Reducing message overhead of AODV routing protocol in urban area by using link availability prediction

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Abstract—**Mobile ad hoc networks are special kind of wireless networks, there is no fixed structure in these networks but they have nodes movement ability that add their complexity. These networks are established without defined structure and mostly used in military services, rescue operation in damaged areas, conferences and etc. According to these networks characteristics, different routing protocols have been proposed; it can be addressed to AODV protocol. In this paper we have optimized AODV routing protocol performance by using link availability prediction in urban area by Hello message mechanism. In order to modeling urban area we employed Manhattan mobility model for node's movement. The results of simulations show that new method reduces message overhead and average of broken links metrics relative to classic AODV algorithm.**

Keywords— Mobile ad hoc networks; AODV routing protocol; Link availability prediction; Manhattan mobility model.

I. INTRODUCTION

Because of wide range applications and services, wireless networks are rapidly developed and their services are optimized. Wireless networks are divided into two categories architecturally; structured and non-structured networks. Requiring calculations in order to access nodes to each other is considered as main characteristics in wireless networks. A non-structured network or mobile ad hoc network involves only mobile nodes that they are employed for data exchange and network management without any fixed station and wired connection. Each mobile node does not act like a host but it acts like a router and nodes are responsible for transmitting packets to network's mobile nodes. Usually, mobile ad hoc network topology consists of nodes entering and leaving network continuously. There is no central control or fixed structure for network configuration support and network reconfiguration [1]. Generally, these networks involve combination of the same nodes that communicate without central and wirelessly.

Because of mobile ad hoc network unavailable nature, rout discovery and maintenance issues are important. By considering Limited battery power and lack of wide bandwidth in each node we seek cost effective routing methods. In these networks, data packets are transferred by a storing and retransmission continuous operation via interface nodes and the aim of routing is to transfer packets reliably from source to destination node. In addition quantifying delays is another goal in routing process. Different routing algorithms are proposed for these networks with unique advantages and disadvantages. From programming perspective, routing protocols are divided into two categories: Proactive and reactive protocols. AODV Protocol proposed by Perkins [2], is a popular routing algorithm for mobile ad hoc network, it is reactive and also one of effective routing protocols.

Node's mobility model is a main issue in MANETs. These models are responsible for dictating movement patterns to mobile nodes across network. Since mobility patterns can play an important role in routing protocol productivity, so, the aim of movement models is to imitate movement pattern in real application. Several mobility models have been proposed in order to ad hoc network modeling. RWP is one of famous mobility models. In this model each node selects other node randomly as destination and moves toward it with constant speed in $[0,V_{max}]$. After getting to destination node, stops in a random period and then selects other node and repeat previous procedure. In this model, next destination node, speed and stop period are selected randomly [3]. Besides RWP movement model, real movement models have been proposed. For example, in order to modeling movement of army facilities and entering related parameters, RPGM model is proposed. This model based on tanks group movement toward defined several destinations in battle field [4]. Currently, freeway mobility model and also Manhattan model were proposed that the movement of nodes is limited to street width [5]. In [6] route available time under different movement models and its effect on routing protocols are analyzed.

In this paper, a new method has been proposed in order to reduce message overhead of AODV algorithm in urban area by predicting links availability. By predicting neighbor nodes positions it can be determined probability of link termination with source node, so they can be deleted from active neighbors list. Since these neighbor nodes cause to broadcast some RREQ messages and consequently unsuccessful RREP messages in network. We used Manhattan mobility model in order to modeling urban area for obtaining real results. Previously several researches have been conducted related to this issue which we will address to them. In [7] AODV-AP algorithm has been proposed that restricts the route discoveries for inaccessible nodes in

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network and increases AODV algorithm efficiency by predicting other node's accessibility via common routing operations and storing it in routing tables. In [8] an optimized AODV algorithm was proposed by using Hello message mechanism in RWP mobility model that reduces message overhead by predicting nodes link availability. In [9], a new routing algorithm was proposed based on node's movement prediction in urban area that it is effective relative to other routing algorithm. In [10], a new algorithm based on AODV using nodes mobility prediction has been proposed that controls discovery, maintenance and switching route by estimation of distance and direction of nodes mobility.

In sections 2 and 3 the classic AODV algorithm and Manhattan mobility model reviewed and in section 4 a proposed method and its efficiency evaluation are presented and section 5 concluded the article.

II. INTRODUCTION TO CLASSIC AODV PROTOCOL

AODV protocol is a reactive dynamic routing algorithm that route discovery is conducted when a new route is required. When a source node needs to transmit a packet to destination node, in case that there is no routing information in its routing table, a route discovery procedure is carried out by broadcasting a RREQ message. Upon receiving RREQ message, every node creates or updates reverse route to returning to source node. If the node which has receives RREQ, is not destination node or if it has not any fresh route to destination, it has to rebroadcast the RREQ packet. In other case a RREP was created and sent to source node by reverse route. Similarly, forward destination route is updated receiving RREP. When RREP reach source node, route discovering period is ended and a new route is created and now it can be used for sending waiting data packets in buffer.

When a route is created toward defined destination, each node should use a number of links or network layer mechanisms in order to preserve the route. In other words, current node tries to know accessibility of next hop toward destination node. In AODV a rout is usually preserved by obligation of sending periodical Hello message in defined periods by nodes to their neighbors. Failure in receiving tow continuous Hello message by one neighbor is considered as termination of link between node and that neighbor. In this case a RERR message is created and sent to related nodes. In case of forwarding RERR message each node updates its routing table by invalidating corresponding route and finally broken routes are omitted from routing table.

III. MANHATTAN MOBILITY MODEL

Manhattan mobility model was proposed for urban area mobility modeling. In this model, mobile nodes allowed to move in vertical and horizontal streets on map. Nodes can turn left and right or continue directly in vertical and horizontal street intersection. This model uses area maps which have vertical and horizontal streets and every street has two lanes in both sides. A mobile node's speed in a period depends on node's speed in previous period. Node's speed is limited by front nodes in similar lane. This model depends on two dimensional space and time and also environmental and geographical limits are considered in nodes mobility.

IV. PROPOSED METHOD

According to this fact that nodes move continuously in mobile ad hoc networks and it is possible that the nodes got away and as a result, their link terminated and they left radio range, so, receiving Hello massage from neighbors in current time is not reason for node and neighbor link availability in defined future; Since it is possible that in period between two continuous Hello messages or in defined future, the link is expired. AODV classic algorithm without attention to this issue, broadcasts RREQ message to its all neighbors when a new rout discovery is required, the neighbors continue this procedure and so on, that it lead to broadcasting massive RREQ messages in network that most of them fail because of node's link unavailability. Thus, it is better that every node predicts its link availability with neighbors for next defined period and save them in order to prevent sending RREQ messages to neighbors which likely their links will expire.

It is assumed that all nodes are equipped with GPS[1] that announces geographical position, speed and direction of movement. When a node sends Hello message, it sends these data in separated fields in Hello message pack. The neighbor nodes after receiving these data, predict radio link availability by following method, so, link availability and unavailability are stored as numerical parameter in a table. In this case, every node can predict that which neighbor node leaves neighborhood in near future. The results of this prediction are stored in prediction table in each node. So, in case of route discovery need, before sending RREQ message by source node, according to its prediction table, number of its neighbors, by possibility of link expiration are omitted from RREQ message sending list and it will send RREQ messages only to the neighbors with link availability confidence. The neighbors send message similarly until destination node receives the message. In this case number of failed route request and route reply packets is reduced in network and finally, message overhead level is reduced because of discovery and maintenance operation improvement.

A. *Manner of prediction*

In order to obtain close to reality movement and organized mobility direction of nodes, their movement pattern is considered in urban area so we use Manhattan mobility model. For doing so, urban area map is analyzed and delivered to nodes in comprehensible manned. The map involves vertical and horizontal streets and their intersections in desired amount and it can be written as a simple text file with defined format. Information about number and amount of vertical and horizontal streets,

1 Global Positioning System

movement direction, their length, intersections and etc. is entered in a text file and sent to all nodes. By this method an approximately real area urban is provided for nodes in a text file structure to prediction operation. "Fig. 1" shows city map text file format and "Fig. 2", indicates some part of prepared text file related to a city map.

```
HOR_STREET_NUM <num_of_horizontal_street>
VER_STREET_NUM <num_of_vertical_street>
LANE_NUM <overall_num_of_lanes>

LANE <street_id> <lane_id> <direction> <start_x0> <start_y0> <end_x0> <end_y0>
<total_number_of_crosspoints_in_this_lane> <vmin> <vmax>
CROSSPOINT <crosspoint_id> <street_id> <lane_id> <direction> <position_x><position_y>
CROSSPOINT <crosspoint_id> <street_id> <lane_id> <direction> <position_x><position_y>
...
LANE <street_id> <lane_id> <direction> <start_x0> <start_y0> <end_x0> <end_y0>
<total_number_of_crosspoints_in_this_lane> <vmin> <vmax>
CROSSPOINT <crosspoint_id> <street_id> <lane_id> <direction> <position_x><position_y>
CROSSPOINT <crosspoint_id> <street_id> <lane_id> <direction> <position_x><position_y>
...
```

Figure 1. City map text file's format

```
HOR_STREET_NUM 2
VER_STREET_NUM 2
LANE_NUM 8
LANE 0 0 1 0.10 332.33 999.90 332.33 4 1.00 10.00
CROSSPOINT 0 2 0 1 332.33 332.33
CROSSPOINT 1 2 1 -1 333.33 332.33
CROSSPOINT 2 3 0 1 665.67 332.33
CROSSPOINT 3 3 1 -1 666.67 332.33
LANE 0 1 -1 999.90 333.33 0.10 333.33 4 1.00 10.00
CROSSPOINT 0 3 1 -1 666.67 333.33
CROSSPOINT 1 3 0 1 665.67 333.33
CROSSPOINT 2 2 1 -1 333.33 333.33
CROSSPOINT 3 2 0 1 332.33 333.33
LANE 1 0 1 0.10 665.67 999.90 665.67 4 1.00 10.00
CROSSPOINT 0 2 0 1 332.33 665.67
CROSSPOINT 1 2 1 -1 333.33 665.67
CROSSPOINT 2 3 0 1 665.67 665.67
CROSSPOINT 3 3 1 -1 666.67 665.67
```

Figure 2. Some parts of a sample map text file used in Manhattan model

The possibility of different movement vehicles with different speed is high but it is assumed that each node has constant and defined speed and a node in its speed period cannot change its speed. So, according to this fact that speed, movement direction and current position of each vehicle will be transferred to other neighbors, thus the nodes can estimate their and the neighbor's geographical position after defined time and calculates distance.

In "Fig. 3" a parts of simple map related to urban area shown by considering four mobile nodes a, b, c, d, with directional streets and intersection. Mobile nodes can position in different places of a map. If every small circle on map is considered as a node and every big circle is considered as radio range, so two desired nodes on map in the same radio range establish a link and became neighbor.

For example in map shown in "Fig. 3", node A and B, B and C and also C and D establish a link between together and became neighbor. Their relations are shown with dashed lines. Thus by considering different combination of two nodes on map, more links are made, but limited number of these links is remained and others are broken because of increasing distance and leaving radio range. Using links with probability of breaking is unreliable for routing that cause data packets reduction and increase RREQ and RREP messages in network.

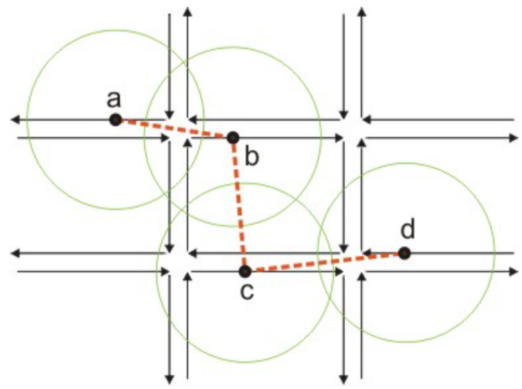

Figure 3. City map with nodes in streets

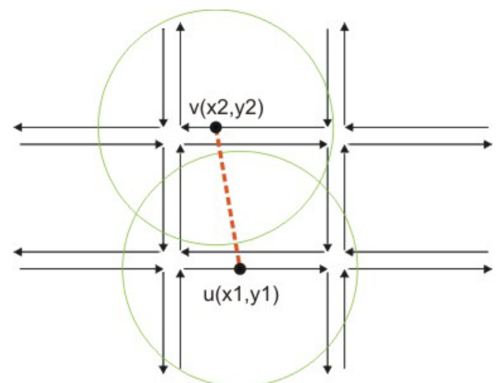

Figure 4. The map before prediction

In "Fig. 4" there is a link between nodes u and v shown in dashed lines. In other words nodes v and u is neighbor since they are in each other radio range. (x_1, y_1) and (x_2, y_2) are coordination of nodes u and v respectively. By assuming that u and v move by speed v_1 and v_2, (v_1 is four time more than v_2). After passing t time (for example period between two Hello messages) Nodes in new positions are shown in "Fig. 5" according to (v= x/t).

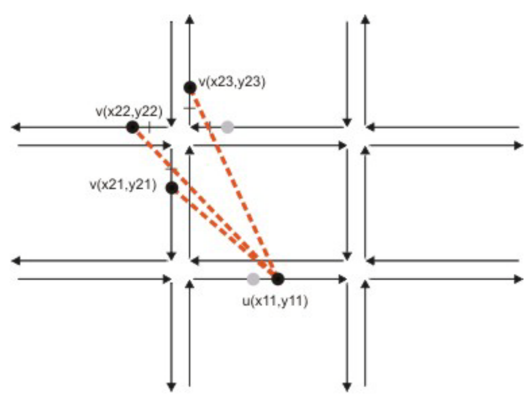

Figure 5. Node positions in new position on map after t time

As you see, the new position of node v is predicated in one of the next three coordination ((x_{21}, y_{21}), (x_{22}, y_{22}), (x_{23}, y_{23})) and new position of node u is predicted in next coordination (x_{11}, y_{11}). Now, based on nodes u and v next positions, node u can calculate direct distance between itself and three next positions of v by "(1)", "(2)" and "(3)".

$$\sqrt{(x_{11}-x_{21})^2+(y_{11}-y_{21})^2} \tag{1}$$

$$\sqrt{(x_{11}-x_{22})^2+(y_{11}-y_{22})^2} \tag{2}$$

$$\sqrt{(x_{11}-x_{23})^2+(y_{11}-y_{23})^2} \tag{3}$$

Equation (1) calculates distance between next position of node u and the first next position of node v. Like that, (2) and (3) calculate distances between next position of node u and the second and third next positions of node u respectively. If each of these direct distances is lower than nodes radio transmitting radius, R, it means that two nodes will be in each other radio range. So, if direct distance between next position of node u and each three next position of node v lower than R, it means that in each three states they are in each radio range that link of u and v nodes is available minimum in t. Thus node u will have prediction filed of node v equally to 1 in its prediction table. But if distance of three next positions of node v with next position of node u is more than R even in one of the states, the link expiration is possible. So, Node u will have prediction field related to node v equally to 0. Other nodes continue this procedure with their neighbors. All nodes will have link availability status among neighbors until the next Hello message or defined time, t. This function is conducted as periodically after receiving Hello message from neighbors and prediction table is updated.

B. Predication table specification

Each record in node's prediction table involves characteristics of node's link with one of current neighbors. This characteristic consists of neighbor node's IP address plus 0 or 1 that indicates link availability status. So each node's prediction table involves records for all current neighbors with "neighbor's IP address" and "its link availability status" fields in each record that link availability status is 0 or 1 indicating stability of link between source node and related neighbor.

TABLE1. SAMPLE OF A NODE'S PREDICTION TABLE

Neighbor's IP address	Link availability status
192.168.0.2	1
192.168.0.3	1
192.168.0.4	0
192.168.0.5	1

For example if four records of table 1 are source node prediction table records with IP address equal to 192.168.0.1, IP address field that lead to 2, 3, 4, and 5 are neighbor nodes that related to source node and source node link availability status field is a number that presented in record's next field. In this example the source node link availability status field number with IP address equal to 192.168.0.4 is 0, it means that the link expiration is possible.

Prediction table records are updated in each Hello message sending and receiving response from neighbors and extra records related to expired links are omitted. If the positions of current neighbors change, these changes are applied in related record and in case of new neighbor, a new record is created in node prediction table. In case of omitting a neighbor because of expiration of link, its record is omitted from node's prediction table to prevent undesired growth in prediction table and accordingly overhead by extra information.

C. AODV algorithm after appling proposed method

As before mentioned, every node can predict that which node will leave neighborhood, so the results of this prediction are in node's prediction table. Thus in case of new route discovery requirement the source node prevent sending RREQ message to neighbor with zero link availability status field and send route request message only to neighbors with available link. The neighbors continue this procedure and so on. In this case the number of unsuccessful route request and route reply packets because of link expiration is reduced and finally control packet reception is reduced in route discovery and maintenance operations in the network. It is important to note that prediction table and also conducting the prediction procedure have overhead but according to simulation results the ratio of this overhead is trivial compared with results of algorithm optimization.

D. Performance evaluation of proposed method

1) Simulation parameters

All simulations were carried out by Glomosim network simulator [11, 12]. Manhattan mobility model was used and simulation area was considered in 800m × 800m to 1600m × 1600m in different simulations. Minimum radio range of every node is 250m and "2-Ray Path Loss" model was employed as broadcast model. In MAC layer, MACA protocol is used with bandwidth of 2 mbps. Node's movement speed is between 0m/s to 10 m/s that different speeds were considered in different simulations. Node's stop or pause time was selected 10 to 300 seconds randomly and number of nodes was ranged between 20 to 70 nodes. Every point in diagrams was obtained from average of 30 simulations with distributed nodes in different primary positions.

After randomly distribution of nodes in simulation environment the nodes move 60 seconds in order to distribution in simulation environment. Then 20 data sessions start. Size of each packet is 512 bytes and sending ratio is four packets per second. Maximum number of packets for sending in each data session is 60000. So a 60000 packets mass can be received by 20 selected destinations. 20 sources and 20 destinations are selected randomly. The movement is continued a period of 1800 seconds. All data sessions use CBR traffic model and client and server nodes number is selected randomly.

2) Simulation modes

Simulations of proposed method were carried out according to nodes and environment characteristics in three different modes:

- **Simulation in different node speeds:** In this mode number of nodes and environment size are considered 50 and 1000m×1000m respectively. But nodes speed ranges from 0 to10 m/s. Thus different simulations were conducted with speeds 0, 0-2, 2-4 and so on.
- **Simulation in different node numbers:** In this mode the environment size is 1000m ×1000m and nodes speed is 0-3 m/s, but the number of nodes in different simulations ranges from 20 to 70.
- **Simulation in different environment size:** In this mode the number of nodes is fixed and equals to 50, and nodes speed ranges between 0-3 m/s but area size ranges between 800m×800m to 1800m×1800m in different simulations.

3) Simulation metrics

In order to evaluation of proposed algorithm's performance and comparison with classic AODV algorithm, different metrics were evaluated in different simulation modes. Studied metrics are:

- **Message overhead**: The number of network layer controlling message transmitting.
- **Average of broken links**: Average of broken links between nodes in a simulation.

"Fig. 6" shows network scenario selected for evaluation of proposed method. We simulate approximately real area that involves different blocks which there are vertical and horizontal streets between these blocks. Dimensions of each block is 100m×100m, so, the length of each street between two intersections is 100m. For example, when the area dimensions are 1000m×1000 m, this environment will be like "Fig. 6".

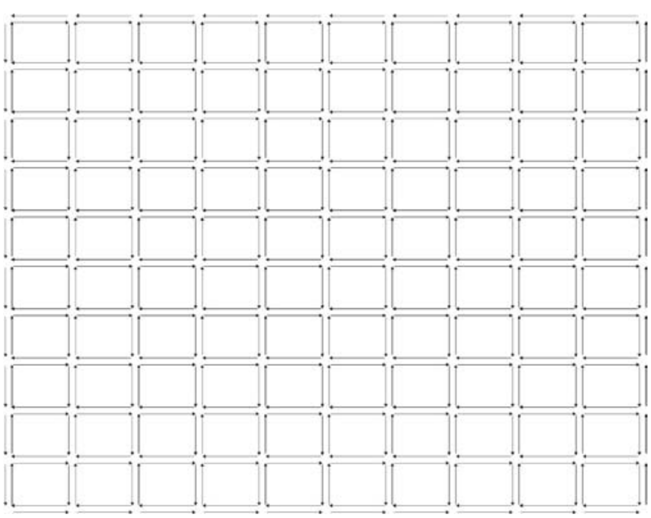

Figure 6. A simulation area with 1000m×1000m using Manhattan model

4) Simulation results

- *Average of broken links*

Average of broken links between nodes and their neighbors in different simulations with different speeds, different number of nodes and different dimensions are shown in diagram of "Fig. 7", "Fig. 8" and "Fig. 9". As you see, in proposed method there are lower broken links relative to main algorithm. Thus, by using new method only available links are made. According to this fact that links are created after prediction, so probable unavailable are prevented and accordingly, average of link break is quantified.

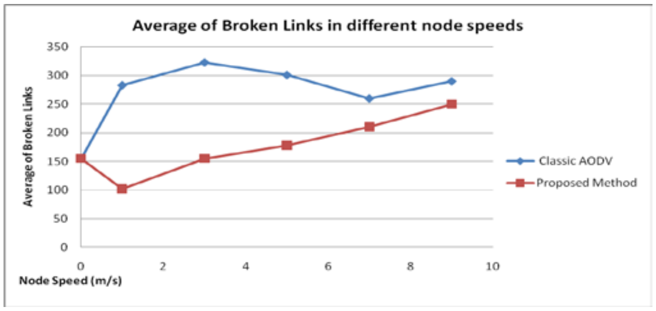

Figure 7. Average of broken links in different node speeds

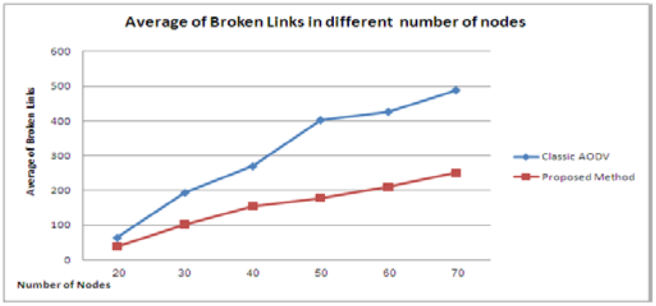

Figure 8. Average of broken links in different number of nodes

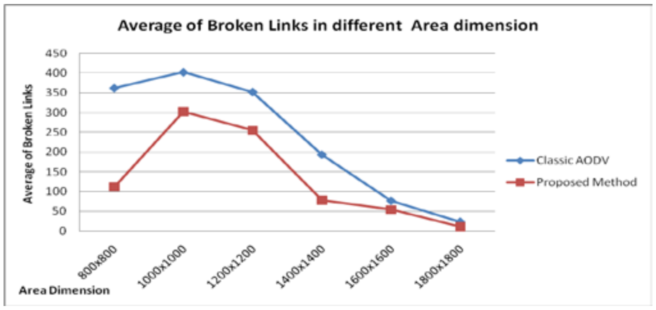

Figure 9. Average of broken links in different area dimension

- *Message overhead*

Control packet reception involves number of route request, route reply and Hello message packets that they were evaluated in three different simulation modes with different speeds, different number of nodes and different dimensions and shown in "Fig. 10", "Fig. 11" and "Fig. 12".

In proposed method control packet number reduced considerably in three modes. Since because of prediction of link between source node and its neighbors in next time, in new method some neighbors are omitted from message broadcasting list, so the number of unsuccessful route request and route reply packets are reduced and as a consequence, control packet reception is reduced in route discovery and maintenance operations. According to this fact that in high speeds, the probability of error in prediction is high, so in low speeds the proposed method's performance will high. Totally, our proposed method has high performance in low speeds.

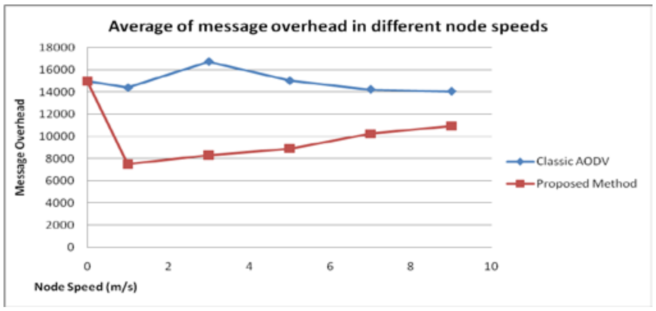

Figure 10. Average of message overhead in different node speeds

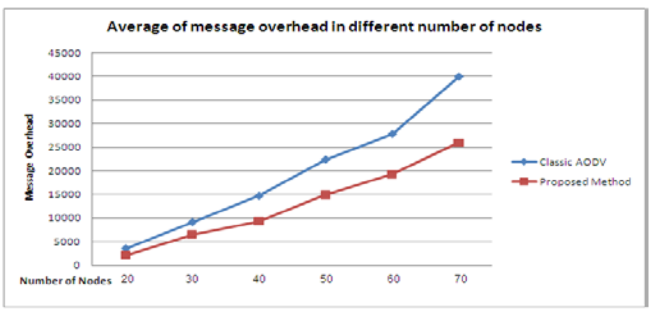

Figure 11. Average of message overhead in different number of nodes

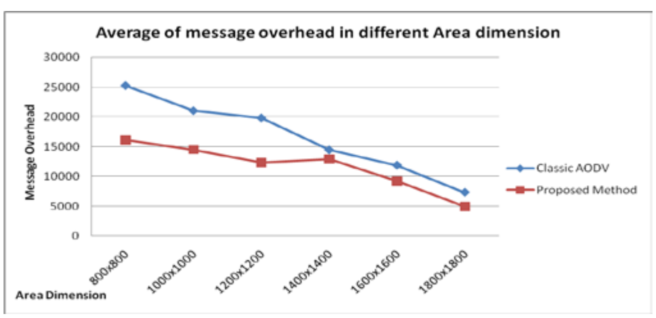

Figure 12. Average of message overhead in different area dimensions

Conclusion

Most part of control packet reception in AODV protocol relates to RREQ and RREP messages that distributed in network in order to rout discovery. But, high numbers of these packets are unsuccessful and omitted because of broken links. In order to prevent this problem, a new method based on link availability prediction was proposed that by using Hello message mechanism provides capability for identification of available links in AODV algorithm before broadcasting route request messages, so massive distribution of failed messages is prevented. The results of simulations show that the new method reduces AODV algorithm's message overhead considerably, and optimizes average of broken links relative to classic AODV algorithm.

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