AN IMPROVED DYNAMIC LOAD BALANCING ROUTING PROTOCOL BASED ON MESH NETWORK

Ding XIONG [1], Lu YAN[2]

An improved dynamic load balancing routing protocol is proposed in this paper based on MESH network. A cost-effective integrated link state routing algorithm is designed in this protocol, the mechanism of real-time monitoring and timely adjustment is adopted in this algorithm to the link state, the source nodes with routing redundancy is actively notified to use or focus on the secondary routing when the link changes greatly. Moreover, a timely back off algorithm is proposed in this protocol, it solves the network fairness problem when the multi-path task and the single-path task compete for the link. The simulation results show that the proposed protocol can effectively avoid the congestion of network nodes, it can achieve better dynamic load balancing effect, and the utilization rate of network resources is improved.

Keywords: load balancing, link-state, multi-path routing; wireless mesh network, metric

1. Introduction

Wireless Mesh Network (WMN) is a kind of multi-hop, self-organizing and self-healing broadband wireless network structure, which will become the ideal networking mode for wireless metropolitan area backbone network. Wireless mesh network core technology is a routing protocol, including three types: first-type routing protocol, reactive routing protocol and hybrid routing protocol. First-type routing protocol is constantly detecting network topology and link quality changes, the routing table is updated according to the change, such as DSDV [1], WRP [2,3] and CGSR [4]. Reactive routing is also called on-demand routing, for example, AODV [5], DSR [6], TORA [7], These node does not need to maintain timely and accurate routing information, and only needs to find the route. Hybrid routing protocol combines the advantages of both, such as: ZRP protocol is a hierarchical structure routing protocol with a mix of on-demand and active routing strategy [8]. However, the above standard routing protocols lack effective load balancing mechanism, which makes some nodes take more tasks (overload), while others are idle (light load), and this cannot make full use of WMN resources.

1 Senior Engineer, Faculty of Information Science and Engineering, Hunan International Economics University, Changsha, China, e-mail: 66754252@qq.com
2 Senior Engineer, Department of E-commerce, Faculty of Information Science and Engineering, Hunan International Economics University, China, e-mail: 2610492@qq.com

Multipath routing is a solution to load balancing. The so-called multi-path routing refers to a route discovery process, and a number of routes can be found to reach the destination node, and then these routes are use as needed to transmit data, the utilization of the entire network resources are improved. In recent years, some of the multi-path routing protocols are mostly based on DSR or AODV, such as SMR [9], AOMDV [10], MSR [11], AODV-BR [12], NDM [13].

The MSR and SMR based on DSR is a typical multi-path protocol. MSR is a multipath extension to the DSR protocol, that combines on-demand, multipath and source routing. The key point of the agreement is to reduce the group and send the delay, raise the load balancing ability of the whole network. According to the detection result and the weighted cyclic scheduling algorithm is used, the data flow can be divided into multiple independent paths, so that the load balance can be achieved [14,15]. In this protocol, the delay is used as the metric of the path specification, and the state of the path is sensed by RTT, the purpose is to make full use of network resources. SMR is also an on-demand routing protocol, which uses a split approach: that is, data packets are distributed in two special paths, one is the shortest path, and the other is shortest path with the greatest independence. This method can not only effectively utilize the network resources, the load balancing ability of the whole network is improved, but also it can effectively prevent the network congestion under the condition of large load.

Based on the AODV protocol, AOMDV, AODV-BR], NDM and so on are extended. AOMDV (vector routing protocol with on-demand multi-path distance) obtain a number of acyclic and link disjoint path in the route discovery process. AOMDV can take full advantage of the existing routing information in AODV, so it only need to add a small amount of additional overhead when calculating multipath. AODV-BR (Backup Routing Protocol) introduces some new ideas in loopback routing reply messages, and maintains multiple routes to the destination node without increasing the number of control messages. NDM protocol increases the routing request node table and it records each intermediate node from the source node s to the destination node d; NDM RREP returns to the independent routing, by taking into account the cost of routing and complexity factors, NDM generally choose the number of paths according to the specific situation.

Ching-Ju Lin et al. proposed a MESH network load balancing scheme based on resource allocation [16]. S. Waharte et al. proposed a load-aware Mesh network load balancing scheme [17]. Kharasani et al. proposed a load-balanced routing algorithm for multi-radio wireless Mesh networks [18,19]. A disjoint multipath routing protocol (MRAODV-DM) was proposed for search [20]. Liu et al. proposed a load balancing routing protocol based on ant colony optimization algorithm in wireless Mesh network [21]. Hybrid Wireless MESH Routing Protocol HWMP is a routing protocol which is used in the draft IEEE802.11s, and is it is a hybrid routing protocol [22]. in the Mesh Point (MP), a mesh node (MP) can be used as the root node of the routing tree, it can establish the route quickly to the root node, and the best route can be discovered and maintained by the MP oneself. HWMP combines both *apriori* routing and counterfeit routing, it mainly uses tree-based routing (TBR) [23] and an improved protocol for AODV [24] (Radio-Metric AODV, RM -AODV) [25,26]. HWMP greatly improves the performance of WMN, but it relies too much on the processing of the root node, which makes the root node overload, and there are many places that can be improved.

2. LBDSM design

DSR adopts the source routing method. The source host knows which path it can reach to the target host and can choose the proper path to send the data packet., so DSR is used to design the dynamic source routing protocol of multi-path routing load balancing(LBDSRM).

2.1 Load balancing metric

The routing criteria includes hop count, RTT, per-hop packet delay, ETT, ETX, WCETT [27,28], and so on in the WMN routing protocol. The hop count measures the link quality by counting the number of nodes in the link. RTT (Round Trip Time) measures the link quality by measuring the Round Trip Time of unicast detection packets. Each hop packet pair delay is measured by a node sent to the neighbor node, the delay between the link state is analyzed between the two data packets. ETX (expected number of transmissions) is to estimate the number of retransmissions of unicast packets by counting the loss rate of the neighbor test packets. WCETT (weighted cumulative ETT) is a combination of the throughput of the entire path, it will be controlled by the impact of the bottleneck channel, and the number of hops are increased on the consumption of resources to find the weighted average.

Although it is very simple for the algorithm based on hop count, there are many shortest paths with the same hop number in a dense network. If only a few routes are selected in many minimum hop criteria, it is highly probable that the optimal link is not selected. The RTT, per-hop packet delay and ETX algorithm are used as a routing standard, although great progress has been made in many ways than the use of hops as a routing standard, because they are sent to detect packets to the way, the state information of the link is collected, it will bring some extra expenses to the whole network system. As a WCETT based on multi-channel system, it can solve the balance of throughput, bandwidth, hop count, delay and so on, but it still does not solve the problem of large cost of collecting information. In the LBDSRM protocol, we design a routing metric with a small cost, and the running efficiency of the protocol is improved. Metric computing is based on the collection of node information, including bandwidth, amount of data sent, buffer space and other information.

The real-time network card bandwidth of the node can reflect the state of the communication link of the node in a certain extent. Real-time bandwidth of the card Bi is defined for the wireless router node i. The number of received (R_i) and transmitted (S_i) data are recorded at node i, and the throughput performance of wireless routing node i is defined as $C_i = R_i + S_i$.

The number of data packets to be processed in the transmit and receive buffer queues can reflect the state of the node link. The congestion index is defined as $SQ_i = 1$ when the ratio of the sending queue length to the maximum queue length of the routing node i is greater than 60%. When the ratio of the sending queue length of the routing node i to the maximum queue length exceeds 80%, the exponent is defined as $SQ_i = 2$; otherwise, $SQ_i = 0$. The received queue saturation level RQ_i is also true for node i.

Because there is a delay between the calculation of the route and the use of the last route, it is better to have the ability to predict the congestion trend in the future. Therefore, we introduce the congestion prediction mechanism in the routing criterion calculation. The specific method is to do a comparison between the current saturation sum (including the receiving queue and the sending queue) and the previous statistical sum of the saturation, and pre-judgment factor P_i and saturation difference threshold μ are defined:

The sum of the current saturation> the sum of the previous statistics and the difference> μ, then $P_i = 1$.

The sum of the current saturations <sum of the previous statistics and the difference> μ, then $P_i = -1$.

The sum of the current saturation and the saturation of the previous statistic is less than or equal to 0, then $P_i = 0$.

From the node data which is collected above, it is possible to define an integrated link weight value W_i between the node i and its neighbor node, which is calculated as formula (1):

$$Wi = \left\lfloor \frac{Ci}{Bi} \times 10 \right\rfloor + SQi + RQi + Pi \quad (1)$$

In order to make the link without the congestion node more advantageous than the link with the congestion node, we adopt an over-limit accumulation mechanism to improve the handling of routing in this special case. The specific method is: the weight value of a single node is calculated; a congestion threshold n is set according to the specific circumstances of the network. When the weight value of a single node exceeds the congestion threshold, the node is considered to be congested and the degree of congestion is measured by the excess value. When the weight value is calculated, the excess is added to the final weight value W_i. The weight value of the improved node is calculated as follows:

$$W_i = W_i + (W_i - n) \quad \text{when } W_i > n$$
$$W_i = W_i \quad \text{when } W_i <= n \qquad (2)$$

To sum up, the total weight W_p of paths with k nodes is the formula (3):

$$Wp = \sum_{i=1}^{k} \left(\left\lfloor \frac{Ci}{Bi} \times 10 \right\rfloor + SQi + RQi + Pi \right) \qquad (3)$$

2.2 Load Balanced Multipath Routing Mechanism

The main idea of the LBDSRM algorithm is that after the route discovery process, the sending task is distributed proportionally according to the total weight of the integrated link of each path, and the data is sent by using several optimal paths. And data is sent at the same time each node real-time monitoring of their own state, once there is a big change, the source node is in time notified to make the necessary adjustments. The algorithm also uses a back-off mechanism in a timely manner, so that the multi-path transmission task and the single-path transmission task have certain network fairness in the event of network resource contention, and it can effectively avoid bottleneck node congestion in this case. The algorithm achieves the dynamic load balancing of the network, and it greatly improves the utilization rate of the whole network resource.

Several parameters in the algorithm need be set. After several simulations, we find that the optimal allocation value of the algorithm is different in different network environments. Now we take the simulation of the network environment as an example of the best configuration, and it is described as follows:

In the route discovery process, the source node S discovers that the destination node D has K effective paths, and the order of the weights is P_1, P_2 ... P_K.

When K = 1, there is only one path, and the assignment ratio of the path P^1 is 100%.

When K = 2, there are 2 paths, let X = $(WP_2-WP_1) / WP_1$

When X <= 5%, the task distribution ratio of P_1 and P_2 are 50%.

When 20%> X> 5%, P_1 task distribution ratio is 70%, P_2 task distribution ratio is 30%.

When 40%> X> = 20%, the task allocation ratio of P_1 is 90%, and P_2 is 10%.

When X> = 40%, the task allocation ratio of P_1 is 100%, P_2 is 0%.

When K = 3, there are three paths, let X = $(WP_2 - WP_1) / WP_1$ (first P_2 and P_3 as a whole).

When X <= 5%, the task allocation ratio of P_1 and P_2 P_3 are 50%.

When 20%> X> 5%, P_1 task distribution ratio is 70%, P_2 P_3 is 30%.

When 40%> X> = 20%, the task allocation ratio of P_1 is 90% and that of P_2 P_3 is 10%.

When X> = 40%, the task allocation ratio of P_1 is 100%, P_2 P_3 is 0%.

For the task assignment of P_2 and P_3, the calculation is performed by referring to the algorithm when K = 2.

·When K> 3, the best first three paths are selected, the distribution algorithm is calculated according to K = 3.

In order to make the nodes with only single-path routing have certain network fairness when transmitting data, when the task of multipath transmission and the task oft only single-path transmission is contention on some node or some link, the node initiates a back off algorithm. If the node is currently W <n (congestion threshold), its weight is W = n, and its change is notified to the source node of the sending task, and it is required to adjust the proportion of its sending task according to the new node state data. If the node current W> = n (congestion threshold), its weight W = ∞, and the source node of the sending task is notified to avoid the assignment of the transmission task on this path, and the transmission proportion of other paths is adjusted.

To avoid generating excessive route responses during route discovery, the protocol also specifies the number of times which a route response is generated. In the LBDSRM protocol, only three paths are used, so there is no need to find too many paths in route discovery. One RREQ can only respond once to the intermediate node, and one RREQ can respond to the first three arrivals for the destination node. So that the source node can get a better multi-path information, but also it does not lead to the impact of network response to the proliferation of routing performance. Multi-path routing load balancing algorithm flow chart is shown in Fig. 1:

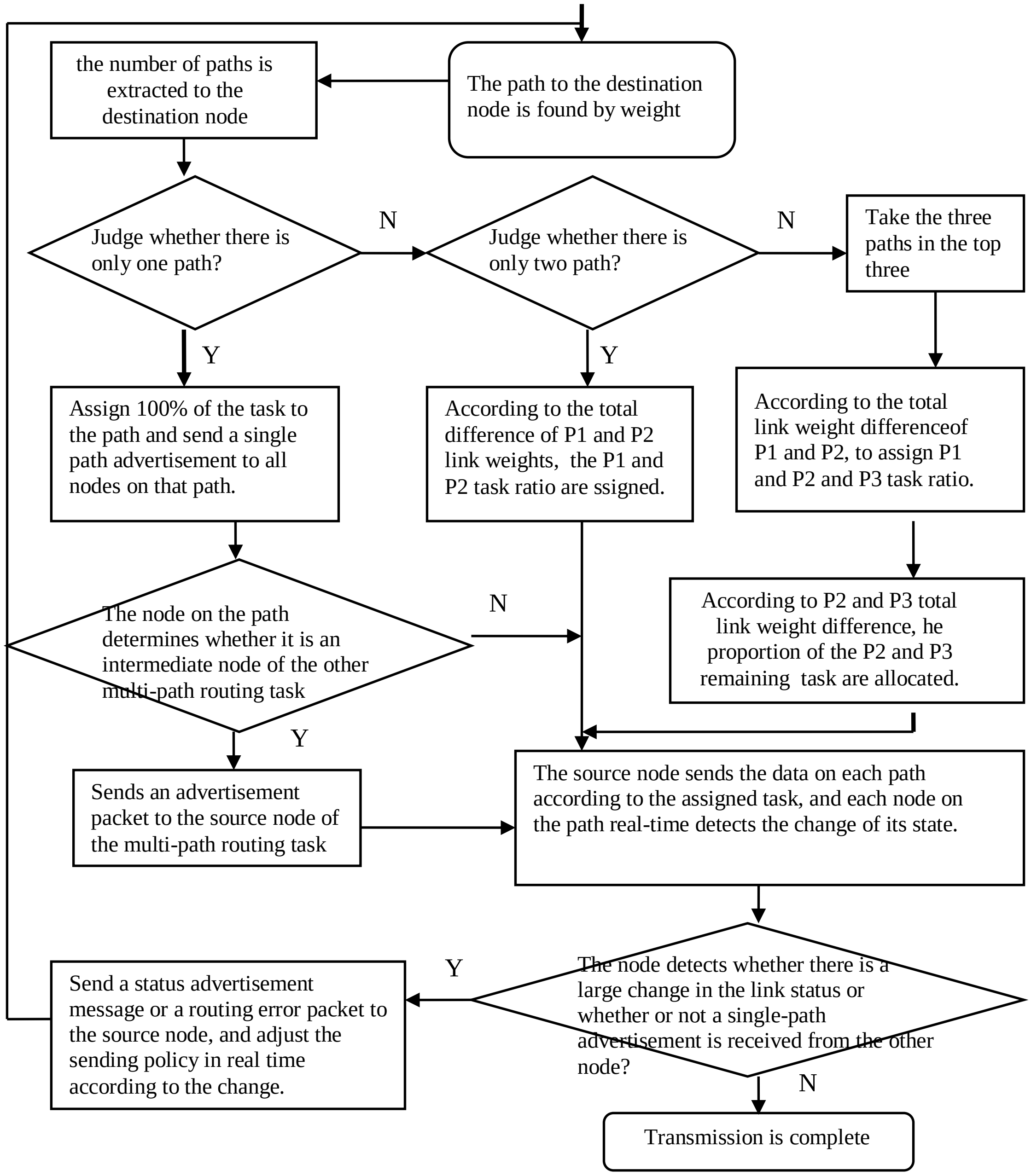

Fig.1 Multi-path routing load balancing algorithm flow chart

2.3 LBDSM protocol work process:

2.3.1 Route discovery process

When a mobile node needs to send out information and the routing cache does not have the necessary routing information, it initiates the route discovery process and sends a RREQ by using flooding. The RREQ structure includes the address of the source node, the address of the destination node, the unique sequence number, the accumulated link weights, and so on. Each node that receives RREQ first checks its own routing request table to see if it needs to process the message:

If the address of the node is already in the route record of the RREQ packet, the node discards the request packet and does not process it.

If there is no source node and request sequence number of the RREQ message in the routing request table, the node adds its current real-time link weight value to the accumulated link weight item in the RREQ message, and then it checks whether it Is the destination node in the RREQ packet. If yes, it sends a route reply packet to the source node; if not, it adds its own address to the route record table of the route request message, and then the extended route request message is forwarded to all the forward links.

If the RREQ packet contains the source node and the request sequence number in the RREQ packet, it indicates that the node has processed the same RREQ packet recently. The node will check whether it is the destination node: If it is the number of processing sessions, If the request message is not received, it will be discarded. If the request packet is not received, the request packet will be discarded; otherwise, the router sends a route reply packet to the source node.

A route request from the source node may receive multiple return route responses, and each route reply message carries a valid path information to the destination node, and each path information includes not only a detailed route to the destination node, but also the cumulative link weight for this path. Unlike the DSR, the protocol records all the returned path information and the corresponding accumulated link weights, multipath routing is implemented at different aggregate link weights, and data is sent to the destination node.

2.3.2 Route maintenance process

When multiple routing information is established, the route maintenance process is entered. The route maintenance process is mainly responsible for the following tasks:

a) the validity between real-time monitoring and the link of the neighbors, and of the response changes is caused in topology by the routing information changes. LBDSRM detects errors in link transmission through link detection, passive acknowledgment, and acknowledgment packet transmission. In this case, the relevant node sends out a routing error packet. By sending "routing error packet messages and acknowledgments", the routing failure is reported to the mobile node, the report should be promptly to maintain the validity of the route after each node routing updates. Before the node is resumed, the network temporarily deletes the node from the cache of other nodes and deletes all transmission paths which is connected to the node.

b) real-time monitoring of the node's link state, and the node state change reporting mechanism is timely started, dynamic load balancing is achieved. When the node monitors its own real-time link status and the history record weight difference, which was recorded by the node weight record table, it reaches the link notification threshold f, it indicates change that the current link status is compared with the original one. The source node sends a routing node state, advertisement message is changed to the source node, the source node is informed to adjust the task proportion of the multi-path route source node according to the content of the report. The combination of multipath routing mechanism and node change reporting mechanism, it can effectively reduce the probability of network load inequality.

c) The node real-time monitors the single-path route and the multi-path route link competition. When the node detects that it is the contention node of the single-path and multi-path routing tasks, the node modifies the W-value according to the real-time status of the node and sends a Node-State Change Advertisement message to the source node of the multi-path route, the source node adjusts the transmission task proportion of the multiple paths according to the content of the report, and it adopts the timely back-off mechanism it makes the multi-path routing task avoid the competition path in advance, so as to reduce the possibility of congestion occurrence, the overall performance of the system is improved, the purpose of load balancing is achieved.

3. Protocol simulation and analysis

3.1 LBDSM agreement working example:

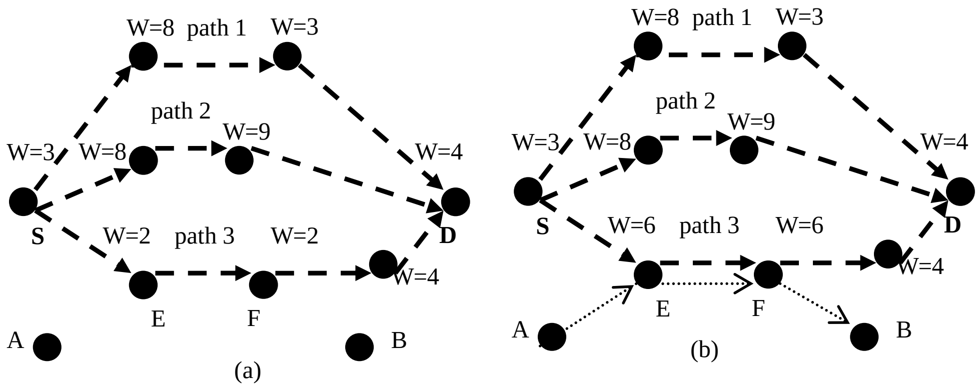

Fig. 2 LIBDRM protocol specific example map

As it is shown in Fig. 2 (a), when node S has data to be sent to D, three paths to node D (no other node contention) are found in the route discovery, which indicates that the path state of the composite link weights are path 1 = 18, path 2 = 24, and path 3 = 15, respectively. According to LBDSRM protocol, the 27%,3%,70% transmission task is assigned to the three paths of the multipath routing algorithm. The main task is placed on the best path 3, and the data are sent simultaneously to three paths.

As is shown in Fig. 2 (b), after running for a period of time, node A needs to send data to node B. It only finds one path to the destination node (coinciding with path 3 which is used by S-node task). In order to make multipath transmission, the node A sends an avoidance notice to the other nodes on the path, so that the state weights of the nodes E and F are changed from 2 to the congestion limit value 6, and the node S is informed, when the node S to send the task has not yet completed, so it will use the new link state data to to send tasks, and three routes are re-allocated. The integrated link weights are path 1 = 18, path 2 = 24, and path 3 = 23, respectively for the new path state. According to LBDSRM protocol, 70%, % 15, % 15 of the transmission task were allocated for three routes in the multi-path routing algorithm, the main task is on the path 1. This effectively alleviates the sending task on the path 3 with the contention node and the single path sending task is reserved to the node A to avoid congestion of the bottleneck node in this case, and the dynamic load balancing of the network is realized.

3.2 Simulation environment and parameter setting

In the simulation parameter selection, we try to use the system default settings, such as 802.11 basic data bandwidth is 2Mbits, in the choice of packet size, CBR business generator is used, the generator package size is 512 byte. The same simulation scenario is used in each routing protocol, 50 nodes are randomly arranged in the 600m * 600m network, each node has the same node movement model, the node moving speed is set at 20m / s within the random uniform distribution, node pause simulation time is 0s, 10s, 20s, 40s, 100s. When the parameters of the improved routing protocol are configured, the better setting parameters are selected according to the results of the test data. For example, the value of the congestion threshold n is set to 6, the saturation difference threshold is 0.05, the link change notification threshold f has a value of 0.2, and the rest of the parameters use the values which was described previously.

3.3 Simulation results and analysis

The LBDSM protocol, DSR protocol and MSR protocol are simulated in the NS2 environment, and the average end-to-end delay and normalized routing overhead data are obtained. The simulation results are analyzed. The average end-to-end delay is the most important measure of the optimal load-balancing routing algorithm. The normalized route cost is the number of the routing management packets, the destination node needs to receive one packet successfully. It can be expressed by the total routing cost *100% / the packets which is received by the destination node. Normalized route cost is the main technical index to measure the efficiency of routing protocols. The number of source nodes which is used in the simulation are: 10 and 30, respectively. Node pause time is: 0s (very high mobility), 10s,20s,40s,100, packet transmission rate is 4 packets / sec. The experimental data results are shown in Fig. 3 and Fig. 4:

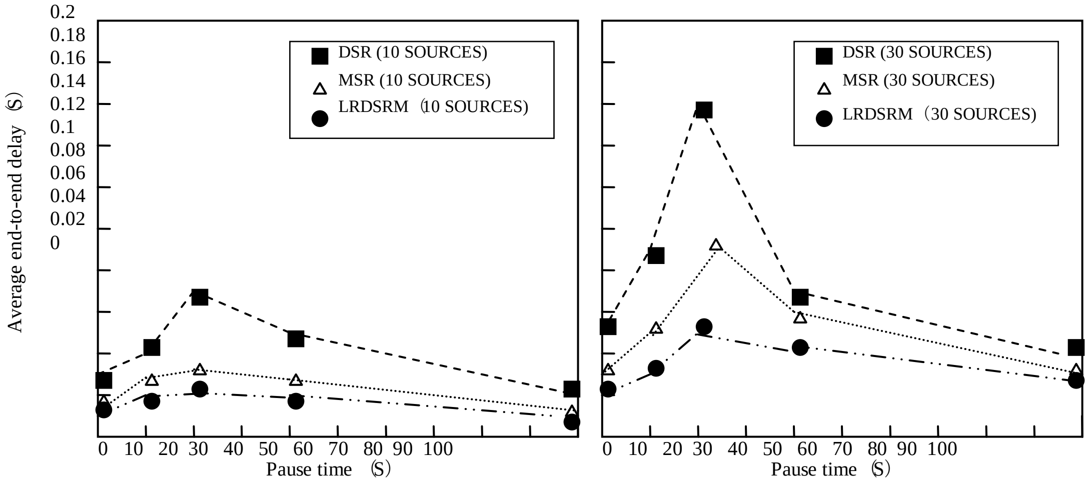

Fig.3 Average end-to-end delay comparison graph

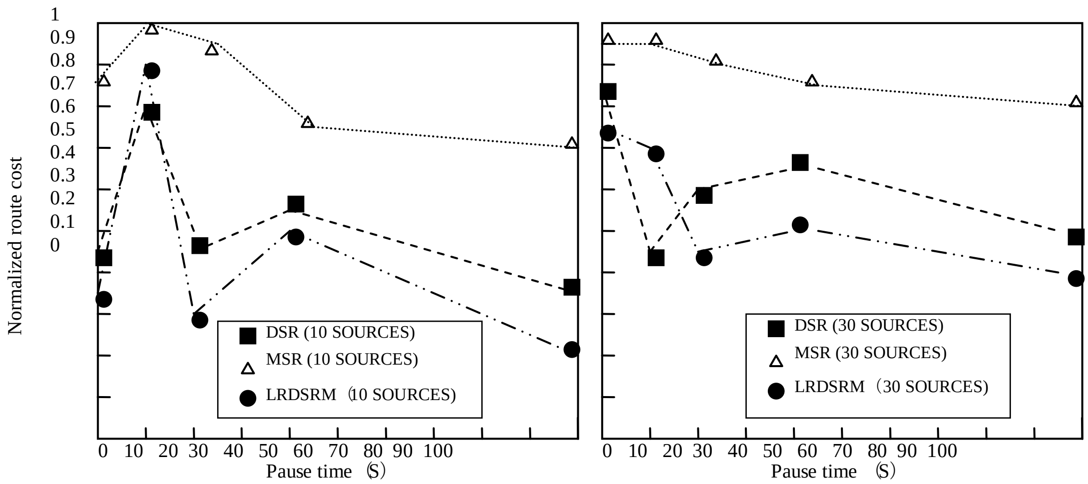

Fig.4 Normalized route cost comparison graph

From the data in Fig. 3, we can see that both the LBDSRM protocol and the MSR protocol use the multi-path routing mechanism, they are better than the DSR protocol in the environment of 10 source nodes (light load) or 30 source nodes (overload), The average end-to-end delay is short, which means that the multi-path routing mechanism can effectively distribute the network load and avoid node congestion, so as to realize the network load balancing. The end-to-end delay of the LBDSRM protocol is much lower than that of the MSR protocol, especially in the case of 30 source nodes. This is mainly because the LBDSRM protocol takes into account the link state and node queue saturation degree, but also the predictive factor and overrun accumulation mechanism are introduced, and the link back-off strategy is solved for the single-path routing tasks and multi-path routing tasks, so it is more effective than the MSR protocol to avoid the actual more congestion avoidance and congestion avoidance, higher dynamic load balancing effect is achieved, thus it can effectively avoid the delay increase which is caused by packet loss, queue buffering and retransmission which is caused by node overload. As the residence time increases, the end-to-end delay of these protocols decreases, because the mobility of nodes decreases after the increase of the dwell time, which reduces the cost of routing maintenance and reduces the cost of routing unreachable which is resulting in packet loss and the delay which is caused by frequent routing discovery.

As can be seen from Fig. 4, MSR protocol overhead is much larger than the LBDSRM agreement and the DSR protocol. This is mainly because the MSR protocol measures the link quality by measuring the round-trip time of a unicast packet. This means that a large number of probe packets need to be sent, so the overhead is kept at a high level. The LBDSRM protocol and DSR protocol do not need to send additional probe packets, so the overhead is small. Generally speaking, the LBDSRM protocol has advantages over the DSR protocol, it is mainly because the LBDSRM protocol adopts the multi-path mechanism and reduces the probability of re-initiating the route discovery due to the interruption of the link. Therefore, the overhead is relatively small. However, when the network changes rapidly, the change notification mechanism in the LBDSRM protocol can cause more change notification messages to be sent. Therefore, in this special case, the overhead may be higher than that of the DSR protocol, the Fig. 4 also confirms this point.

3.4 Comparison with other works

Several solutions presented till date do not have the strong substantiation for their scalability and fault-tolerance. The problems that Ire found are that the investigations are performed with only some thousand nodes without considering failures or realistic loads. Table 1 compares our work with that of other works.

Table 1

Comparison to other works

Work Name	Number of Nodes	Failure	LB	Work load
LBDSRM	1,000,000	Yes	Yes	Traces
PD_MinRC	500	Yes	Yes	Poisson Distribution
iHLBA	100	No	Yes	Random Generation
GA	5	No	Yes	Random Generation
QAFT	256	Yes	No	Uniform Distribution
New Model	1,000,000	Yes	No	Traces

More issues were found with other decentralized scheduling platforms PD_MinRC [29], iHLBA [30], GA [31], QAFT [32] and New Model [33]. They experiment with less than 10,000 nodes, no node failures or synthetic workloads.

4. Conclusions and outlook

There are two basic usage modes of existing multipath routing: (1) Multiple paths (simultaneous multipath) are used at the same time. (2) the main path is first used, replacement path (replace the multipath) is used after the main path is the failure. In solving the load balancing problem, the multipath mode is superior to the replacement multipath mode. The existing multipath protocols are somewhat flawed. For example, the disadvantage of MSR is that the processing overhead increases obviously when sending packets. SMR has too many RREQ packets to transmit, which brings additional packet sorting to the destination node. AOMDV also exists that data transmission often cannot use the shortest path and other issues. Therefore, there is a large space for the optimization of multi-path routing protocols.

This paper proposes a multi-path routing protocol with high load balancing capability. Firstly, the existing wireless WMN routing metric and multi-path routing protocol is studied to solve the balance problem. Then, based on the DSR protocol, a load balancing dynamic source routing protocol is proposed based on Multi-Path Routing-LBDSRM. The protocol adopts the algorithm of comprehensive link-state routing criterion, and multi-path data is used to solve the problem of dynamic load balancing in the network. It can realize the full utilization of network resources. Finally, simulation and simulation of LBDSRM protocol, MSR protocol and DSR protocol are carried out under the environment of network simulation tool NS-2. The performance of these protocols is simulated and compared under the same environment. The experimental results show that LBDSRM protocol has many performances, there are more advantages than other protocols in the treatment of load balancing problem.

The proposed LBDSRM protocol uses an integrated link-state routing criterion with predictor, out-of-band accumulation, etc., and it adopts a multi-path routing technology that incorporates timely back off, limited number of paths, the dynamic load balancing of the whole network is realized, the congestion of the nodes is effectively avoided, and the performance of the whole network is improved, and the relative overhead is small, and the efficiency is high. LBDSRM protocol has more advantages than the MSR protocol and DSR protocol, there are the more obvious advantages especially in the network load environment. This is useful exploration for the future of wireless network development and popularization.

Acknowledgements

This study is sponsored by the National Natural Science Foundation project (51375484) of China.

REFERENCES

[1]. *Charlese.P., Pvarin. B.*, Highly Dynamic Destination-Sequenced Distance-Vector(DSDV) Routing for Mobile Computers, UK:ACM SIGCOMM’94,1994.

[2]. *Murthy Shree,Garcia-Luna-Aceves*, “An Efficient Routing Protocol for Wireless Networks”, in Mobile Networks and Applications, 10,1(2) ,1996,pp. 183–197

[3]. *Chen Xun, Han Peng*,et al., A multi-channel MAC protocol for wireless sensor networks, 2006. The Sixth IEEE International Conference on Computer and Information Technology (CIT'06),0-7695-2687-X/06

[4]. *Su Jing, Guo Wei,* “Summarization of wireless mobile Ad hoc network routing protocols”, in CHINA MEASUREMENT TECHNOLOGY, 35(2), 2005, pp.91-93

[5]. *Perkins C, Royer E, Das S,* Ad hoc on demand distance vector (AODV) routing, Fremont, California: The Internet Engineering Task Force (IETF) , 2002

[6]. *D. Johnson, Y. Hu, D. Maltz*., The Dynamic Source Routing Protocol (DSR) for Mobile Ad Hoc Networks for IPv4, RFC 4728, 2007, http://tools.ietf.org/html/rfc4728.

[7]. *V. Park, S. Corson*, Temporally-Ordered Routing Algorithm (TORA) Version 1 Functional Specification, 2001, http://tools.ietf.org/id/draft-ietf-manet-tora-spec-04.txt.

[8]. *Zygmunt J. Haas*, A New Routing Protocol for the Reconfigurable Wireless Networks, San Diego, California, USA: IEEE ICUPC'97, 1997,562-566

[9]. *Lee S J, Gerla M*, Split Multipath Routing with Maximally Disjoint Paths in Ad Hoc Network, IEEE ICC, 2001,3201-3205.

[10]. *Marina MK, Das SR*. On-Demand Multipath Distance Vector Routing for Ad Hoc Network, IEEE ICNP, 2001.

[11]. *Wang Lei, Zhang Lianfang, et al.*, Multipath Source Routing in Wireless Ad Hoc Networks, Halifax，Nova Scotia, Canada: 2000 IEEE Canadian conference on Electrical and Computer Engineering, 479-483.

[12]. *S.J. Lee, M. Gerla*. AODV-BR Backup routing in adhoc networks, IEEE WCNC,2000, 1311-1316.

[13]. *Sun Lei, Ge Lindong*, “A Node Disjoint Multipath Routing Protocol in Mobile Ad Hoc Networks”,in COMPUTER ENGINEERING AND APPLICATIONS, 41(3),2005,pp.159-161

[14]. *Pavlos Antoniou Andreas Pitsillides*, A bio-inspired approach for streaming applications in wireless sensor networks based on the Lotka-Volterra competition model. 17(17), 2010.

[15]. *Johnson D B, Maltz D A., Hu Y C*, The Dynamic Source Routing Protocol for Mobile Ad Hoc Networks (DSR), Tech Rep ,2007.

[16]. *Ching-Ju Lin, Cheng-Fu Chou*, Route-Aware Load-Balanced Resource Allocation for Wireless Mesh Networks, WCNC at direction of IEEE Communication Society subject matter experts for publication,2007.

[17]. *S. Waharte, B. Ishibashi, R. Boutaba*, Interference-Aware Routing Metric for Improved Load Balancing in Wireless Mesh Network ICC at direction of IEEE Communication Society subject matter experts for publication,2008.

[18]. *Kharasani N M, Zukarnain Z A.*, Performance evaluation of routing with load-balancing in multi-radio wireless mesh networks. International Journal of Digital Content Technology and Its Applications, 2011.5(2):64-71

[19]. *Oraves R Padhye J Zill B*, Routing in multi-radio, multi-hop wireless mesh networks,2004, Philadephia Pennsylvania, USA.
[20]. *Feng Wen-Jiang, Zhang Li, et al*., Multipath and load balancing routing protocol in multi-radio wireless Mesh network, in Journal of system Simulation, 23(11), 2011, pp.2518-2522
[21]. *Liu C X,Chang, G R,Jia J et al.*, A load balanced routing protocol based on ant colony algorithm for wireless mesh network// Proceedings of the 5th International Conference on Genetic and Evolutionary computing (ICGEC 2011), Kinmen, China, 2011, 295-298
[22]. IEEE 802.11s. IEEE amendment, mesh networking. IEEE P 802. 11s/D1. 06, Piscataway,2007.
[23]. *Raniwala A, Chiueh T.C.*, Architecture and Algorithms for an IEEE 802.11-based Multi-Channel Wireless Mesh Network. IEEE INFOCOM Conference, 2005, Piscataway: 2223-2234
[24]. *Perkins C, Royer B E, Das S.* , Ad Hoc On-Demand Distance Vector (AODV) Routing. IETF Experimental RFC 3561,2003.
[25]. IEEE Task Group S., Simple Efficient Extensible Mesh (SEE-Mesh) Proposal. IEEE P802.11 Wireless LANs, IEEE Document 802.11-05/0562r0, 2005.
[26]. *Raniwala A Gopalan K Chiueh T,* Architecture and algorithms for an IEEE 802, 11-based multi-channel wireless mesh network ,2005.
[27]. *R. Draves, J. Padhye, B. Zill.*, Routing in Multi-Radio, Multi-Hop Wireless Mesh Networks, ACM Annual Int'l. Conf. Mobile Comp.and Net. (MOBICOM),2004.
[28]. *MA Liang Mieso, K*, A routing metric for load balancing in wireless MESH networks, 2007. AINAW'07, 0-7695-2847-3/07, IEEE
[29]. *Balasangameshwara Jasma, Nedunchezhian Raju*, Performance-Driven Load Balancing with Primary-Backup Approach for Computational Grids with Low Communication Cost and Replication Cost IEEE Transactions on Computers, vol. 62, no. 5, 2013, pp. 990-1003.
[30]. *Y.-H. Lee, S. Leu and R.-S. Chang*, Improving Job Scheduling Algorithms in a Grid Environment Future Generation Computer Systems, vol. 27, 2011, pp. 991-998.
[31]. *Yajun Li, Yuhang Yang, Maode Ma, Liang Zhou*, "A Hybrid Load Balancing Strategy of Sequential Tasks for Grid Computing Environments", in Future Generation Computer Systems, no. 25, 2009, pp. 819-828.
[32]. *Khan, Rafiqul Z., and Md F. Ali*, An Efficient Diffusion Load Balancing Algorithm in Distributed System. International, in Journal of Information Technology and Computer Science (IJITCS) 6, no. 8, 65,2014.
[33]. *Celaya, Javier, and Unai Arronategui*, "A Task Routing Approach to Large-Scale Scheduling Future Generation", in Computer Systems, vol.29,2013, pp. 1097-1111.