Sensors & Transducers, Vol. 22, Special Issue, June 2013, pp. 22-28

www.sensorsportal.com

Sensors & Transducers

http://www.sensorsportal.com

A MANET Routing Algorithm Based on Difference Degree and Stability of Nodes

[1,*] Yanyan Han, [1] Deshi Li, [1, 2] Jugen Nie

[1] School of Electronic Information, Wuhan University, China

[2] College of Information, Nanchang Institute of Technology, Nanchang, China

Tel.:/fax: +86-027-68774465

E-mail: hanyan4981@163.com, dsli@whu.edu.cn, niejugen@163.com

Received: 15 April 2013 /Accepted: 20 June 2013 /Published: 28 June 2013

Abstract: Aiming at the team-based mobile ad-hoc networks (MANETs), this paper proposes a main-route mechanism by the mobility difference degree of nodes and a backup route mechanism by the nodes stability. In this paper, the whole network is divided into different partitions, and the prediction node computes the changing rate of local topology to determine whether local status broadcast is needed. In order to reduce the similarity of the main route and backup route and minimize the probability of simultaneous failure of the two routes, different routing metrics are used to discover these two routes to ensure reliable data transmission. As a result, the availability of backup route can be increased when the main route fails. While a link is broken, we advance a novel local confirmation method of link interruption and local route reparation. The simulation results shows that our routing algorithm is effective and can improve the network performance significantly. *Copyright © 2013 IFSA.*

Keywords: MANET, Routing, Difference degree, Stability, Link interruption.

1. Introduction

Mobile Ad hoc Network (MANET) is a multi-hop temporary autonomous system composed by mobile terminals with radio antennas. It depends on the ability of communication and information processing for each terminal, rather than the external infrastructure or base station. The feature of autonomy makes MANET a perfect candidate to implement many monitoring and tracking tasks both in academic and industry fields. The nodes are assumed to be homogeneous with the similar resources and capability, of which the primary function is to share information in a timely way.

MANET nodes form a network on demand to transmit data from one side to another. Due to the mobility of MANET nodes, the network topology is dynamic, transmission bandwidth is limited and energy is restricted etc, so how to build an end-to-end reliable route is the key issue and constraint in stable data transmission. Especially when a route fails, another new route must be discovered timely to ensure normal data transmission. Therefore, it is necessary to set up a backup route besides the main route.

The challenge of routing in MANET is as following. First, the mobility pattern for each node may be different despite of the overall consistent moving area. The relative movement leads to the change of a link between nodes such that they may be out of the communication range with each other. Therefore, a link may be disconnected for a while. At this time, we need another path in order to continue the normal data transmission. Secondly, we don't want to change the route too frequently in case the relative movement of nodes is highly dynamic, which means we prefer a stable route to a shortest route when the

Article number P_SI_374

topology is dramatically changing. That is the motive why we propose the routing algorithm based on difference degree and stability of nodes.

Our contribution in this paper is that we first propose the idea of main route and backup route selection under different criteria, where the former is based on the nodal degree difference and the latter is based on the stability of two nodes. As under dynamic network topology the stability of a route is more important than the temporal efficiency of a route. In detail, we use the prediction node to estimate the changing rate of local topology to initiate a local broadcast. In case of route interruption, we give the strategy to confirm the interrupted section and use route maintenance to rebuild a new path.

The rest of the paper is organized as follows. Relevant research is discussed in the next section. Section 3 gives related definitions in the routing protocol and Section 4 describes the protocol in three stages. Next the simulation and analysis are introduced to verify the efficiency of our proposal. Finally, we conclude the whole paper.

2. Related Work

Currently, there has been a lot of research in the area of MANET routing protocols. In the prospect of trigger mechanism of routing algorithms, there are basically proactive routing, reactive routing and hybrid routing. Since the proactive routing cannot accommodate the condition of node mobility and changing topology, we only discuss the reactive routing protocols. In [1], when nodes receive the broadcast of a source node, the one with the minimal delay is selected to forward the packet. Literature [2] proposes a hybrid source routing protocol, in which nodes are divides into different zones by distance and takes the payload of zone header into account. In [3], nodes with similar mobility model are distributed into the same cluster and the connection probability of nodes is updated using moving average. Literature [4] chooses routes by estimation of the residual lifetime of backup route and makes a tradeoff between link residual lifetime and throughput with preference of maximal throughput. Literature [5] utilizes the changing rate of received signal strength to calculate the available bandwidth and link residual lifetime and predict the traffic and energy of node to select a path with maximal energy.

In [6], the author differentiates kind nodes and malicious nodes and chooses nodes with the largest belief degree to form the current route. In literature [7], mobile nodes collect the positions and forwarding model of neighbor nodes in the phase of route acknowledgement, to correct the main route to maximize its bandwidth. In [8], the main route is discovered by AODV and backup route is established in the process of data transmission. Backup route is mainly composed by nodes not in the main route, and when either of them fails, the other can be utilized. Literature [9] integrates nodes speed, neighbors' speed and number of neighbors into a routing metric to derive a most stable path. In [10], for the payload of central node is heavy, it advances a payload balance mechanism, in which the traffic of central node can be transferred to others and the concentration degree is taken as the routing metric. Paper [11] adopts mobility prediction and load balance to derive a more stable route.

In the present research of MANET routing, the objective parameters of routing algorithms include node distance, nodes neighbor number, link residual energy, link residual bandwidth, payload balancing, link transmission rate etc. after the link is determined, there should be one or more backup routes to guarantee normal data transmission when the main route fails. However, the routing metric of backup route is always the same as the main route, which means the final backup route is the sub-optimal solution of the initial objective function (the optimal solution is the main route). So the nodes set in backup route have the similar characteristics of mobility or positions with the nodes in the main route. If the main route is broken, it indicates that the mobility of nodes on the route is not stable. If nodes in the backup route are also not stable, route is likely to break due to the similar mobility model. Therefore, once the main route interrupts, the backup route, the backup route may be also failed so that there is no use to build a backup route.

This paper proposes a MANET routing protocol-route establishment and maintenance based on nodes difference degree and lifetime (REMDLE). The key idea is that the routing metrics of main route and backup roué are different in order to minimize the similarity of two routes, with consideration of nodes' load balancing. We advance a local confirmation method of link interruption and local route reparation. In addition, we divide the network into different partitions to determine whether broadcast the local network status after estimating the changing rate of local topology.

The application background is the mobile team of multiple independent mobile nodes, which is able to make decisions toward changing environment autonomously, but the moving pattern is restricted by the mobility of the whole team. The typical example is the mobile robot team cooperates to complete specific tasks.

3. Definitions

In order to clearly describe the network condition involved in the routing process, we first define the following concepts.

3.1. Main Route and Backup Route

Main route includes nodes with the least difference, which emphasizes the efficiency of data transmission. Backup route is made up of nodes with the highest stability, which is related with the changing rate of nodes mobility while considering the congestion and payload of nodes. Comparatively, it emphasizes the availability of data transmission.

3.2. Nodal Difference Degree (dd)

It depends on three variables:
distance error $\Delta d = \sqrt{(x1-x2)^2+(y1-y2)^2}$,
angle error $\Delta\theta = \cos(\theta 1-\theta 2)+1$,
and speed error $\Delta v = \min(v1,v2)/\max(v1,v2)$, so

$$dd = \frac{\Delta\theta}{\Delta d + \Delta d} \tag{1}$$

3.3. Speed Variance σ (v)

It reflects the changing rate of node speed, and n is the historical values and E(v) is the average speed in time of T. The less σ(v) is, the more stable node v is.

$$\sigma(v) = \sqrt{\frac{1}{n}\cdot\sum[v-E(v)]^2} \tag{2}$$

3.4. Link Stability S

The stability of a link is also related with nodes distance. Besides, node-disjoint backup route is preferred because the shared nodes or links may influence both routes if they fail on one route. So some restrictions are made on the nodes both on two routes to reduce their correlation.

$$S = \frac{1}{\mu_1\cdot\frac{rt\_num}{total\_rtnum}+\mu_2\cdot\frac{\sigma(v)}{v_{av}}+\mu_3\cdot\frac{d}{r}} \tag{3}$$

where $\frac{rt\_num}{total\_rtnum}$ indicates that if a node belongs to more than one route, it is not likely to be included in another new route.

3.5. Link Expiration Time (LET)

$$LET = \frac{-(ab+cd)-\sqrt{(a^2+c^2)r^2-(ad-bc)^2}}{a^2+c^2} \tag{4}$$

where $a = v_i\cos\theta_i - v_j\cos\theta_j$, $b = x_i - x_j$, $c = v_i\sin\theta_i - v_j\sin\theta_j$, $d = y_i - y_j$. LET is the minimal connection time of two nodes, v_i and v_j are the velocities, (x_i, y_i) and (x_j, y_j) are coordinates, r is the effective transmission range. The lager LET is, the longer the link will be.

3.6. Topology Changing Rate

Node counts its neighbors to make sure if it can become a prediction node by the latest broadcasting information. To determine whether to broadcast nodes status, the prediction node calculates the topology changing vector of its partition in period of T_{stb}. Then a local average speed V_{av} is derived, after Δt, a new central position *C'(x, y)* is estimated. So assuming the network partition moves with Vav in Δt, another position *C''(x, y)* can be obtained as shown in Fig.1.

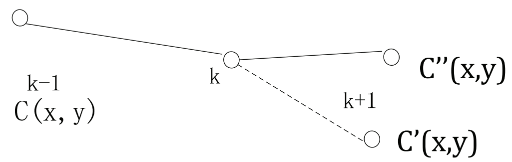

Fig. 1. Central node and its positions.

$$\vec{a} = C'(x,y) - C(x,y)$$
$$\vec{b} = C''(x,y) - C(x,y) \tag{5}$$

So the two vector error is defined as $d_c = \vec{a} - \vec{b}$, if ||dc||>r, it is perceived the topology changes so great that a local broadcast is needed.

But there is a question about who can be elected as the prediction node. First, the node should have multiple neighbors, i.e. it is the common neighbor for multiple nodes and once the node is a prediction node, other nodes in this partition cannot become the prediction node any more. Secondly, a node could be in different partitions, so its status information can be received by other partitions. Thirdly, the node that first satisfies the condition that more than λ neighbors are found will become the prediction node. In this way, the isolated nodes that don't belong to any partitions keep the connection with other nodes by changing its moving status.

3.7. Improved Random Walking Mobility Model

The mobility model is based on random walking mobility model. It has the following features: the moving time of every node is composed of some mobility epochs with random length, in which the node velocity v_{in} and direction θ_{in} keeps constant. In this paper, to control the topology changes in some extent, we make some improvement—the speed in an epoch is mainly stable, but if a node finds it is too far away from its neighbors, it will adjust its speed to ensure it doesn't become an isolated node.

4. Protocol Description

Due to the fact that the data flow in MANET can be in either direction, our routing scheme is demand oriented which is consisted of three major stages: route discovery, disconnected route confirmation and route maintenance. Each stage is discussed in the following.

4.1. Route Discovery

The objective function of the main route selection:

$$\max(LET / d_s) \tag{6}$$

The objective function of the backup route selection:

$$\max(LET \cdot S) \tag{7}$$

The reason why stable path is chosen as the backup route is that if nodes mobility is stable in a certain period, it is reasonable to deduce that they will also move in a stable pattern in the future time, so we can predict their approximate positions. If all nodes in a route are stable nodes, whose velocities are changing slowly, the path is inclined to be quasi-static and not prone to interruption. As a result, this kind of route is more suitable to transmit data. The route discovery phase is shown in Fig. 2.

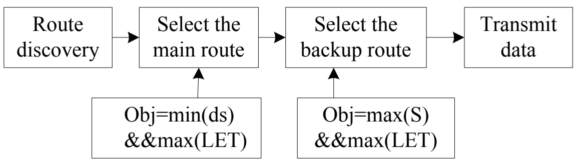

Fig. 2. Modules of route discovery.

Since the direction of data flow is not determinate, the scheme of route discovery is demand driven. In the initial stage of replying the acknowledgement packet from the destination node, the main route is selected by Eq. (6). After the main route is decided, the backup route will be selected by Eq. (7). And then data transmission begins immediately. Fig. 3 shows how route discovery stage is realized.

4.2. Confirmation of Link Interruption

After two routes are established as in Fig. 4, source node 0 sends data to destination node 4, and 4 will reply Data Packet Reply (DREP) when receiving the data. If there are some link interruptions in transmission, node 0 will not receive DREP in T1, so it is assumed that this route has failed, but it is not possible to confirm which link is broken. Here, we propose a policy of confirming link interruption.

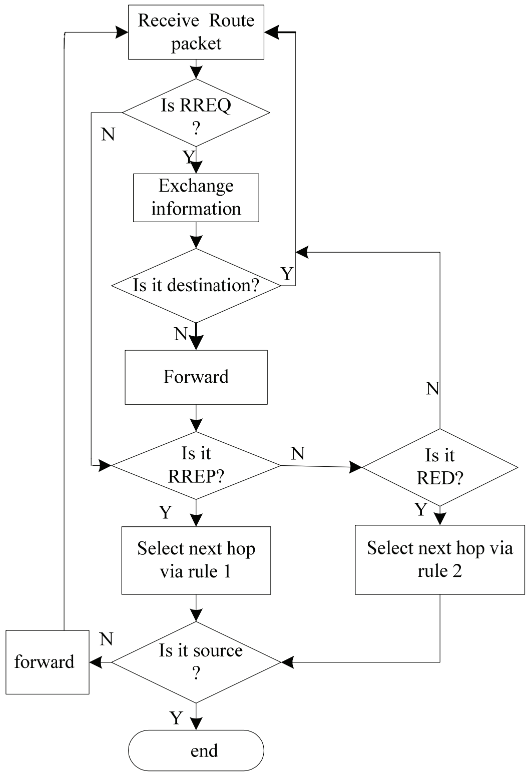

Fig. 3. Route discovery.

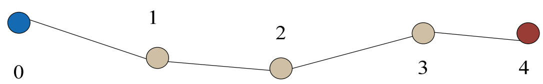

Fig. 4. Demonstration of a path.

There are two cases in link interruption: I. Link interruption in the phase of transmitting data packet; II. Link interruption in the phase of transmitting reply packet.

Case I. the starting node of the broken link is the one which firstly satisfies (8):

$$\begin{cases} a.\text{it receives the data} \\ b.\text{it doesn't receive the reply} \end{cases} \tag{8}$$

And the ending node of the broken link is the one which lastly satisfies (9):

$$\begin{cases} a.\text{it doesn't receive the data} \\ b.\text{it doesn't receive the reply} \end{cases} \tag{9}$$

So we can determine the link which is disconnected on the route in case I.

Case II. The starting node of the broken link is the one which lastly satisfies (10):

$$\begin{cases} a.\text{it receives the data} \\ b.\text{it receives the reply} \end{cases} \quad (10)$$

And the ending node of the broken link is the one which firstly satisfies (11):

$$\begin{cases} a.\text{it receives the data} \\ b.\text{it doesn't receive the reply} \end{cases} \quad (11)$$

So we can determine the link which is disconnected on the route in case II.

For instance, if link 2->3 is disconnected, then node 2 is the first node satisfying condition (1), since node 2 receives the reply earlier than node 1. Node 3 and 4 both can satisfy condition (2), so that we can only find the link 2->3 is disconnected but can't make sure the status of link 3->4. If link 3->2 is broken, then node 3 is the last one satisfying condition (3), but either node 2, 1 or 0 satisfies condition (4). Therefore, we can only confirm the subsection of interruption rather than the accurate links. After that, the process of route maintenance is started by the node that first discovers the route failure in order to get a new route from the backup routes. The detailed process is illustrated in Fig. 5.

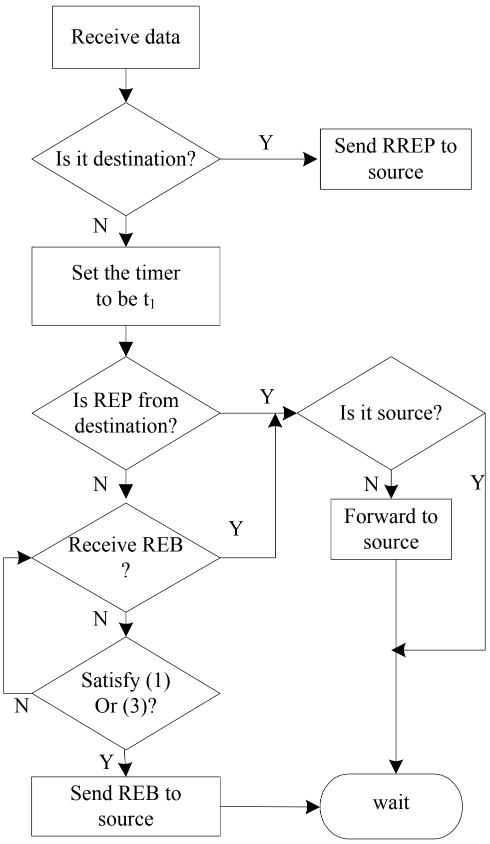

Fig. 5. Route disconnection confirmation.

4.3. Route Maintenance

If link α—>β is broken, since node *α* has received the data from the source node, but has not received Route Reply (RREP) within T2, so *α* assumes that the path *α*—>destination node is broken, and *α* will send a Route Maintenance packet (RM) to the source node. When the downstream nodes receive RM, they will check whether there is an available route from them to the destination node. If there is, they will send RRM to the destination, otherwise, they do nothing. When the upstream nodes receive RM, they will check whether they are the destination. If not, they simply forward RM, and if they are, they will go to sleep and wait for the REB to set up the backup route to the source node, as shown in Fig. 6.

Once a new route is set up, the initial main route is considered as the new backup route, which means nodes still keep the routing information since it is highly possible for this new route to become disconnected again. Notice that after the first route failure, the following route selections are all based on the backup route criteria. So that the stability of new route is better than the initial main route.

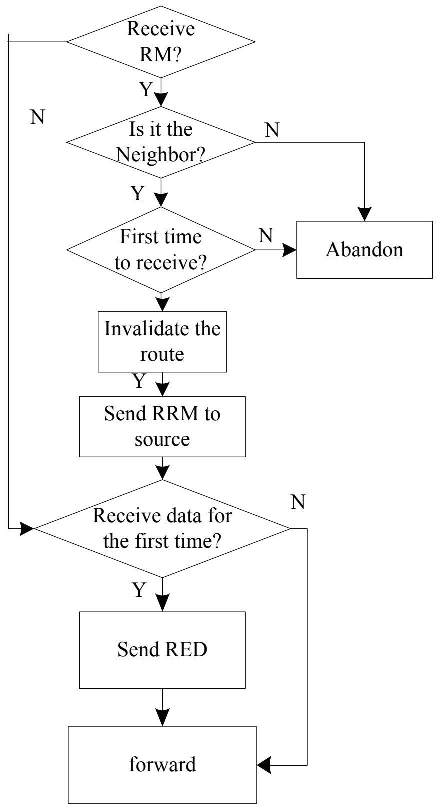

Fig. 6. Route maintenance process.

5. Simulation and Analysis

Simulation setup: mobility model is the improved random walking mobility model. There are 20 nodes in the network randomly deployed. The node speed is varied between 2 m/s and 12 m/s, Packet size is 512 bit, with the data generation of CBR.

In the simulation, we mainly compare our algorithm REMDS with Ad hoc On-Demand Distance Vector Routing (AODV) in the prospect of average link interruption rate, packet delivery rate and end to end delay. By comparison we can derive that when the main route fails, REMDS adopts the backup route mainly composed of stable nodes, whose changing rate of moving status is relatively small and the connectivity is quite steady. AODV doesn't consider the changing speed and varied relative positions between nodes, so there may be more broken links. Therefore, the link interruption rate of REMDS is lower than that of AODV as Fig. 7 denotes.

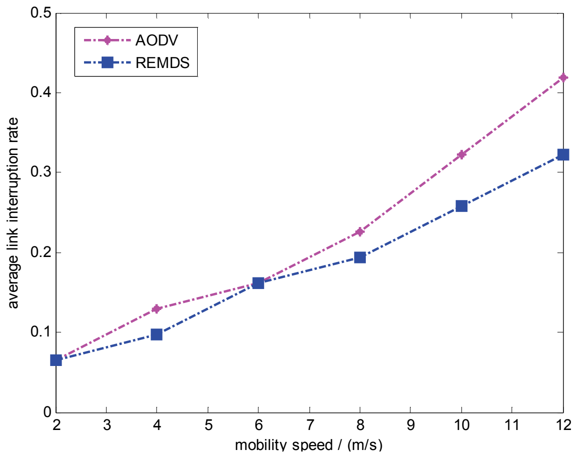

Fig. 7. Average link interruption rate.

Link interruption rate is critical to evaluate the efficiency of a routing scheme because here the MANET is inclined to be a disruption tolerant network. With the same network topology variation, the lower interruption rate indicates there are more stable routes for reliable date delivery.

However, it can only be guaranteed that the path is available and relatively stable when using the backup route in REMDS, rather than that the path has the minimum hop count from the source node to the destination node in AODV. Therefore, the end to end delay is a little higher than in AODV, as shown in Fig. 8.

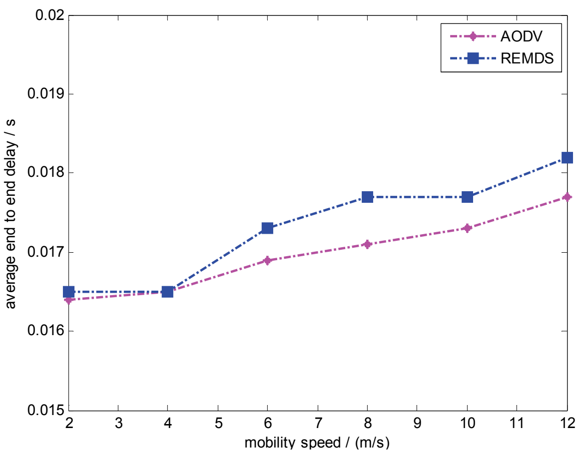

Fig. 8. Average packet delivery rate.

When the main route is connected, the packet delivery ratio (PDR) is almost the same, but once it is not available, the stable backup route in REMDS can ensure the data to reach the destination as much as possible, resulting in higher PDR than that in AODV, as Fig. 9 indicates.

The packet delivery rate and average delay are sometimes a tradeoff. Since in such a dynamic MANET, it is more important to successfully deliver the packet to the destination while the delivery latency can be a little compromised due to a longer transmission path. But the waiting time for a new route to be established and the frequency to change routes are decreased so that the overall performance is better.

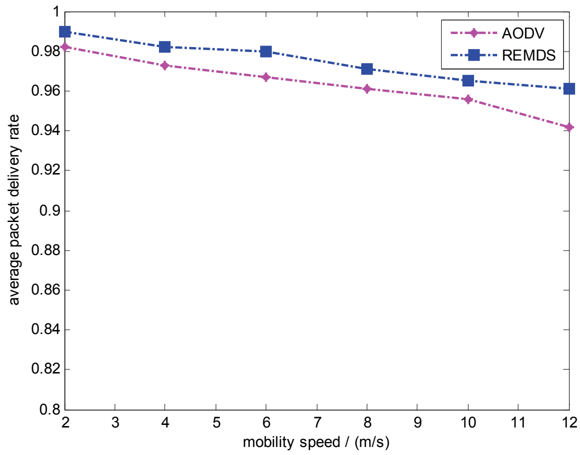

Fig. 9. Average end to end delay.

6. Conclusion

This paper proposes a main route protocol REMDS, which is based on nodes difference degree and a backup route protocol based on nodes mobility stability. In MANET, traditional backup route selection is closely related with the main route, where the optimal solution satisfying the same objective function becomes the main route and the sub-optimal solution becomes the backup route. In order to decrease the correlation between the two routes, we advance to use different objective functions in route discovery with consideration of node's load balancing. This can improve the availability of backup route when the main route fails. In addition, we present a local confirmation method of link interruption, and it can efficiently conduct local route reparations.

Acknowledgments

The authors would like to thank the reviewers for their detailed comments that have helped to improve the quality of the paper. This work was funded in parts by National Basic Research Program of China (973

Program) 2011CB707106, NSF China 60972044 and the Fundamental Research Funds for the Central Universities 201121202020002.

References

[1]. Hongpeng Wang and Zhongqiu Li, Self-selection Based Adaptive Routing for MANET, *World Congress on Computer Science and Information Engineering,* Vol. 1, 2009, pp. 418-422.

[2]. Wenhua He, A zoned MANET routing protocol, *Computer Engineering and Applications*, 2007, Vol. 28.

[3]. Ha Dang, Hongyi Wu, Clustering and Cluster-Based Routing Protocol for Delay-Tolerant Mobile Networks, *IEEE Transactions on Wireless Communications*, Vol. 9, 2010, pp. 1874-1881.

[4]. Agarwal, S., Ahuja, A., Singh, J. P. and Shorey, R., Route-Lifetime Assessment Based Routing (RABR) Protocol for Mobile Ad-Hoc Networks, in *Proceedings of the IEEE International Conference on Communications,* Vol. 3, 2000, pp. 1697-1701.

[5]. Ching-Wen Chen, Chuan-Chi Weng and Yu-Chen Kuo, Signal strength based routing for power saving in mobile ad hoc networks, *Journal of Systems and Software*, 2010, Vol. 83, pp. 1373-1386.

[6]. Haidar Safa, Hassan Artail, Diana Tabet, A cluster-based trust-aware routing protocol for mobile ad hoc networks, *Wireless Networks*, 2010, Vol. 16.

[7]. Chuan-Chi Weng, Ching-Wen Chen, Chang-Jung Ku and Shiow-Fen Hwang, A Bandwidth-Based Power-Aware Routing Protocol with Low Route Discovery Overhead in Mobile Ad hoc Networks, *Computer Journal,* Vol. 53, 2010, pp. 969-990.

[8]. Chang-Woo Ahn, Sang-Hwa Chung, Tae-Hun Kim and Su-Young Kang, A Node-Disjoint Multipath Routing Protocol Based on AODV in Mobile Ad hoc Networks, in *Proceedings of the 7th International Conference on Information Technology,* 2010.

[9]. Cao Trong Hieu, Choong Seon Hong, A New Routing Protocol with High Throughput Route Metric for Multi Rate Mobile Ad hoc Networks, in *Proceedings of the 17th IEEE Workshop on Local and Metropolitan Area Networks*, 2010, pp. 1-5.

[10]. Oussama Souihli, Mounir Frikha and Mahmoud Ben Hamouda, Load-balancing in MANET shortest-path routing protocols, *Ad Hoc Networks*, 2009, Vol. 7.

[11]. Changgeng Tan, Huayuan Wang and Juan Wu, Lity prediction in the Ad hoc network, *Computer Simulation*, 2009, Vol. 5.