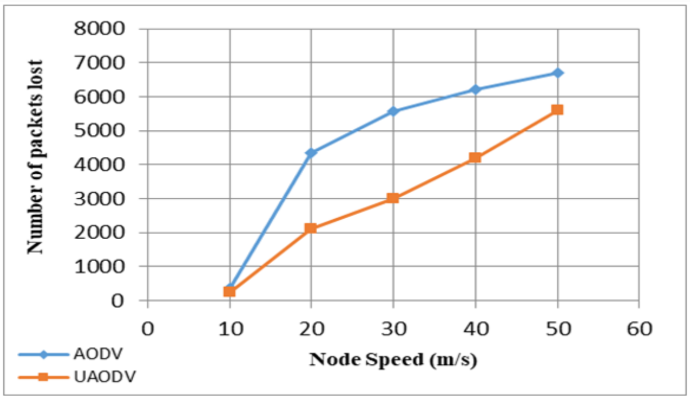

Fig. 4(b). Lost packets versus node speed.

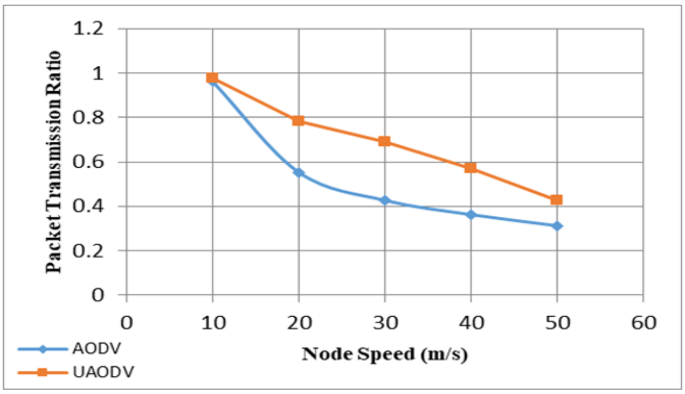

Fig. 4(c). Packet transmission ratio versus node speed.

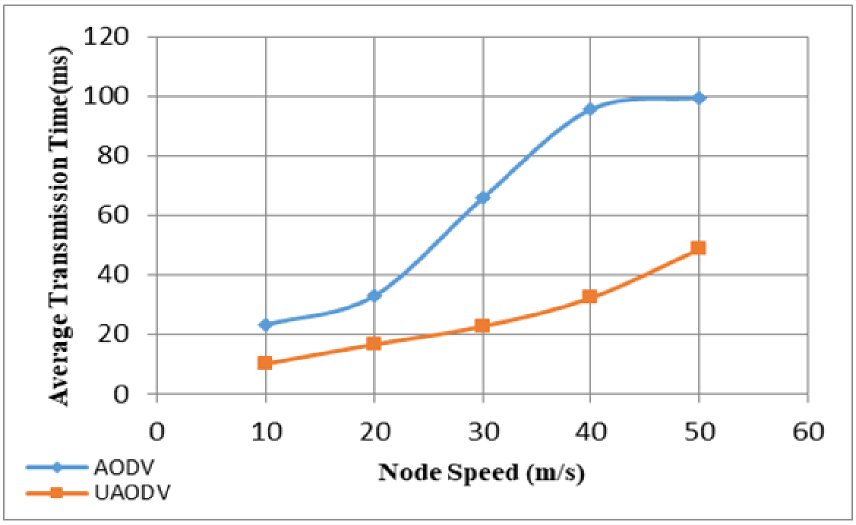

Fig. 4(d). Transmission time delay versus node speed.

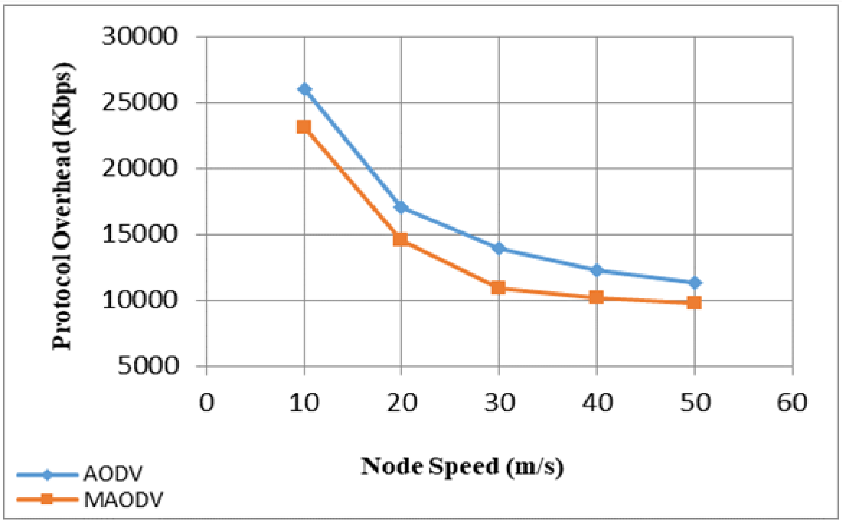

Fig. 4(e). Protocol overhead versus node speed.

8.2. Different network load

Figures 5(a) to (e) show the UAODV efficiency in comparison with the original AODV under a variety of the network loads and fixed speed of the node. It was noticed from results that there have been enhancements in the efficiency of the UAODV concerning the throughput of the network, the number of the lost packets, average time of transmission, ratio of packet transmission, and overhead of the protocol. Such enhancement has resulted from the reduction of the control messages of the protocol at the use of the UAODV protocol. The reduction of control messages leads to reduce the congestion which reduces number of packets lost as well as reduces bandwidth consumption which gives more network resources to transfer data rather than control messages.

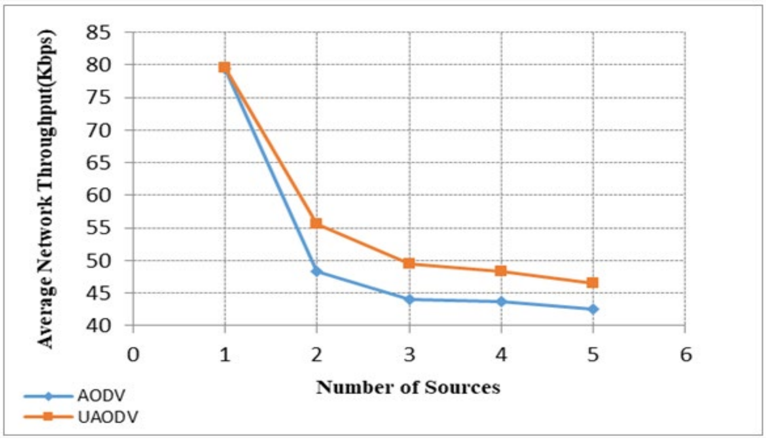

Fig. 5(a). Network throughput versus number of sources.

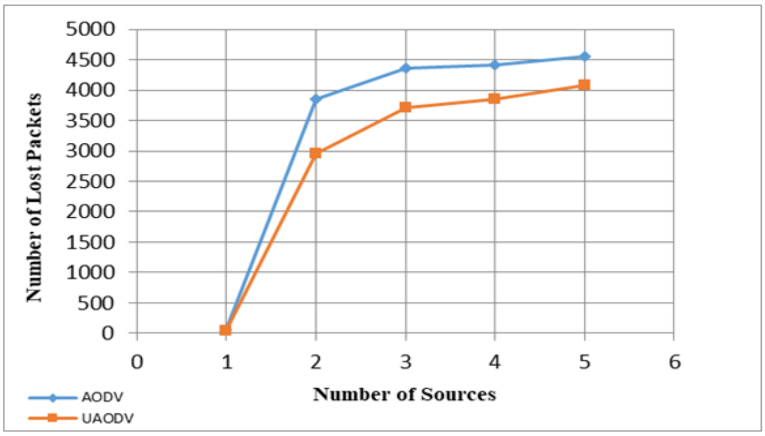

Fig. 5(b). Lost packets versus number of sources.

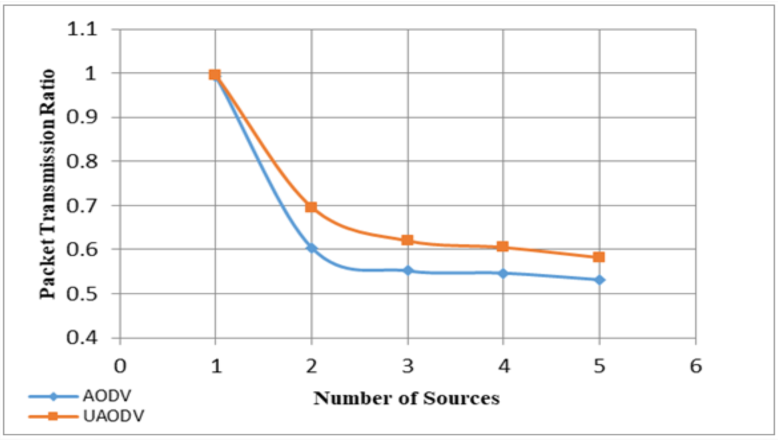

Fig. 5(c). Packet transmission ratio versus number of sources.

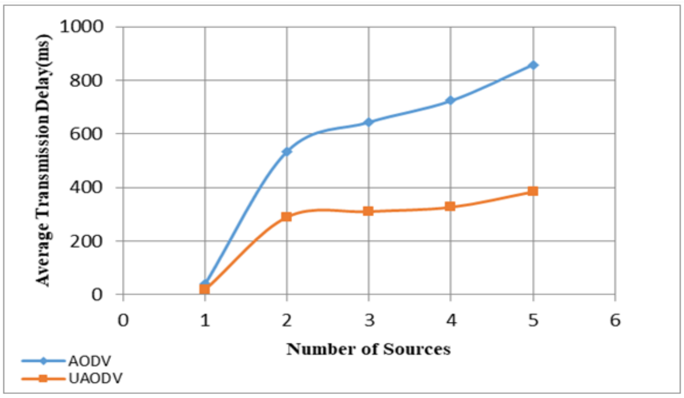

Fig. 5(d). Transmission time delay versus number of sources.

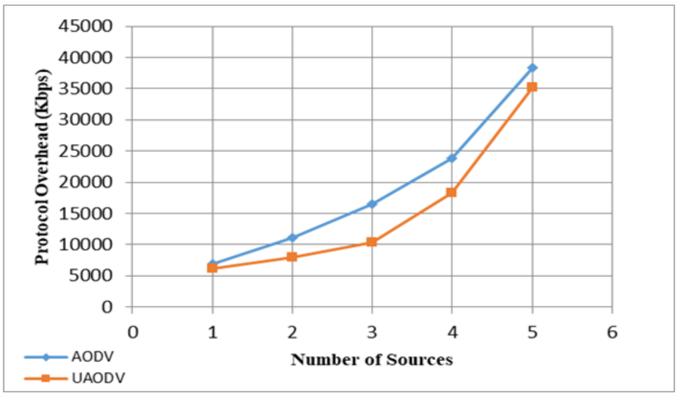

Fig. 5(e). Protocol overhead versus number of sources.

9. Conclusions

Vehicular Network (VANET) is self-organizing, distributed communication networks created through moving vehicles. VANETs are facing a lot of considerable issues affecting the network's performance such as lacking inherent organization and frequently topological changes, which makes routing one of the challenging tasks in VANET. This paper presented and evaluated an algorithm that works at modifying the AODV routing protocol operation for the purpose of improving the efficiency of the routing in the vehicular Ad Hoc networks. In this study, we introduced a novel algorithm based on modifying the repairing mechanism of AODV routing protocol for repairing broken link between source and destination by decreasing protocol overhead. Consequently, decreasing bandwidth consumption leads to improve its performance. The modified protocol (UAODV) is shown to have improved the routing performance by preventing maintenance agent of the AODV routing protocol from flooding the network with control messages (RREQ and RERR) that results in reducing the overhead of the protocol and the overflow of the network. The development is performed by forcing the upstream node of the broken link to rediscover, maintain, and modify the broken link.

Experimental results of our proposed method show that (UAODV) outperformance has been better in comparison to the AODV at various vehicle's speeds and network offered load which make it suitable to be used in VANETs environments.

References

1. Ilyas, M. (2017). *The handbook of ad hoc wireless networks* (1st ed.). CRC press.
2. Roy, R.R. (2010). *Handbook of mobile ad hoc networks for mobility models.* (1st ed.). Boston: Springer Science & Business Media.
3. Saha, S.; Roy, U.; and Sinha, D. (2015). Neural network based modified aodv routing protocol in VANET. *European Journal of Advances in Engineering and Technology*, 2(10), 17-25.
4. Yang, X.; Zhang, W.; Lu, H.; and Zhao, L. (2020). V2V routing in VANET based on heuristic Q-learning. *International Journal of Computers, Communications and Control*, 15(5), 1-17.
5. Lin, J.; Wan, J.; Wang, Q.; Deng, P.; Zhou, K.; and Qiao, Y. (2016). A survey on position-based routing for vehicular ad hoc networks. *Telecommunication Systems*, 62(1), 15-30.
6. Souidi, M.; Habbani,.; Berradi, H.; and ElMahdi, F. (2019). Geographic forwarding rules to reduce broadcast redundancy in mobile ad hoc wireless networks. *Personal and Ubiquitous Computing,* 23(5), 765-775.
7. Angurala, M.; Bala, M.; and Bamber, S.S. (2020). Performance analysis of modified aodv routing protocol with lifetime extension of wireless sensor networks. *IEEE Access*, 8, 10606-10613.
8. Perkins, C.E.; Belding-Royer, E.; and Das, S. (2003). Ad hoc On-Demand Distance Vector (AODV) routing. *Internet Engineering Task Force (IETF),* RFC3561, 10.
9. Jubair, M.A.; Mostafa, S.A.; Mustapha, A.; and Gunasekaran, S.S. (2018). Performance evaluation of ad-hoc on-demand distance vector and optimized link state routing protocols in mobile ad-hoc networks. *International Journal on Advanced Science, Engineering and Information Technology*, 8(4), 1277-1283.
10. Abbas, N.I.; Ilkan, M.; and Ozen, E. (2015). Fuzzy approach to improving route stability of the aodv routing protocol. *EURASIP Journal on Wireless Communications and Networking*, 1/205, 1-11.
11. Yadav, A.; Singh, Y.N.; and Singh, R.R. (2015). Improving routing performance in aodv with link prediction in mobile adhoc networks. *Wireless Personal Communications*, 83(1), 603-618.
12. Kabir, T.; Nurain, N.; and Kabir, M.H. (2015). Pro-aodv (proactive aodv): simple modifications to aodv for proactively minimizing congestion in vanets. *International Conference on Networking Systems and Security (NSysS)*, 1-6.
13. Zhang, D.-g.; Song. X.-d.; Wang, X.; and Ma, Y.-y. (2015). Extended aodv routing method based on distributed minimum transmission (DMT) for WSN. *AEU-International Journal of Electronics and Communications*, 69(1), 371-381.
14. Sharma, V.; Alam, B.; and Doja, M.N. (2018). Performance enhancement of AODV routing protocol using ANFIS technique. *Quality, IT and Business Operations*, 307-312.

15. Kandali, K.; Bennis, H.; Mohamed, B. (2019). A novel route discovery mechanism based on neighborhood broadcasting methods in VANET. *International Conference on Artificial Intelligence and Symbolic Computation*, 1-12.
16. Bamhdi, A.M. (2020). Efficient dynamic-power AODV routing protocol based on node density. *Computer Standards & Interfaces*, 70, 103406.
17. Darabkh, K.A.; Judeh, M.S.A.; Salameh, H.B.; and Althunibat, S. (2018). Mobility aware and dual phase AODV protocol with adaptive hello messages over vehicular ad hoc networks. *AEU-International Journal of Electronics and Communications*, 94, 277-292.
18. Ahmed, A.; and Tiwari, A. (2021). Aodv_ext_bp_dsr–a hybrid aodv and dsr protocol. *Materials Today: Proceedings*.
19. Deepak, S.; and Anandakumar, H. (2019). AODV route discovery and route maintenance in MANETs. 2019 *5th. International Conference on Advanced Computing and Communication Systems(ICACCS),* 1187-1191.
20. Shantaf, A.M.; Kurnaz, S.; and Mohammed, A.H. (2020). Performance evaluation of three mobile ad-hoc network routing protocols in different environments. *2020 International Congress on Human-Computer Interaction, Optimization and Robotic Applications (HORA)*.
21. Khanh, Q.V.; Ban, N.T.; Nam, V.H.; Tuan, D.M.; and Han, N.D. (2019). Survey of recent routing metrics and protocols for mobile ad-hoc networks. *Journal of Communications*, 14(2), 110-120.