A Probability Based Load Balancing Algorithm Applicable to MANET

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***Abstract* — A probability based load balancing algorithm is proposed in order to solve the problems of increased network delay and reduced handling capacity caused by network congestion in 4G network, wherein the nodes make use of historical load information to map network load state and employ probabilistic algorithm for routing admission to balance loads. The historical state based load mapping can effectively remove the difficulty in judging the load state in distributed independent operation, etc., and the probabilistic algorithm can effectively overcome the fuzzy judgment upon threshold admission, and meanwhile lots of broadcast packets are reduced to save channel resources. On the basis of combining the classical on-demand routing protocol, H&P_DSR (History and Probability Based Dynamic Source Routing) has been designed to significantly improve network throughput and reduce time delay, without increasing any channel occupancy.**

Keywords - 4G network; routing protocol; load balancing; routing admission; broadcast signa

I. INTRODUCTION

Due to the network performance reduction brought by network congestion, people are paying more and more attention to load balancing technology. At present, load balance is usually realized at routing layer, and the load balancing algorithms mainly include ant colony algorithm, perception-based load balancing algorithm, etc. Therein, the ant colony algorithm, proposed by Italian scholar, is an excellent heuristic stochastic optimization algorithm and employs positive feedback mechanism to realize distributed global optimization and accordingly optimize the routing through continuously updating information elements; the inherent concurrent computation feature is favourable for realizing decentralized control, thus enabling the ant colony algorithm to be applied in routing protocol through various modes [1]. The other frequently researched algorithm is the perception-based load balancing algorithm; literature proposes a statistics based load measuring method, wherein the nodes statistically receive data packets, and accordingly an LCV (load coefficient of variance) is designed as the load measurement in order to select the route with optimal metric and further realize load balance; literature also proposes a load balancing algorithm, wherein the idle times of the node and the neighbour nodes are jointly used for measurement in order to not only consider the load condition of the node itself, but also consider the influence brought when other transmitting nodes compete for channels; literature proposes a channel occupancy rate based load balancing algorithm, wherein the channel occupancy rate perceived by the node is taken as the load metric [2-3].

The above load balancing algorithms all take one or several parameters including queue length, time delay, channel busyness, etc. as the load measurement, and the thoughts thereof are to carry load information during the route establishment process in order to enable the destination mode to select the path with light load to establish route. The article proposes a kind of new routing admission based load balancing algorithm, namely H&P (Historical and Probability) algorithm composed of historical information based load mapping mechanism and probability based routing admission. This algorithm can effectively solve the problems of inaccurate load state judgment and weak adaptation to threshold admission criterion for routing admission [4], and meanwhile H&P_DSR is designed through combining H&P algorithm and classical on-demand routing protocol DSR [5].

II. ALGORITHM DESCRIPTION

At present, most routing admission algorithms for load balancing are realized on the basis of threshold criterion. In other words, a threshold value is set to judge the routing admission, namely admitting (or forbidding) the route with the metric less than (or more than) the threshold value. Compared with the threshold based routing admission mechanism [6], the probability based algorithm does not directly determine whether to admit the route but gives an admission probability through information summary in

order to enable the node to implement routing admission according to the probability.

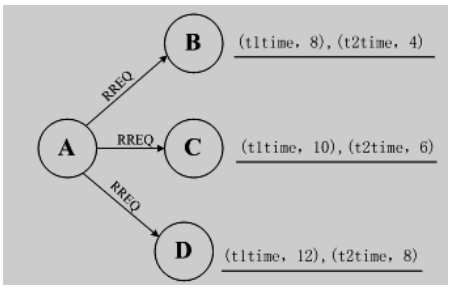

Figure 1. Load description for nodes at different moments

As shown in Fig. 1, nodes B, C and D have received the routing request from node A, and the load descriptions for nodes B, C and D at t1 are respectively 8, 10 and 12; if the threshold value is 7, then such threshold value setting cannot be used to distinguish the loads of nodes B, C and D, because the loads of the three nodes all above the threshold value [7-8]. Similarly, the load descriptions for nodes B, C and D at t2 are respectively 4, 6 and 8; if the threshold value is 10, then such threshold value still cannot be used to distinguish the three nodes and the three nodes actually have large load difference.

The probabilistic algorithm aims at obtaining different routing admission probabilities according to different load description values. For example, if the load description values are respectively 8, 10 and 12, then the probabilistic algorithm respectively gives 80%, 60% and 30% as the admission probabilities and the routing admission results for the three nodes B, C and D are undoubtedly different from each other; compared with other two nodes, node D certainly transmits more RREQs [9]. The probability based algorithm can accurately distinguish the loads of different nodes and then give different strategies to different loads.

A corresponding admission probability shall be provided to a fixed load. If the preset load is regarded as an independent variable and the corresponding admission probability is regarded as a function value, then the corresponding function relationship between the load and the admission probability can be determined as [10]:

$$P = F(L) \tag{1}$$

Therein, P is admission probability, L is node load, and F is probability function. If a certain load L is given, then the routing admission probability P can be calculated through above formula. Meanwhile, the probability function F can be fitted through multiple curves. Theoretically, all monotonic decrease function curves are suitable, and the large load description value is corresponding to small admission probability (the larger the load description value, the heavier the load), but different protocol performances are corresponding to different curves.

For example, one node randomly moves in a certain network, and after enough long time, the node will theoretically traverse the network and experience various load states in the network. We call this as the network ergodicity of the node. Namely after enough long time, the node can master enough rich network load information which is highly correlated to the loads of other nodes at present moment. Therefore, when experiencing various network load states, the node will record the load description values at corresponding moment as the horizontal comparison reference for routing admission in order to make the route more accurate.

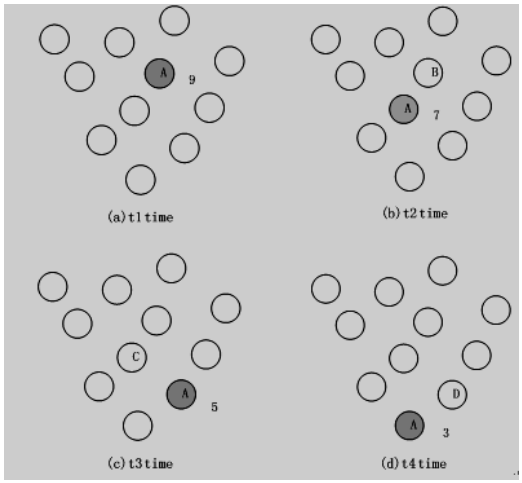

Figure 2. Relationship between node position and load

Fig. 2 is the network topology for four close moments, and the colored node in the figure refers to the same node A. According to the figure, within the period from t1 to t4, node A moves from the center of the network to the edge of the network (other nodes also move, but we do not care), and the node position after movement is replaced by other node. As shown in Fig. 2(b), at t2, node B moves to the position which belongs to node A at t1, similarly for other figures. The change of node position in the network leads to the change of the node load state and the load description values for node A at t1, t2, t3 and t4 are respectively 9, 7, 5 and 3. Obviously, the node load is gradually reduced.

H&P algorithm is mainly realized in H&P_DSR protocol through following rules:

Rule I: Design of load characterization: many characterizations can be used to describe network load and such characterizations mainly include time delay, channel occupancy time, route number, buffer queue length, etc., wherein the time delay characterization is used to select a route with shortest time delay; the channel occupancy time takes the channel occupancy time perceived by the node as the load metric; the route number takes the number of the routes that the node passes by as the load metric; and the buffer queue length takes the buffer length of the node interface queue as the load metric.

Rule II: Load information learning and collection: in H&P algorithm, the network load state judgment depends on the information collected during node running. The more the load information collected by the node, the more accurate the judged network load distribution and the better the load balancing effect. The node cannot collect enough

load information at the beginning, so the routing admission is not judged in previous periods but normal routing is carried out. The node only samples and records the network load condition including the maximum load characterization value (L_{Max}), the minimum value (L_{Min}) and the average value during node running (L_{Ave}).

The routing admission intervention time can be flexibly set. Theoretically, the longer the time, the richer the information collected by the node and the more accurate the routing admission judgment. Actually, the time can be designed according to specific application and is related to node movement speed, communication distance, etc. Under present simulation scene, within 2000*2000m2 area, if the average node movement speed is 20m/s and the communication distance is 400m, then it theoretically takes about 30s for the node to move from the edge of the network to the center. On this basis, the routing admission intervention time can be set as 30s and the similar calculation can be carried out for other application scenes.

Rule III: Design of probability function: select the frequently-used and intuitive straight line for probability function fitting. Therein, the straight line function is assumed as:

$$P = F(L) = \alpha * L + \beta \tag{2}$$

Therein, α and β are both unknown constants. According to Rule II for the historical load information recorded by the node, the large load shall be corresponding to small admission probability while the small load shall be corresponding to large admission probability. Specifically, correspond the minimum load L_{Min} to the maximum admission probability P_{Max} to obtain one coordinate point A(L_{Min} , P_{Max}), and similarly correspond the maximum load L_{Max} to the minimum admission probability P_{Min} to obtain another coordinate point B(L_{Max} , P_{Min}), and then substitute the known coordinate points A and B into the straight line function to obtain the following equation set:

$$\begin{cases} P_{Min} = \alpha * L_{Max} + \beta \\ P_{Max} = \alpha * L_{Min} + \beta \end{cases} \tag{3}$$

Solve the equation set to obtain:

$$\begin{cases} \alpha = \dfrac{P_{Min} - P_{Max}}{L_{Max} - L_{Min}} \\ \beta = P_{Min} - \dfrac{P_{Min} - P_{Max}}{L_{Max} - L_{Min}} * L_{Min} \end{cases} \tag{4}$$

Substitute into the straight line function to obtain the mapping function of the load and the admission probability:

$$P = F(L) = \frac{P_{Min} - P_{Max}}{L_{Max} - L_{Min}} * L + P_{Min} - \frac{P_{Min} - P_{Max}}{L_{Max} - L_{Min}} * L_{Min} \tag{5}$$

When the node receives RREQ, substitute the load description value into the function to obtain the routing admission probability and further decide whether to accept this route.

In formula (5), P_{Max} and P_{Min} are adjustable parameters, and the setting principle thereof is to firstly ensure the normal route establishment and accordingly optimize the routing and reduce redundancy.

Therefore, P_{Max} shall be set as a restively large value, but P_{Min} shall be adjusted according to network density, namely small P_{Min} for large-density network, vice versa. In present network simulation scene, the average number of the neighbour nodes of the node is approximately 4; if the average admission probability of the node is 50%, then the admitted routes can be ensured for at least two nodes, thus to ensure route establishment and reserve one backup route as well as control the redundancy within acceptable range. Accordingly, it is necessary to set $P_{Max} = 90\%$ and $P_{Min} = 20\%$ in the protocol. The node can obtain the routing admission probability through formula (5) according to present load description value.

III. SIMULATION ANALYSIS

This section aims at comparing the probability based routing admission and the threshold based routing admission through simulation. The simulation parameters are as shown in Table 1.

TABLE I SIMULATION PARAMETER CONFIGURATION

Physical Channel	IEEE802.11Phsical Layer Channel Specification
Channel bandwidth	1Mbit/s
MAC protocol	802.11
Routing protocol	Load-balancing DSR protocol (based on probability and threshold
Transport layer	UDP
Application layer	CBR
Movement model	Random movement

In the simulation, set 32 nodes distributed in 2000*2000m2 area, configure 16 pairs of CBR streams for the application layer, wherein the length of the data packet of CBR stream is randomly selected, and change the time interval for transmitting data to adjust the load added by CBR stream to the network. Meanwhile, adopt H&P_DSR protocol as the routing protocol and respectively adopt the threshold based algorithm and the probability based algorithm.

At present, the threshold value in the threshold based algorithm is usually manually set according to experience or sampling test. For fairness purpose, it is necessary to obtain load characterization parameter data through experiments in order to set the threshold value for the threshold based algorithm. Under present simulation setting, it is necessary to respectively set light load and heavy load and adopt non-balancing DSR protocol, wherein the load characterization values of various nodes at a certain moment respectively under heavy load and light load are as shown in Fig.3 and Fig.4. In the figures, the horizontal axis stands for the nodes

while the vertical axis stands for the load characterization values corresponding to various nodes, and the straight line stands for the average load characterization value of all nodes. According to the figures, regardless of heavy load or light load, the nodes have significantly different loads. Even under heavy network load condition, there are also nodes with light load. Through calculation, the average load characterization value under heavy load condition is 10.096 while that under light load condition is 5.115, so the two threshold values for the threshold based algorithm shall be respectively set as A=10 and B=5 in order to distinguish the nodes with different loads and accordingly realize the load balancing effect .

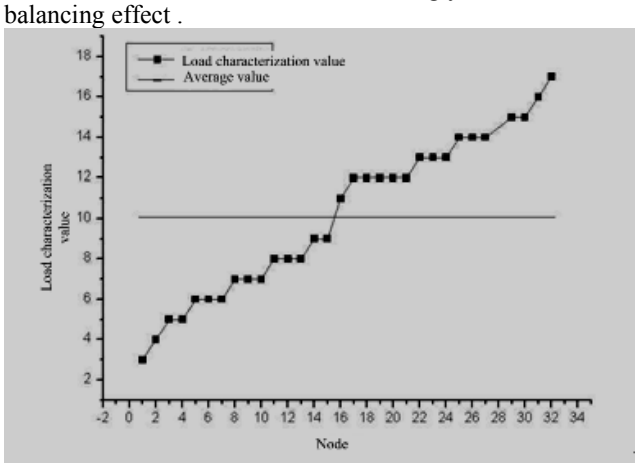

Figure 3. Load characterization value distribution under heavy load condition

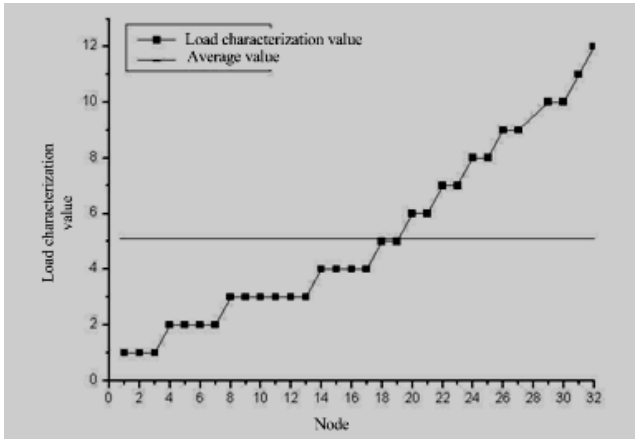

Figure 4. Load characterization value distribution under light load condition

The average values for 30 simulations of threshold based algorithm and probability based algorithm are respectively as shown in Fig.5 and Fig.6. Fig. 5 refers to the network throughput curve and Fig.6 refers to average end-to-end time delay curve, wherein the horizontal axes stand for the normalized network load and the vertical axes respectively stand for network throughput and average end-to-end time delay.

The judgment threshold value of the curve based on threshold value A is 10, and after the network load is gradually increased, the load description values of various nodes fluctuate around 10, thus indicating that the judgment threshold value 10 can accurately distinguish the nodes with different loads; oppositely, the judgment threshold value 5 is lower than the load description values of most nodes, so it cannot effectively balance the network loads and the throughput and the time delay performance of the network are reduced more or less at this moment. According to the simulation curve, the threshold value 5 has better algorithm performance under light network load while the threshold value 10 has better algorithm performance under heavy network load.

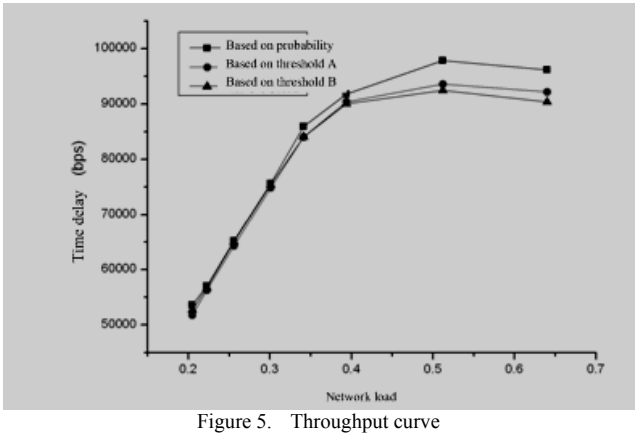

Figure 5. Throughput curve

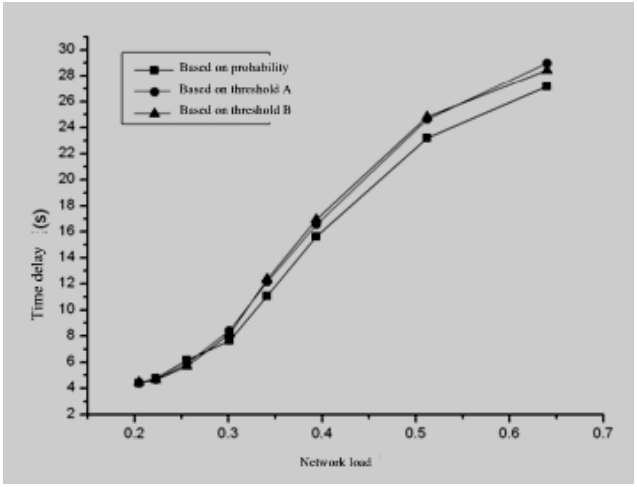

Figure 6. Time delay curve

IV. CONCLUSIONS CONFLICT OF INTEREST ACKNOWLEDGMENT

The article proposes a routing admission based load balancing algorithm, namely H&P algorithm, and this algorithm adopts historical information based load mapping to perceive network load state and adopts probability based routing admission to dispatch network load. The theoretical analysis and the simulation result show that the load balancing routing protocol H&P_DSR developed according to this method can accurately and effectively balance loads, significantly improve network throughput and reduce average end-to-end time delay. Compared with the routing

response optimization based load balancing algorithm, H&P algorithm can effectively control the inrush of routing broadcast packets and accordingly save channel resources; without any change of the routing protocol data format, this algorithm can be easily combined with the on-demand routing protocol; and this algorithm also has the features of no network throughput increase, excellent load balancing performance and wide applicability. In future, on the one hand, it is necessary to establish theoretical model to verify the algorithm and discuss the parameter setting to further rationalize parameters; on the other hand, it is necessary to further research the realization of the algorithm in specific protocols to make the algorithm have stronger operability in routing protocols.

V. Conflict Of Interest

The authors confirm that this article content has no conflicts of interest.

Acknowledgment

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