Adaptive Threshold Routing Algorithm with Load-balancing for Ad Hoc Networks

Zhijing Xu¹, Kang Wang², Liu Qi¹

¹ College of Information Engineering, Zhejiang University of Technology, Hangzhou, China
Email: zyfxzj@zjut.edu.cn
² Department of Computer and Information Technology, Zhejiang Police College, Hangzhou, China
Email: wangk@zjut.edu.cn

Abstract—Routing algorithm is a challenge for a mobile ad hoc network (MANET), but current routing protocols for MANET consider the path with minimum number of hops as the optimal path to a given destination. This strategy does not balance the traffic load over a MANET, and may result in some disadvantages such as creating congested area, depleting power faster and enlarging time delay in the nodes with heavy duties. In this paper we proposed routing metric can reflect not only the load of the path, but also the load distribution along the path. Simulation results show effectiveness of the routing scheme on balancing the load over all nodes in the network.

Index Terms—Ad hoc, Load balance, Thershold value

I. INTRODUCTION

Ad hoc network is a collection of wireless mobile nodes, forming a temporary network without fixed infrastructure. The network topology changes frequently due to arbitrary movement of the mobile mode, which act as both hosts and routers. For such dynamic networks, routing protocols attract great attentions as they are different from those in wired networks[1,2].

A lot of routing protocols have been presented for ad hoc network. They are generally categorized into table-driven routing and on-demand routing. The former is less efficient since it needs more network resources to maintain up-to-date routing information in each node. While on-demand routing protocol does not always maintain routing information at every node. It only creates route when a packet is desired to be transmitted. Therefore, on-demand routing protocol is the trend in the development of routing protocols for ad hoc network. Among various routing protocols the most prominent ones are ad hoc on-demand distance vector (AODV) and dynamic source routing (DSR). They are both on-demand routing protocols and have been submitted to the Internet engineering task force (IETF) mobile ad hoc networking (MANET) working group as candidates for standardization. However, a major drawback of existing ad hoc routing protocols is that most of them do not consider the problem of load balance.

II. RELATED WORK

There are several types of load balancing in ad hoc networks. One is based on Path, in which the load is balanced by selecting node with less number of active routes. Another is based on Delay, in which the load is balanced by attempting to avoid nodes with high delay. The third is based on Traffic, in which the load is balanced by attempting to distribute the traffic evenly among network nodes. The last one is the most effective type of load balancing. Reference selects a less congestion route at the destination node by comparing the sum of traffic load of each route. While in some references every node can take part in the route selection according to its traffic load[3,4].

In this paper, a new scheme belonging to the Traffic based type is proposed. It can distribute the traffic load evenly among nodes in ad hoc networks. This scheme can be applied to most on-demand routing protocols. It is implemented in the process of route discovery. When an RREQ (route request) message is flooded in the network, not every intermediate node receiving message for the first time will accept and deal with it. The node will first be judged by a threshold to determine if it is overloaded. If so, the RREQ message will be dropped, and the established route will not contain this overload node. Otherwise, the RREQ message will be broadcast again. The threshold used as a criterion is dynamically changing according to the interface queue occupancy (IQO) of nodes on and around the backward path. IQO means the number of packets waiting to be transmitted in a node’s interface queue.

III. LOAD BALANCE ALGORITHM

A. Node Mobile Model

To simulate the movement of the nodes in the mobile ad hoc network, we set up a ad hoc network scenario. There are N nodes in this scenario. Let \( (x_i(t), y_i(t)) \), \( v_i(t) \), \( \theta_i(t) \) be the coordinate, the velocity and the moving direction of mobile node \( i \) at time \( t \), respectively. In our approach, these initial parameters are set with random. We assume a free space propagation model, where the received signal strength solely depends on its distance to the transmitter. These nodes are limited by their transmitting and receiving capabilities. Therefore, they cannot directly reach all of the nodes in the network as most of the nodes are outside of direct rang. In such a scenario, if two nodes can communicate with each other, the distance between these two nodes cannot exceed \( R \). At arbitrary time \( t \), the coordinate of the node \( i \) can be
represented by (1), and the distance between node i and node j can be represented by (2).\[5,6\]

\[
\begin{align*}
    x_i(t) &= x_i(t-1) + v_i(t) \cos \theta_i(t) \\
    y_i(t) &= y_i(t-1) + v_i(t) \sin \theta_i(t)
\end{align*}
\]

(1)

\[
l_{ij}(t) = \sqrt{(x_i(t) - x_j(t))^2 + (y_i(t) - y_j(t))^2}
\]

(2)

B. Node Connetive Model

We can use the connective matrix to depict the connectivity of the network nodes in a dynamic network model. We defined connective matrix as \( D(t) = (d_{ij}(t))_{N \times N} \), the element in the matrix in this matrix should satisfied (3).

\[
d_{ij}(t) = \begin{cases} 
1 & l_{ij}(t) \leq R \\
0 & l_{ij}(t) > R
\end{cases} 
\]

(3)

We denoted \( D^{(i)}(t) \) to represent the ith power of the matrix \( D(t) \). Therefore the connective matrix can be represented by (4).

\[
D^{(i)}(t) = \sum_{k=0}^{\infty} D^{(i+k)}(t)
\]

(4)

Where \( D^{(m)}(t) = (d_{ij}^{(m)}(t))_{N \times N} \), if \( d_{ij}^{(m)} = 0 \) in this matrix, it means that node i cannot reach node j within m hops \( (i \neq j, m \geq 1) \). The graphic is not connectively if and only if there exists element \( d_{ij}^{(i)}(t) = 0, i \neq j \) in matrix \( D^{(i)}(t) \).[7,8,9]

C. Adaptive Load Balance Model

There are N node in the ad hoc network, this paper build a array \( L = (l_{ij})_{N \times N} \) with \( N \times N \) to represents the use condition. The element in the array \( l_{ij} \) represents the usage time of the link between the node i and node j. if \( l_{ij}(t) = 0 \), then the element \( l_{ij} = 0 \).

When the node i send message to node j, if \( l_{ij*min} = 1 \), the link between node m and node n is used; else \( l_{ij*min} = 0 \) show the link between node m and node n is not used. According the counting method, he link usage condition can be represented as follows:[10,11]

\[
\text{Times} = \sum_{i=1}^{N} \sum_{j=1, i \neq j}^{N} \sum_{m=1}^{N} \sum_{n=1}^{N} l_{ij*min}
\]

(5)

In the ad hoc networks, the number of the link which can be used can be obtained from the connective array. The able link in the network can be calculated by (6).

\[
U = \sum_{i=1}^{N} \sum_{j=1, i \neq j}^{N} d_{ij}(t)
\]

(6)

Therefore, the average link usage rate in the networks is defined by EU which is used as the threshold; this is the method of the load-balance algorithm. EU can be calculated by (7).

\[
EU = \frac{\text{Times}}{U} = \frac{\sum_{i=1}^{N} \sum_{j=1, i \neq j}^{N} \sum_{m=1}^{N} l_{ij*min}}{\sum_{i=1}^{N} \sum_{j=1, i \neq j}^{N} d_{ij}(t)}
\]

(7)

When node i send a route require to node j, the min hops route will be selected according to the DSR protocol. The link usage rate of this min hops route may larger than EU. It shows if this route is selected, then the time delay of the network will be serious and the network will congest. In this condition, according to the load-balance algorithm, finding out the link which link usage rate larger than EU, and set the weight of these links as inf. Researching the network from node i to node j according to DSR protocol, and check the new route whether each link usage rate of the link in this route is lower than EU. If the all the link usage rate of the link in the new route is lower than EU, select this route to send messages.

Adaptive load balance model is build on the base of the load balance model. In the load balance model, route searching is based on EU value, if all the link usage rates of the links in all routes are larger than EU, select the route with the min hops. In adaptive load balance, when all the link usage rate of the link in all route is large than EU, select the min usage link rate route to send message.

IV. SIMULATION

We use MATLAB to simulate the multi-path based on load balance algorithm. In dynamic clustering model our simulation models a network of 100 mobile nods placed randomly within a 1000M × 1000M area. Two nodes can communicate with each other; the distance between these two nodes cannot exceed 100M, which is one tenth of the area of the network. Firstly, we simulate the connective condition of the network and the link using frequency in DSR protocol. The results are presented by Figure 1 and Figure 2.

Figure 1. Mobile node in the MANET.
In Figure 2, we can find that in a 1000M × 1000M MANET, every node can communicate with others within 12 hops. Most traffic requires can be finished within 1 hops or 2 hops. In Figure 3, link using frequencies are quite different in the DSR protocol. The busiest link is used 120 times, while the disengagement link is just used 95 times. From the statically view, the mean of the link using frequency is 100 times, the variance of the link using frequency is 1.6818.

In Figure 4, link using frequencies are quite different in the multi-path based on load balance algorithm. The busiest link is used 115 times, while the disengagement link is just used 99 times. From the statically view, the mean of the link using frequency is 100 times, the variance of the link using frequency is 1.3615.

In Figure 5, link using frequencies are quite different in the multi-path based on adaptive load balance algorithm. The busiest link is used 101 times, while the disengagement link is just used 99 times. From the statically view, the mean of the link using frequency is 100 times, the variance of the link using frequency is 0.0130.

V. CONCLUSION

We have presented a multi-path based on load balance algorithm. It is a simple but effective algorithm to balance the load and alleviate congestion in network. Firstly, algorithm analyzes the queuing model and put forward two formulas to evaluating the partial function and whole function for ad hoc networks. Using the connective matrix and traffic matrix, the usage condition of every link and function index can be calculated. At last, we set the threshold value to limit the excessive usage of
links, reduced the possibility of congestion. Simulation and comparisons with some typical route algorithms show our algorithm is robust and effective.

Acknowledgment

This work was supported by a grant from Zhejiang provincial key laboratory of fiber optical communication technology and by Education of Zhejiang Province’s Project (Y200702540).

References