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A LEARNING AUTOMATA-BASED APPROACH FOR DYNAMIC LOAD BALANCING IN MANET

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ABSTRACT

In mobile ad hoc networks (MANET) due to the high mobility of nodes, routing and load balancing are of major problems. In the proposed framework first, routes leading to destination is found and the value of compound route with the average of total probability of nodes for each route is calculated. Final value is considered to select a route among all routes leading to the destination. We considered the parameters in order to balance the load on the network and use of learning automata technique to select the optimal route. Simulation result shows that the proposed approach offers better performance in terms of energy consumption and the number of packets received by the sink.

1. INTRODUCTION

Many of the activities that are taking place in today's world are dependent on services offered by computer networks, and MANET networks are one of the networks that have many applications. Load balancing and network congestion are major problems in MANET network routing, therefore load balancing technique in this kind of network so that all data is transmitted intact are important[1]. For this purpose, it is necessary to perform routing in the network so that the load is balanced in all directions as well as it is essential that all the deficiencies that may unbalance the network be identified. Characteristics such as high mobility of the nodes, dynamic topology of the network, low bandwidth, limited power, and energy lead to the complexity of routing algorithms in ad hoc networks. These characteristics make most of routing algorithms on other networks not be applicable for ad hoc networks. Algorithms that perform routing as a single route or those are on demands have not generally solved the problem of load in MANETs.

Some of ad hoc routing algorithms perform routing as a multi-path operation to increase fault tolerance effectively [2, 3]. Most multi-route routing algorithms after route discovery process where they found multiple routes from source to destination choose one of them as the main route and begin

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sending data on it. They keep the other routes as alternative routes and in case of failure of the main route, they use one of the alternative routes for sending data. Using a permanent route leads to decrease of nodes energy level. Ending of the node energy in a route leads to failure of nodes. It creates gaps in the network and decreases the performance of the network.

Given the need for load balancing in MANETs and its importance, in this paper, we consider upgrading parameters that directly affect the type of balance to improve load balancing in this type of networks. To this end, a framework based on learning automata are proposed by considering nodes energy, signal strength and hop count of each route in MANETs.

2. LITERATURE REVIEW

Many studies have been done on load balancing of MANET, the most important of them are reviewed. In [4], different load balancing techniques in wireless mesh networks have been investigated to avoid congestion in gateways, as well as the effective parameters that are used in these techniques has been surveyed, In [5], they considered a Cluster-Based Wireless Mesh Architecture which the Wireless Mesh Network is divided into clusters that could minimize the load on a cluster or updating overhead during topology change due to mobility of mesh nodes. In [6], a method has been proposed to balance load by considering three metrics: 1) Route Energy, 2) queue traffic, and 3) hop count with the corresponding weight. In [7], priority-scheduling technique based on fuzzy is used to determine effects of this method on routing protocols AODV and DSR. In this method, a priority index is added to each packet in the queue nodes and this priority index is based on queue length, data rate, and packet expiration time.

In [8], stable routing algorithms based on fuzzy are provided for MANET to strengthen quality of services (QOS). One of the major problems in QOS routing in MANET is ensuring that one route is established in the network until the end of data transmission. To reduce the number of broken routes, a reliable routing algorithm that uses fuzzy logic is presented. This algorithm chooses a sustainable route based on the position of nodes and data rate. Moreover, a new protocol has been presented for maintenance of routes so that when a route breaks, a new route is established. In [9], Energy Efficiency in MANET routing protocols load balancing is studied. The presented works in this paper are: 1) New energy efficient AODV-based node caching routing protocol with adaptive workload balancing(AODV-NC-WLB); 2) New application of energy efficiency metrics to MANET routing protocols; 3) implementation and simulation of the study in. In [10], multiple adaptive routing has been offered for load balancing. In this method, an algorithm is used which detects multiple routes to the destination called Fail-Safe routing. There is one main route, which composed of nodes with minimal load, delay, and highest bandwidth. In routing when the average load of a node has an increase beyond the threshold, to reduce the traffic load on that congested route, traffic is distributed over multiple other routes. In [11], an energy efficient routing in MANETs based on learning automata are suggested. The proposed protocol is able to apply effectively with regard to limited energy. This method is applied in a version of AODV routing algorithm (i.e., routing AODV with learning automata) (AAODV). A representative of learning automata runs on each node, and this representative dynamically trains the best route to the destination. In [12], the efficiency of routing protocols of traffic-oriented load balancing in MANET has been compared.

In [13], Load Balancing Parallel Routing Protocol (LBPRP) has been provided that solves the problems of previous multiple routing protocols and distributes data in parallel in all directions at the same time. In this paper, a simple test scenario has been presented to ensure that the model is effective and credible. LBPRP prepares load balancing, reduces delay, increases packet delivery ratio and throughput. In [14], the performance analysis of load balancing in MANET routing protocols is done. In [15], the load balancing protocols in MANET are investigated. In addition to the above-mentioned methods that are more important, other methods are provided in the literature for load balancing in MANET.

3. THE PROPOSED METHOD

A research group called Tsetlin in the Soviet Union introduced the concept of random automata for the first time in the early 1960s. After that in later research, several application of learning methods in engineering systems such as routing in phone, pattern recognition, Object Partitioning, and Adaptive Control were developed.

Each Stochastic Learning Automata (SLA) include of two main components: 1) A stochastic automata with a limited number of operative that interact with a stochastic environment. 2) A learning algorithm which the automata learns the optimal action by it.

Each automaton can be considered as a Finite State Machine (FSM) that can be presented by the following pentamerous:

$$SA = \{\alpha, \beta, F, G, \phi\} \tag{1}$$

The parameters in this pentamerous are:

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

Setα includes applying the automata where the automata in each iteration, choose one of them. Inputsβ define automata input; the details of it will be discussed in the next section. F and G convert the current state and input to the next output (action) selected by the automata. If F and G areDeterministic, the automaton is called Deterministic Automata. In such a case, by having primary and input modes, output and the next state are uniquely obtained. If mappings F and G are random, automata are called stochastic automata. In that case, only the probabilities related to the next state and corresponding outputs could be determined. Stochastic Automata is divided into two categories: 1) Automata with a fixed structure 2) Automata with Variable Structure.

We use learning automata with variable structure L_{R-P} where the probability selecting p for each action of α is updated according to the following equations. In case of receiving a favorable response from the environment β(k)=0, possibility of that action is rewarded by the following equation:

$$p_j(k+1)=\begin{cases} p_j(k)+a[1-p_j(k)] & j=i \\ (1-a)p_j(k) & \forall j\neq i \end{cases} \quad (2)$$

In case of receiving an unfavorable response from the environment β(k)=1, possibility of that action is fined by the following equation:

$$p_j(k+1)=\begin{cases} (1-b)p_j(k) & j=i \\ (\frac{1}{r-2})+(1-b)p_j(k) & \forall j\neq i \end{cases} \quad (3)$$

In both of the above equations: p_j (k + 1) is probability of automata at the time k + 1, p_j (k) is the probability of automata at time k, *a* is reward, *b* is penalty, and *r* is number of measures.

After creating the existing nodes in the network, two nodes are selected randomly which one of them is a source and the other plays the role of the destination. If two nodes are directly connected to each other, routing does not make sense and packet transmission is performed. Otherwise, the routes between two nodes are determined. An example of this is shown in Figure 1.

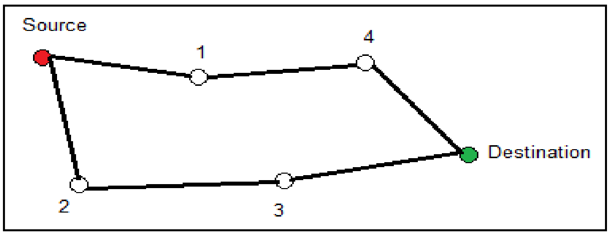

Figure 1: The path between the source and sink

As shown in Figure 1, there are two routes as [source, 1, 4, destination] and [source, 2, 3, destination]. In this protocol, we want to choose the route that is more efficient than other routes. Considered parameters of any route are route energy, signal strength, number of steps, and the average speed of nodes movement in the route. Value given to each route in the first step is based on fuzzy rules. Here for each parameter, two levels are defined. Let us assume that [source, 1, 4, destination] has a value of 0.56 and route [source, 2, 3, destination] has a value of 0.45. Another important point here is the effect parameter of the probability of each node based on learning automata. In this proposed network, there are six nodes, therefore, the initial probability of each node is 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 of each route and average probability of the route, the new value of 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, we calculate the route:
Route A = 0.54

Route B = 0.46

Choosing route is based on the roulette wheel, so a random number is selected, for example, if the generated random number be 0.4 so route A is selected and the packets transmit via this route. Thus, route A is selected as an appropriate route and nodes in this route are selected as appropriate nodes. Therefore, nodes in route A are rewarded and other nodes are penalized, it is given as:

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

$$P(N:2,3)=(1-a)[P(N:2,3)]$$

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

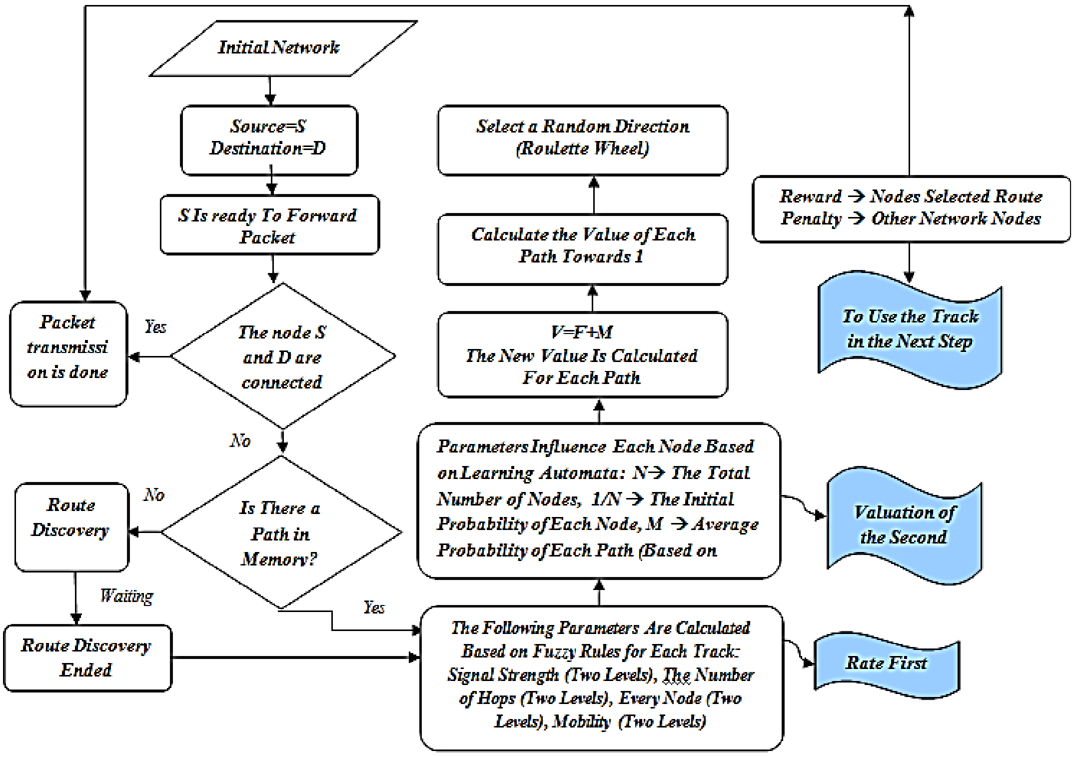

Figure 2: Proposed method

4. EVALUATION AND RESULTS

The absence of infrastructure, freedom of movement in all directions, the ability to communicate with anyone and at any time, independence of any control and other features are the keys to popularity of MANET, even if it is an emerging technology. Despite of this success, MANETs still have several drawbacks such as the dynamic topology, variable within flow, limited connections and bandwidth, limited power supply and lower security. In addition, the displacement of nodes that is an important advantage in MANET is the main source of many problems. For example, when nodes come out of the other nodes, the connection is interrupted. Speed sets used in the simulation are: Speeds= [2 3 4 5]

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

Network Space investigated when the number of nodes changes is as 280, 396, 485, 560, and

627 meters and the number of nodes in the network are 50 nodes, 100 nodes, 150 nodes, 200 nodes, and 250 nodes, respectively, and constant speed of 2 meters per second.

This simulation defined with the dimensions above is carried out in an outdoor environment. There is no height difference between the nodes. Simulation time is evenly 5000 milliseconds in each scenario. It should be noted that the simulation was conducted in a manner that can provide different statistics. The number of nodes is variable and there is no problem in terms of increasing or decreasing nodes, and their number can be expanded.

4.1 CHANGE IN THE NUMBER OF NODES IN FIXED SPACE

The results vary with increasing number of nodes in the network and average number of steps. Nevertheless, it is noteworthy that the number of steps has a reduced rate showing better performance of the proposed protocol in environments with large scale.

Another parameter studied here is the rate of successful packet transmission. With increasing the number of nodes in the network, packet successful transmission rate increases. It should be noted that the rate of increasing, in this case, decreases with increasing the number of nodes in the network. Therefore, we can say that in the proposed protocol, network performance is improved with increase in its scale.

Figure 3 shows changes in energy consumption in MANET based on the proposed protocol compared to changes in the number of nodes. As expected with the increase in the number of nodes in the environment, energy consumption increases. It should be noted that slight increase in the number of nodes has no effect on energy consumption and after increase in the number of nodes from certain values, energy consumption increases and then remains fixed.

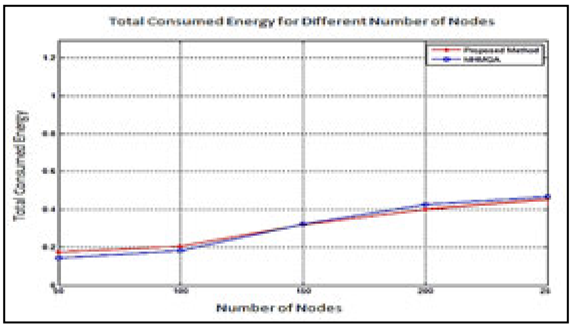

Figure 3: Energy consumption in MANET based on the proposed protocol compared to changes in the number of nodes

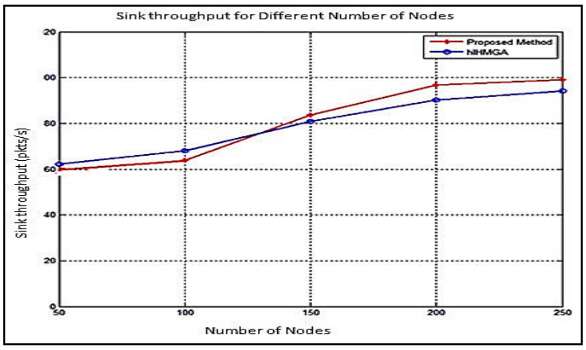

Figure 4: The number of packets received by the sink

According to the results, it is expected that the number of packets received by the sink increase with increasing the number of nodes. This increase is shown in Figure 4. As learning automata are used here, it can be stated that increasing the number of nodes has a positive effect on the learning process.

4.2 CHANGE IN THE SPEED OF THE NODE

The parameter that has been studied here is successful transmission rate of packets compared to different speeds. Figure 5 shows the rate of successful packet transmission relative to speed. With increasing the speed, transmission rate of the nodes in the network did not change significantly. It should be noted that the number of nodes used in this simulation is 200 nodes network, and network space in 500 × 500 square meters.

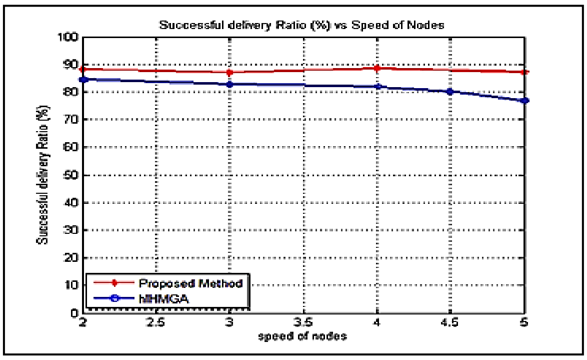

Figure 5: The rate of successful packet transmission in ratio to the speed of the node

4.3 NETWORK WITH FIXED DENSITY

Here, the influence of the number of nodes in MANET with fixed density or increase of environmental aspects on parameters such as energy consumption, change in the number of steps, successful transmission percentage, and the number of successful submissions received by the sinks were evaluated. To this end, node's movement speed was considered constant and equal to 2 m/s. The number of nodes was variable and respectively 50, 100, 150, 200 and 250 nodes in the area. Packet transmission speed was considered constant and equal to 100 packets per second. Length and width of the environment where nodes are is considered equal to 280, 396, 485, 560 and 627 meters.

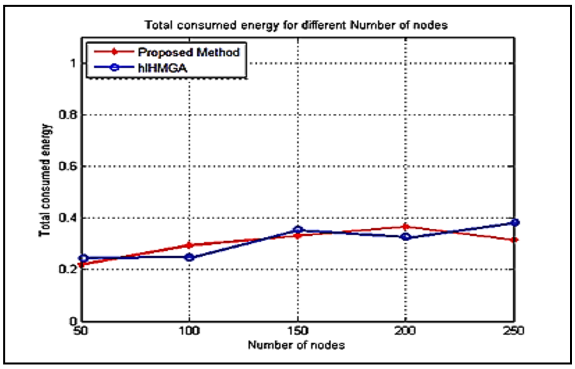

Figure 6: Change in total energy consumption in ratio to change in the number of nodes in the network with constant density

Figure 6 shows the change in total energy consumption in ratio to change in the number of nodes in the network with constant density. As shown, by increase in number of nodes in the network, energy consumption also increases. This increase could be due to increased connectivity between nodes, increased congestion, increase in the number of transactions and communications. The quantity and quality of increase of energy consumption in this mode are different from when the density is variable. Here the rate of increase is decreasing.

Figure 7 shows the change in the number of packets received by the sink in ratio to increase the number of nodes in the network with fixed density. As shown in Fig., with increase in the number of nodes in the network, number of incoming packets to the sinks reduces. Since energy consumption and the number of steps increase in the route, and the ratio of successful submission of package reduces, so according to previous figures, it is expected that the packet received by the sink reduce as well.

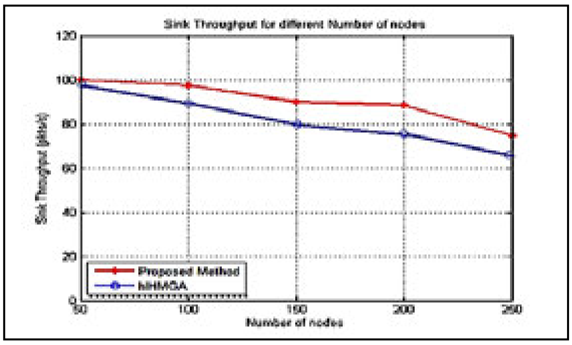

Figure7: The number of packets received by the sink in ratio to increase the number of nodes in the network with fixed density

Figure 8 shows the simulated time on each node in the whole time. As shown, except for a few nodes, most nodes have equal amount of load. In the proposed method, it has been tried to use all nodes to transmit packets. That is why energy consumption is improved, the number of lost packets has reduced, and successful transition has increased, all of which has happened due to more uniform distribution of the load on the network as shown in Figure 8, happened.

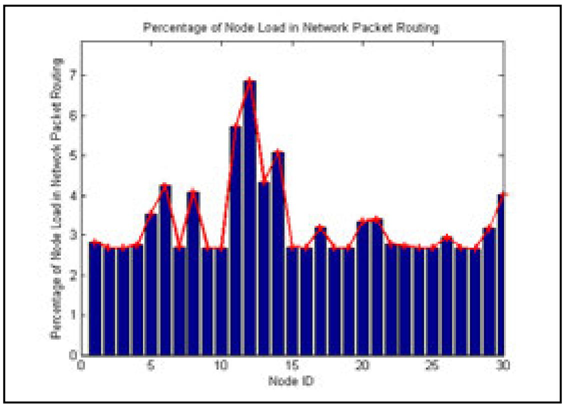

Figure 8: Simulated time on each node in the whole time

5. CONCLUSION

MANETs are self-organizing networks without centralized control or fixed structure and contain dynamic, mobile, and wireless nodes. Hence, they are called ad-hoc that do not have definite and fixed network structure, and each node transmits the data itself. The use of this network is in military systems, small personal and administrative networks, and ad hoc networks of vehicles. After creating random nodes in the network, two nodes are selected, one of which is as a resource and the other one plays the role of destination. In this protocol, we want to choose the route that is more efficient than other routes.

The parameters considered here of any route are energy route, signal strength, number of steps, and the average speed of movement of nodes in the route. The value given to each route in the first step is based on fuzzy rules. Choosing route is based on the roulette wheel, so a random number is selected, based on which the desired route is selected. Therefore, the nodes in the route are rewarded and other nodes are fined. The results show that the proposed method has better performance in terms of energy consumption and the number of packets received by the sink.

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