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Creating Dynamic Sub-Route to Control Congestion Based on Learning Automata Technique in Mobile Ad Hoc Networks

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Abstract

Ad hoc mobile networks have dynamic topology with no central management. Because of the high mobility of nodes, the network topology may change constantly, so creating a routing with high reliability is one of the major challenges of these networks .In the proposed framework first, by finding directions to the destination and calculating the value of the rout the combination of this value with the average total probability of nodes for each route is considered to be a final value and by choosing a route among all routes leading to destination, routing operation is performed randomly and desirability or undesirability of the rout will be examined based on learning automata technique to select the optimal route for the next times. The proposed method attempts to encompass all parameters to control congestion on the network accurately and efficiently. To evaluate the proposed method, the results were compared with previous related works and compared with other methods which indicated that the proposed method has a better performance.

Keywords: *Ad Hoc Mobile Networks, Congestion Control, Learning Automata, Routing, Energy*

1. Introduction

In today's world many of activities depend on the services that are provided by computer networks and among which Manet is the one that has many applications. Load balancing and network congestion is a major problem in Manet networks routing and so an important issue is to create load balancing in these types of networks to allow all data to be transmitted safely to the destination. Accordingly it is necessary to perform routing in the network in a way that the load is balanced in all directions. It is therefore necessary to identify all the deficiencies that may unbalance the network load. Characteristics such as high mobility of nodes and the resulted dynamic topology of the network, low bandwidth, and even limited power and energy can cause complexity of routing algorithms in ad hoc networks. All these properties make most of the ideas contained in other networks routing algorithms inefficient for ad hoc networks. One-way routing algorithms demand type algorithms that do not solve the problem of congestion control comprehensively. Among the ad hoc network routing algorithms, some algorithms perform routing by multi-route method which increases fault effectively. Most multi-route routing algorithms, after finding multiple routes from source to destination in route discovery process, will select one of these routes as the main direction and begin sending data through the same route and will keep other routes as alternatives; and in case that the main route is down, one of the alternative routes will be used to send information and until a route is working and its forming nodes contain energy, that route will be used, in this way all the nodes will eventually run out of energy. Termination of energy of the nodes on one rout will cause gaps and fragmentations in the network that has a direct impact on network performance and routing. This problem can be observed in both one-route and multi-route routing algorithms.

2. Research Background

A lot of work has been provided in the area of congestion control in Mamet network, the most important of which are as follows: In [1] a method has been proposed to control traffic that distributes congestion on three key metrics along with relative weight value: 1) Route Energy 2) queue traffic 3) number of steps.

In [2] Priority fuzzy scheduling technique has been used to determine effects of this method on reactive routing protocols of AODV and DSR. In this method, a priority index will be added to each packet in the queue of the nodes and this priority index is based on the queue length, data rate and expiry time of the packets.

In [3] fuzzy stable routing algorithms are provided for MANET networks .The goal of the proposed design is to strengthen the QOS. One of the most important problems of QOS routing in MANET network is to ensure that one rout will work until the end of data transmission. And to reduce the number of broken routes, a new reliable routing algorithm is presented that uses fuzzy logic. And while routing, this algorithm selects a sustainable route based on the position of nodes and the data rate. Also a new protocol is presented to maintain/repair routes to establish a new route in case a route is broken.

In [4] Energy Efficiency method is studied in load balancing of MANET routing protocols. And the issues presented in this paper are: 1) Energy efficiency in the storage node routing protocols based on AODV with adaptive balance volume (AODV-NC-WLB) 2) New application of energy efficiency parameters of MANET routing protocols 3) Implementation and simulation of NS-2 study in energy efficiency of AODV-NC-WLB, maintaining substantial improvement in throughput, overflow, delivery and delay rates over AODV standard for high-volume work scenarios.

In [5] multiple adaptive routing is offered for load balancing. In this method an algorithm is used which detects multiple routes to the destination known as "Fail-Safe". And there is also a main route with all interface nodes and multiple routes include nodes with minimal load and higher remaining power and energy and include the highest bandwidth. And when the average load has a greater bandwidth than an increasing node during routing, in order to reduce the traffic load on that route, it distributes the traffic over other multiple routes.

In [6] a new method of MANET routing network is presented by considering energy by learning automata technique; in this method for MANET networks based on the best route selection using learning automata technique is proposed. The proposed protocol can be effectively imposed on route with regard to limited energy. This method is implemented on a version of the AODV routing algorithm (i.e., the AODV routing by learning automata) (AAODV), one representative of learning automata is run on each node and this representative dynamically trains the best way. The protocol is composed of three modes that train the best route to destination at any node.

In [7] the performance of load balance traffic routing protocols in ad hoc networks is compared.

In [8] load balancing parallel routing protocols (LBPRP) are provided; this protocol solves the problems of previous multiple routing protocols and distributes data among all the routes in parallel at the same time. In this paper, a simple test scenario is presented to ensure that the model is effective and valid. LBPRP leads to load balancing, reduces delays and increases the packet delivery ratio and throughput.

3. The Proposed Method

The process during which organisms learn various subjects has long been a favorite topic for experts. Studies conducted in this area are focused on two main branches:

• Understanding the process during which living organisms learn.

• Obtaining the methods by which learning capability could be created in machines.

The concept of stochastic automata was first introduced by Tsetlin research team in the early 1960s in the Soviet Union. After that in further researches, several examples of the application of learning methods in engineering systems were developed examples of which include application in phone navigation, pattern recognition, object partitioning and adaptive control.

Stochastic Learning Automata: The SLA is comprised of two major components.

- Stochastic automata the practices of which are limited and is interacting with a random environment.
- Learning algorithm by the use of which automata learns the optimal operation.

Each automaton can be considered a finite state machine that can be represented by the following five member set:

Equation (1-3) $SA = \{\alpha, \beta, F, G, \phi\}$

The parameters of the above five member set include:

- Set of automata operations $\alpha \equiv \{\alpha_1, \alpha_2, ..., \alpha_r\} \equiv$
- Set of automata inputs $\beta \equiv \{\beta_1, \beta_2, ..., \beta_r\} \equiv$
- Function that maps the input and the current state to the next state $F \equiv \phi \times \beta \rightarrow \phi \equiv$
- Output function that maps the current state to the next output $G \equiv \phi \rightarrow \alpha \equiv$
- Set of internal states of the automata at the moment n $\phi(n) \equiv \{\phi_1, \phi_2, ..., \phi_r\} \equiv$

The set α includes automata operations one of which is selected by automata every time. The input set β defines automata inputs the details of which will be discussed in the next section. The mappings F and G convert the current state and data to the next output (operation) which has been chosen by automata. If the mappings F and G are determined, the automaton is called deterministic automaton. In this case, given the initial state and input, output and the next state is uniquely obtained. Now if the mappings F and G are random, automata will also be called stochastic automata. In that case, only the probabilities of next state and relevant outputs can be determined.

Stochastic automaton, itself, is divided into two categories:

- Fixed structure automata

- Variable structure automata

An LR-P automaton is the learning automata with variable structure used here and the probability of choosing p for each action of α can be seen in the following formula. In case of receiving favorable response from the environment β(k)=0 possibility of that action will be rewarded based on the following equation:

$$p_j(\mathrm{k}+1)=\begin{cases} p_j(\mathrm{k})+\mathrm{a}[1-p_j(\mathrm{k})] & j=i \\ (1-\mathrm{a})\,p_j(\mathrm{k}) & \forall j\neq i \end{cases} \tag{1}$$

In case of receiving unfavorable response from the β(k)=1 possibility of that action will be forfeited based on the following equation:

$$p_j(\mathrm{k}+1)=\begin{cases} (1-\mathrm{b})\,\mathrm{p_j}(\mathrm{k}) & \mathrm{j}=\mathrm{i} \\ (\frac{1}{r-2})+(1-\mathrm{b})\,\mathrm{p_j}(\mathrm{k}) & \forall j\neq i \end{cases} \tag{2}$$

In both above equations:

p_j *(k+1)*: the probability of automaton in time k+1 p_j *(k):* the probability of automaton in time k

a: reward b: forfeit r: number of actions

After creation of nodes on the network randomly, two nodes will be randomly chosen, one of which plays the role of the source and the other one destination. If two nodes are directly connected to each other, routing does not mean anything anymore and closed packet transmission is performed. Otherwise routes between these two nodes are determined. Examples of this are shown in Figure 1.

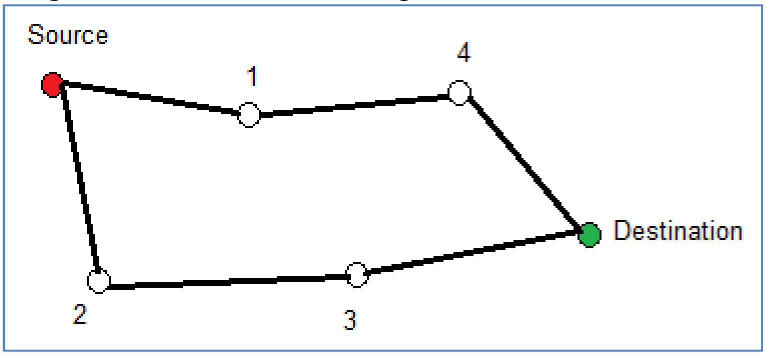

Figure 1. Two route-routes between the source and destination (sink)

As shown in figure, there are two routes [source, 1, 4, destination] and [source, 2, 3, destination]. In this protocol the selected route should be more efficient than other route. The parameters of each route considered include energy of the route, signal strength, number of steps and the average speed of the nodes in the route. The value given to each route in the first stage is based on fuzzy rules. Here two levels are defined for each parameter. Assume the [source, 1, 4, destination] route value is 0.56 and the [source 2, 3, destination] route value is 0.45. Another important point here is the influencing parameter of the probability of each node based on learning automata. In this proposed network we have a total of 6 nodes, so the first probability of every node is $\frac{1}{6} = 0.17$ the average probability of each route is calculated based on the probability of each node:

P([source , 1 , 4 , sink])=0.17
P([source , 2 , 3 , sink])=0.17

Thus, according to the previous value and the average probability of each route, the new value for each route is calculated as follows:

[source , 1 , 4 , sink]= 0.17+0.56= 0.73 (Route A)
[source , 2 , 3 , sink]= 0.17+0.45= 0.62 (Route B)

After calculating the value of each route, the value of the routes is calculated compared to the other one:

Route A= 0.54
Route B= 0.46

Routing is based on the roulette wheel, so a random number is selected, if the random number generated is, for example, 0.4 then route A will be selected and the packet transmission takes place via this route. So the route A will be selected as appropriate route and nodes on this route will be chosen as appropriate nodes. Therefore nodes on route A will be rewarded and other nodes will be forfeited, this action is shown below:

$$P(N{:}Source,\ Sink,\ 1,\ 4)= P(N{:}Source,\ Sink,\ 1,\ 4)+a[1- P(N{:}Source,\ Sink,\ 1,\ 4)] \quad (3)$$

$$P(N{:}2,3)=(1-a)[\ P(N{:}2,3)] \quad (4)$$

The flowchart of the proposed method is shown in Figure 2.

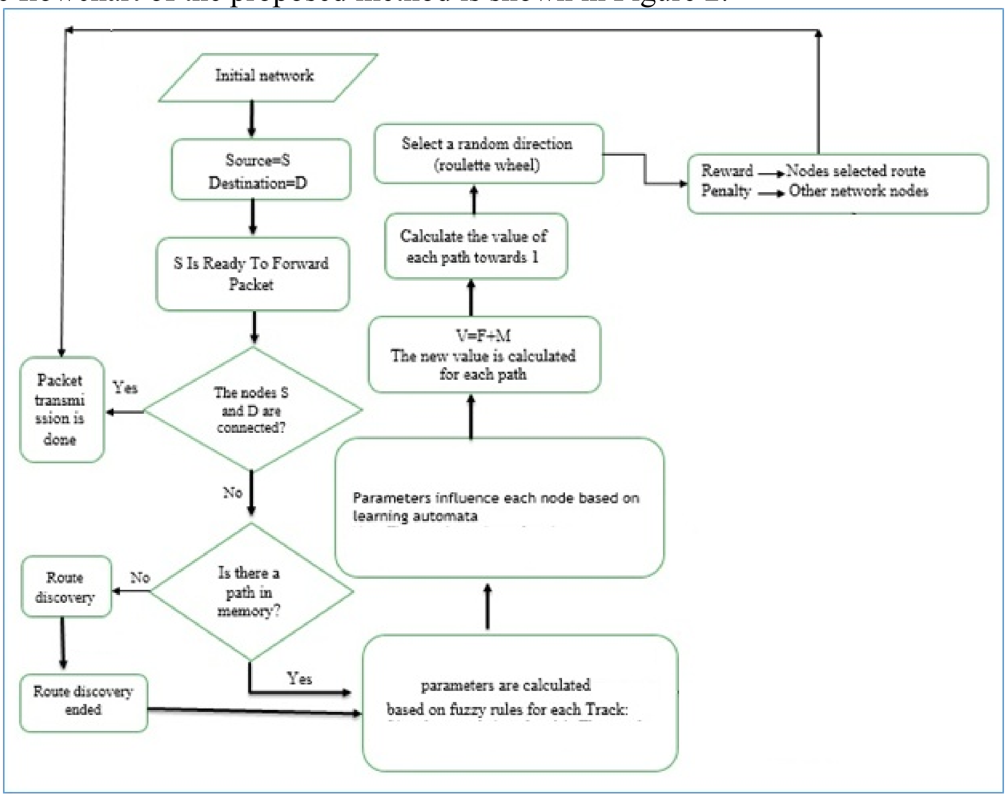

Figure 2. Flowchart of the proposed method

4. Evaluation and Results

MATLAB software version 8 has been used to simulate the proposed method. All the speeds used in this simulation are as follows:
speeds=[1 2 3 4]

This matrix shows the applied speeds are 2 meters per second, 3 meters per second, 4 meters per second, 5 meters per second. The space is 600 × 600 square meters and the number of nodes is variable.

When the number of nodes is changing, space of the Network under study is 396, 560, 627,686 meters respectively and the number of nodes in the network is 100, 200, 250 and 300 nodes respectively; speed is 2 meters per second constantly.

The simulation is performed on the abovementioned dimensions outdoor. There is no height difference between nodes. Simulation time is 5000 milliseconds equally in each scenario. It should be noted that the simulation was done in a way that could give different figures. The number of nodes is variable and increasing or decreasing number of nodes is no problem and can be expanded.

4.1 Changing the Number of Nodes in the Fixed Space

The results vary based on increasing the number of nodes on the network of average number of steps. But it is noteworthy that the number of steps is reducing which indicates better performance of proposed protocol in large scale environments.

Another parameter that has been studied here is the rate of successful transmission of packets. As the number of nodes in the network increases the rate of successful transmission of the packets go up. It should be noted that the rate of increasing in this case reduces with increasing the number of nodes on the network. So we can say that in the proposed protocol, performance of the network improves with increased scale.

Figure 3 shows changes in energy consumption in mobile ad hoc networks based on the proposed protocol changes compared to changes in the number of nodes. As expected increasing the number of nodes in the environment causes energy consumption to rise. It should be noted that the slight increase in the number of nodes has no effect on energy consumption and after increasing the number of nodes from certain values, energy consumption rises and then gets fixed.

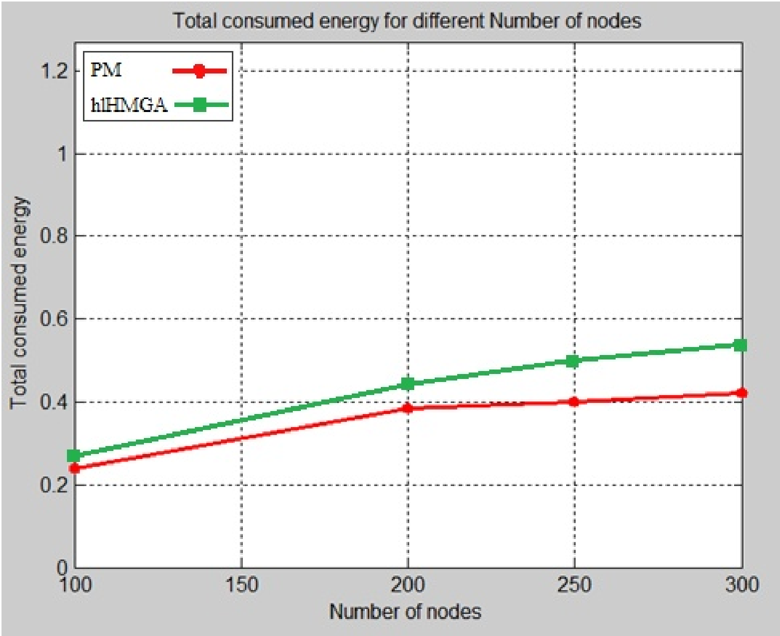

Figure 3. Change in total energy consumption compared to number of nodes

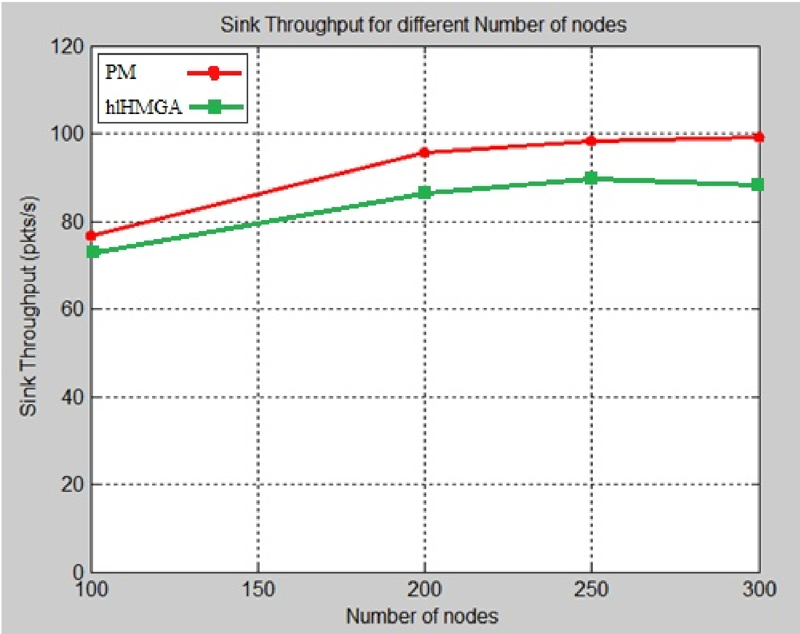

Figure 4. Change of packets received by the sink compared to number of nodes

According to the results it is expected that the number of packets received by the destination to increase when the number of nodes goes up. The increase has been shown in Figure 4. Since learning automata is being used here, we can conclude that increasing the number of nodes has a positive effect on the learning process.

4.2 Changing the Speed of Node Transmission

The parameter studied here is successful transmission rate of packets to different speeds. Figure 5 shows the change in the rate of successful packets transmission to increase speed. Increasing the speed of nodes had no significant effect on the network's packet transmission rate. It should be noted that the number of nodes used in this simulation is 200 , also network space is 500 × 500 square meters.

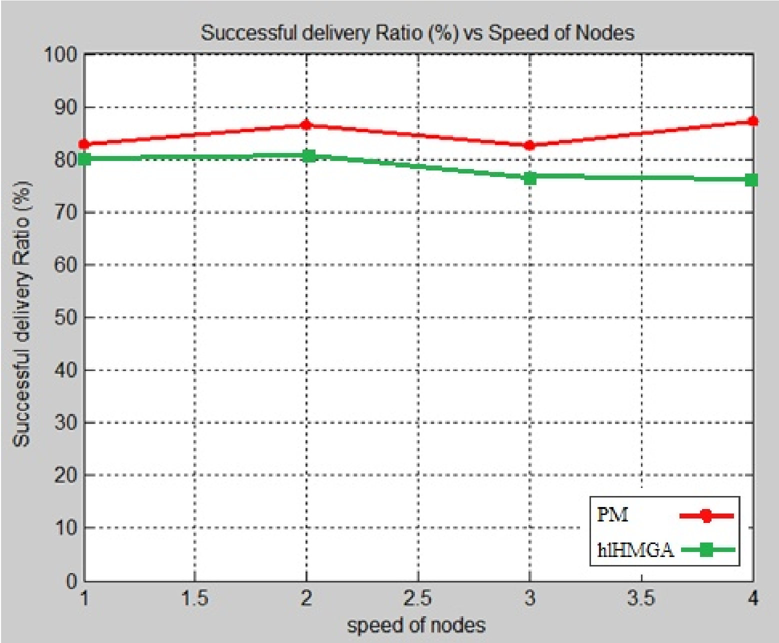

Figure 5. Changing the successful transmission rate versus speed

Figure 6 shows the changes in successful transmission rate versus speed. Results do not show any significant changes in the speed of the nodes on the mentioned parameter of the proposed methods. But in hl HMGA method successful transmission is reduced by increasing the speed so the proposed method does not reduce performance based on node mobility. Mobility of nodes is an important parameter in mobile ad hoc networks.

4.3 Network with Constant Density

Here the influence of the number of nodes in the mobile ad hoc network with fixed density or expanding environment dimension has been evaluated on parameters such as energy consumption, changed the number of steps, the percentage and number of successful transmissions. For this purpose, the speed of the nodes was considered fixed and equal to 2 m/s. The number of nodes is variable and 100, 200, 250,300 nodes were considered in the environment respectively. The speed of packet transmission is considered fixed and equal to 100 packets per second. The length and width of the environment where nodes are located are considered as 396, 560, 627,686 m.

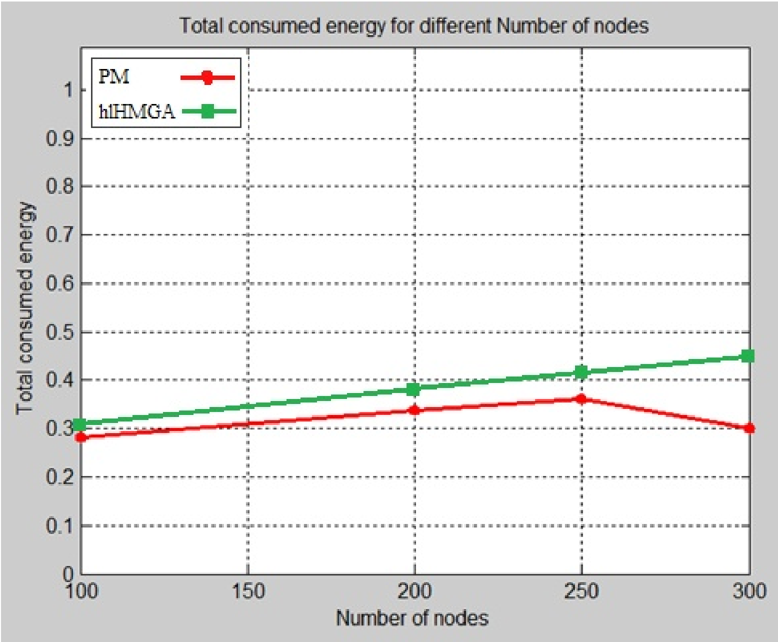

Figure 6. Total energy consumption with constant density and variable node number

Figure 7 shows the change in total energy consumption compared to change in the number of nodes in the network with constant density. As shown increasing the number of nodes in the network, will increase energy consumption. This increase can be attributed to increased connections between nodes, congestion, number of transmissions and communications. The amount of energy consumption and how it increases is different than the case of variable density. Here the increase rate is decreasing.

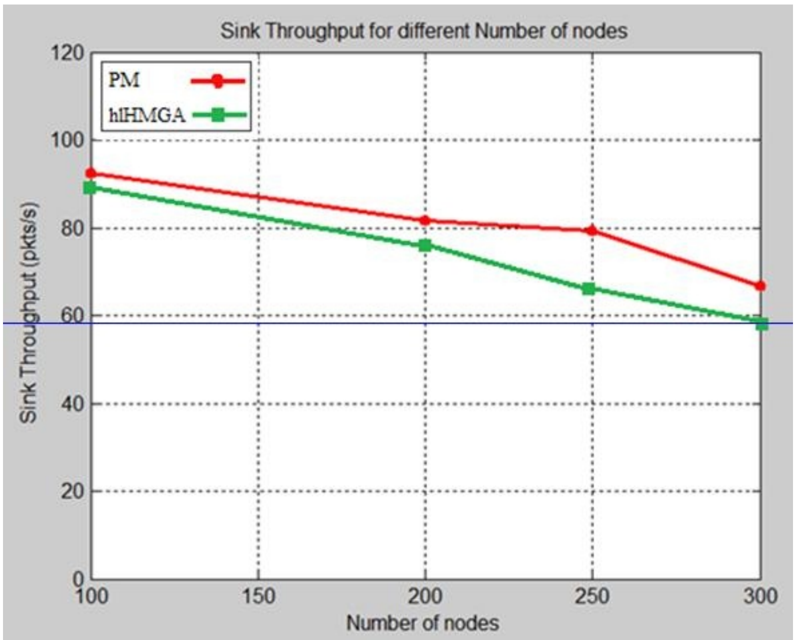

Figure 7. Change in the number of packets received by the sink in network with constant density and variable node number

5. Conclusion

Mobile ad hoc networks are self organizing networks, without centralized control or fixed structure and contain dynamic, mobile, and wireless nodes. Hence they are called "ad hoc" network in which there is no fixed structure and each node transmits the data itself. The network is used in military systems, small personal and administrative networks and vehicles ad hoc networks. After creating random nodes on the network, two nodes will be chosen one of which is the source and the other one is destination. In this protocol it is aimed to choose a route that is more efficient than the others. The considered parameters of each route include energy of the route, signal strength, number of steps and the average speed of the nodes in the route. The value given to each route in the first stage is based on fuzzy rules. Choosing route is based on the roulette wheel, so a random number is selected, and then the desired route will be selected accordingly.

Therefore nodes on the route receive reward and other nodes are forfeited. The results show that the proposed method has a better performance in terms of energy consumption and the number of packets received by the sink.

In this paper used learning automata for congestion control in mobile ad hoc networks. Learning automata algorithm works based on environmental behavior and updates the probability based on rewards and penalty, therefore better performance with increase scale and time. In fact this algorithm learn how to behavior in different situation after passing of time. Because selection probability of an action reach to stable condition. This reason improved networks performance in large scale.

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