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RE-OLSR: Residual Energy-Based OLSR Protocol in Mobile Ad Hoc Networks

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Abstract*-OLSR is a well-known proactive routing protocol designed for mobile ad hoc networks (MANETs). OLSR adopts a concept of an MPR mechanism where only mobile nodes selected as MPR nodes can retransmit broadcast packets received from other mobile nodes. Although OLSR reduces the number of broadcast packets, MPR nodes consume more energy than other mobile nodes. Since mobile nodes in MANETs are powered by battery with limited energy, energy efficiency is a critical issue in designing a routing protocol that affects the overall network performance. This paper proposes a residual energy-based OLSR protocol named RE-OLSR. The RE-OLSR takes residual energy level of each node into account to select MPR nodes. The RE-OLSR also considers the reachability and the degree of one-hop neighbor nodes. The aim of RE-OLSR is to avoid selecting mobile nodes with small residual energy as MPR nodes and concentrating energy consumption in specific nodes. The performance of RE-OLSR is evaluated through simulation experiments. The results show that the proposed scheme improves energy efficiency and enhances network throughput efficiently.

Keywords-MANET; OLSR; MPR selection; Energy efficiency

I. INTRODUCTION

A mobile ad hoc network (MANET) is a dynamic collection of mobile nodes that are interconnected over wireless links. MANETs have no centralized communication controllers or base stations. Mobile nodes can freely and dynamically move and organize themselves into arbitrary and temporary network topologies as shown in Fig. 1. Thus, the network topologies may change rapidly and unpredictably. Due to the absence of any fixed communication infrastructure, each node in MANETs must be capable of functioning not only as a host but also as a router in order to forward packets to further nodes.

The limited resources and highly dynamic nature of MANETs have made a very challenging issue in designing an efficient and reliable routing protocol strategy. A large number of routing protocols have been proposed for MANETs in the past. Such protocols can be categorized as proactive, reactive, and hybrid protocols [1]. The proactive routing protocols (also known as table-driven routing protocols), such as OLSR (optimized link state routing protocol) [2] and DSDV (Destination-Sequenced Distance-Vector) [3], periodically exchange information on each node to maintain up to date routing table for all nodes throughout a network. Thus, they provide fast responses in the sense that when a message needs to be sent, a sender node immediately uses paths which are calculated in advance. On the other hand, the reactive routing protocols (also known as on demand routing protocols), such as AODV (Ad hoc On-demand Distance Vector) [4] and DSR (Dynamic Source Routing) [5], do not need periodic transmission of topological information. The reactive routing protocols establish routing information for a path to destination nodes only when they are required. The hybrid routing protocols, such as TORA (Temporally Ordered Routing Algorithm) [6] and ZRP (Zone Routing Protocol) [7], integrate some characteristics of both reactive and proactive routing protocols.

The characteristics of routing protocols affect energy consumption behavior. Mobile nodes often consume their energy due to various actions such as transmitting packets and receiving packets. Since mobile nodes in MANETs are supplied by battery with limited energy, energy efficiency is a serious problem that affects the overall system performance of MANETs.

One of well-known routing protocols for MANETs is OLSR. The OLSR is a proactive routing protocol as mentioned earlier. The OLSR has been developed at INRIA and standardized by the IETF MANET working group in the draft Request for Comment RFC3626 [2]. In OLSR, the routing table of each mobile node is constructed by periodically performing flooding of broadcast packets. In order to reduce the number of broadcast packets, OLSR uses the idea of multipoint relay (MPR) [8]. Each mobile node selects one-hop neighbor nodes as MPR nodes based on their reachability and degree. Because only MPR nodes can forward broadcast packets received from other mobile nodes, OLSR reduces the number of broadcast packets. Note that MPR nodes transmit more packets than other mobile nodes, so that they consume more energy. In order to efficiently use the energy resource of each mobile node, we have to select MPR nodes carefully.

Energy efficiency is an important issue in OLSR. In the past, several schemes considering energy efficiency in OLSR have been proposed [9]-[15].In [9], the authors extended OLSR to OLSR_EA by selecting paths based on the total energy cost including the transmission power and residual energy level of intermediate nodes. The authors in [10] combined MPR selection and path determination mechanisms which take into consideration of energy efficiency in order to enhance the performance of OLSR.

In [11], the research studied three MPR selection policies named *E*, *M*1*E*, and *M*2*E*. The *E* policy considers only residual energy of one-hop neighbors. The*M*1*E* policy considers the weighted residual energy of an MPR candidate and its one-hop neighbors. Also, the*M2E* policy considers the weighted residual energy of an MPR candidate and its one-hop and two-hop neighbors.

In [12], the authors proposed an energy-efficient broadcast protocol named EBOLSR, which adapts the *M1E* to the broadcast domain. In order to maximize the broadcasting network lifetime, the authors take residual energy of neighboring nodes into consideration when selecting MPR nodes.

The authors of [13] proposed two MPR selection mechanisms named E-OLS: 1 and E-OLSR: 2.They use the amount of residual energy and cost to send packets as metric in order to select MPR nodes. The authors showed that the number of active nodes is increased by their mechanisms. In [14], the authors integrated a modified MPR selection scheme of [13] with a path determination algorithm based on the residual energy level of each link.

The authors of [15] proposed Energy-Efficient OLSR (EE-OLSR). The EE-OLSR introduces the energy aware willingness setting. The energy aware willingness setting decides N_willingness, which is a parameter of OLSR, of each node based on its battery capacity and predicted lifetime. In particular, the battery capacity is divided into three levels: low, medium, and high. Also, the predicted lifetime consists of short, medium, and long. A pair (battery, lifetime) is associated to value of N_willingness(WILL_DEFAULT,WILL_LOW, and WILL_HIGH).

In this paper, we propose a residual energy-based OLSR protocol for MANETs named RE-OLSR, which provides an MPR selection mechanism. The existing MPR selection mechanisms mainly consider residual energy of each node. On the other hand, RE-OLSR selects MPR nodes based on not only the residual energy of one-hop neighbors but also their reachability and degree. The aim of RE-OLSR is to avoid selecting mobile nodes with small residual energy as MPR nodes and concentrating energy consumption in specific nodes. RE-OLSR is expected to reduce energy consumption and enhance the throughput performance of MANETs.

The rest of this paper is organized as follows. Section 2 describes the concept of OLSR. In Section 3, we explain RE-OLSR. Section 4 discusses performance of RE-OLSR with results of simulation experiments. We conclude the paper in Section 5.

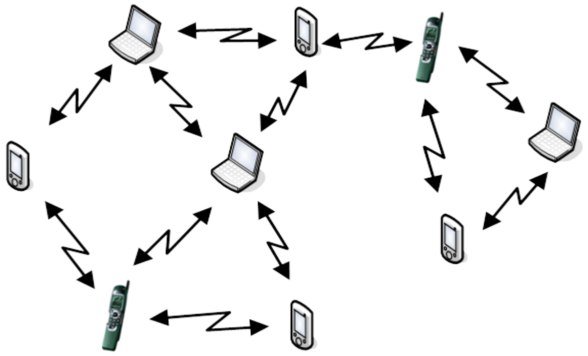

Figure1. Mobile ad hoc network

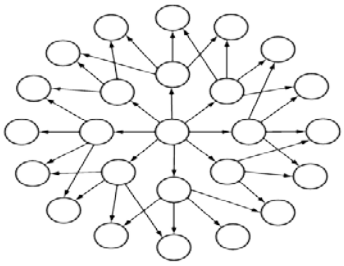

Figure 2(a). Flooding without MPR

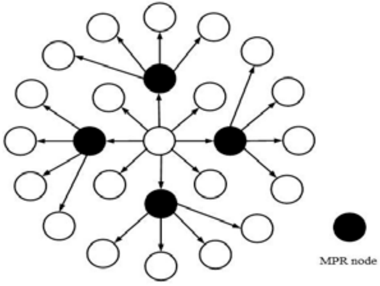

Figure 2(b). Flooding with MPR

II. OPTIMIZED LINK STATE ROUTING (OLSR) PROTOCOL

OLSR is a proactive routing protocol which was developed for MANETs. In OLSR, each mobile node performs flooding of broadcast packets which contain Traffic Control (TC) messages in order to construct its routing table. TC messages have topological information collected by exchange of HELLO messages between each pair of adjacent nodes. In order to reduce the number of broadcast packets, OLSR uses the idea of MPR [8], in which each mobile node selects some of one-hop neighbor nodes as an MPR set. Selected nodes as an MPR set are called MPR nodes and an MPR set consists of MPR nodes of a mobile node. Also, for MPR nodes, a mobile node which selects them as MPR nodes is called an MPR selector. The MRP set of a mobile node covers all its two-hop neighbor nodes. Fig. 2 shows the concept of MPR. As shown in Fig. 2(a), in flooding without MPR, all one-hop neighbor nodes forward the flooding packets to two-hop neighbor nodes. On the other hand, in OLSR, only MPR nodes forward the flooding packets. Although the one-hop neighbor nodes which are not a member of the MPR set receive and process TC messages, they do not retransmit them to further nodes. Therefore, the number of flooding packets is reduced. In what follows, we explain HELLO messages and TC messages in more detail. We also explain how to select MPR nodes.

A. HELLO Message

In order to detect links and neighbors, HELLO messages are periodically sent by each node to its one-hop neighbor nodes according to the hello-interval time. HELLO messages are not forwarded to further nodes. AHELLO message of a mobile node contains information on its one-hop neighbor nodes and links status. Thus, this mechanism enables each node to detect not only their one-hop neighbor nodes but also their two-hop neighbor nodes. This information is used by each node to independently select its own MPR nodes among its symmetric one-hop neighbor nodes.

B. TC Messages

TC messages perform a task of topology declaration. TC messages are broadcasted by each mobile node for advertising its own topological information collected by exchange of HELLO messages. Each mobile node generates the TC messages periodically at every refreshing period called TC-interval except that there are changes detected in the mobile node before the TC-interval. A TC message contains information on its MPR selector set and includes the sequence number associated to the TC message. Only the nodes which are selected as MPR nodes can disseminate TC messages. Based on the information diffused by TC messages, each mobile node creates its own routing table.

C. MPR Selection

Each mobile node has a parameter named N_willingness which indicates the intention of the node to forward packets. Specifically, mobile nodes with large N_willingness are likely to become MPR nodes. The N_willingness of a node is set to be 0 (WILL_NEVER), 1 (WILL_LOW), 3 (WILL_DEFAULT), 6 (WILL_HIGH), or 7 (WILL_ALWAYS). The default value of the N_willingness is WILL_DEFAULT. WILL_NEVER indicates that a mobile node does not wish to forward messages to the next hop, and thus it is not selected as an MPR node. WILL_ALWAYS indicates that a mobile node is always selected as an MPR node.

The heuristic for standard MPR computation for each mobile node is as follows [2], where Na and Nb denote a set of one-hop neighbor nodes and a set of two-hop neighbor nodes, respectively:

1) Select nodes, each of whose N_willingness is WILL_ALWAYS,from $N_a$as members of an MPR set (i.e., MPR nodes).Then, remove two-hop neighbor nodes which are covered by selected nodes from N_b.
2) For each node y inN_a, calculate the degree $D(y)$, which is defined as the number of symmetric one-hop neighbors.
3) Add nodes in N_a, which are the only nodes to provide reachability to a two-hop neighbor node in N_b, to the MPR set. Then, remove two-hop neighbor nodes which are covered by the selected nodes in the MPR set from N_b.
4) Unless N_b is empty, the following steps a) and b) are repeated:

a) For each node $y$in N_a, calculate the reachability $R(y)$, where the reachability denotes the number of nodes in N_b which are not yet covered by at least one MPR node in the MPR set, and which are reachable through node y.

b) Select node y with the highest N willingness from nodes with non-zero reachability in N_a. In case of multiple choices, select a node with highest $R(y)$. If there are multiple nodes with highest reachability, select one with largest $D(y)$ from those nodes. Then add the selected node to the MPR set, and remove the two-hop neighbor nodes which are covered by the selected node from N_b.

5) For optimization, MPR nodes can be removed from the MPR set if the remaining MPR nodes in the MPR set still cover all two-hop neighbor nodes.

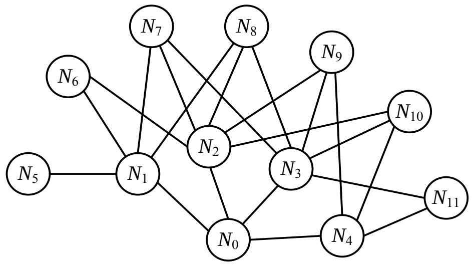

Figure3. One and two hop neighbors

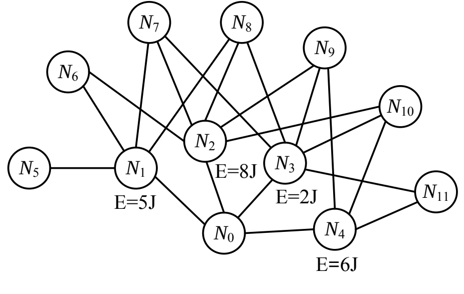

Figure4. Nodes with energy constraint

We show an example of MPR selection with Fig.3, where node N0 is an MPR selector and N_willingness of each node isWILL_DFAULT. According to the above procedure, MPR nodes are selected as follows. Note that Table 1 shows status of Fig. 3. The one-hop neighbor nodes are N1, N2, N3, and N4. Because there are no one-hop neighbor nodes with WILL_ALWAYS, step 1) is omitted. In step 2), D(N1), D(N2), D(N3), and D(N4) are 4, 5, 5, and 3, respectively. Step 3) finds that N5 is covered by only N1. Thus, N1 is selected as an MPR node. In step 4.1), for N2, N3, and N4, reachability R(y) is calculated. In this case, R(N2), R(N3), and R(N4) are 2, 3, and 3, respectively, because N6, N7, and N8arealready covered by N1. Therefore, N3 and N4 are candidates for MPR nodes. Because D(N3) is larger than D(N4), N3 is selected as an MPR node. After that, all two-hop neighbor nodes are covered by MPR nodes. Thus the procedure stops and MPR nodes are N1 and N3 as shown in Table 1.

TableI MPR SELECTING OF OLSR PROTOCOL

Selector Node	**ONE-HOP Neighbors**	**Two-hop Neighbors**	**MPR Nodes**
N_0	N_1, N_2, N_3, N_4	N_5, N_6, N_7, N_8, N_9, N_{10}, N_{11}	N_1, N_3

III. RESIDUAL ENERGY-BASED OLSR

As shown in Fig. 4, we now add energy constraints to the nodes in Fig. 3. In Fig. 4, we assume that nodeN0is selecting its MPR set. When the OLSR standard is used, the MPR set of N0 is {N1, N3} as shown in Table 1. Therefore, only nodes N1 and N3 can forwards flooding packets. However, as it can be seen from Fig. 4, the residual energy ofN3 (2 joules) is smaller than that ofN2 (8 joules) and N4(6 joules).In such a case, we should select other nodes as MPR nodes because energy of N3may run out quickly. In particular, it is not desirable that nodes with low residual energy are selected as MPR nodes in terms of energy efficiency. Furthermore, we should consider reachability and degree. Specifically, we should avoid selecting mobile nodes with low reachability and degree as MPR nodes even if the mobile nodes have much energy. This is because MPR nodes may increase when we consider only residual energy of a mobile node. Note that it is preferable that the number of MPR nodes is small in terms of energy efficiency.

Based on the above consideration, RE-OLSR takes residual energy level into account in order to select MPR nodes. The RE-OLSR also considers reachability and degree of one-hop neighbor nodes. To do so, the heuristic of RE-OLSR modifies the step 4) of the MPR selection in OLSR standard as follows:

4）Unless N_b is empty, the following steps a), b), and c) are repeated:

a) For each node y in N_a, calculate the reachability $R(y)$.

b) For each node y in N_a, calculate the residual energy $E(y)$. Let y_h denotes the node with the highest residual energy whose reachability is more than 0, i.e., $R(y_h)> 0$.

c) If $E(y_h) - E(y) \geq \alpha$ for any node y in N_a, add the node y_h to the MPR set, where α is a parameter. Otherwise, select a node with the highest $R(y)$ from nodes each of whose residual energy $E(y)$ is bigger than $(E(y_h) - \alpha)$ in N_a. If there are multiple nodes with highest reachability, select one with largest $D(y)$ from those nodes. If $D(y)$'s of those nodes are also the same, select one randomly. Then add the selected node to the MPR set, and remove nodes which are covered by the selected node from N_b.

TableII MPR SELECTED BY RE-OLSR

MPR node		
$0 \leq \alpha \leq 2$	$2 < \alpha \leq 6$	$\alpha > 6$
N_1, N_2, N_4	N_1, N_4	N_1, N_3

TableIII SIMULTION PARAMETERS

Simulation Parameters	
Area size	800m x 800m
Number of nodes	50
Max node speed	10 m/s
Simulation time	200 s
Number of traffic sources	20
Traffic type	CBR
Packet size	512 bytes
Propagation model	Two-Ray Ground
Mobility model	Random Waypoint
Media access control	IEEE 802.11
Queue length	50
N_willingness of each node	3
Transmission power	1.2 W
Receiving power	0.6 W
Idle power	0 W

We show an example of RE-OLSR with Fig. 4, where α is set to be 3. Because N5 can be reached through only N1, N1 is selected as an MPR node. After N1 has been selected as an MPR node, the reachability of N2, N3, and N4 becomes 2, 3, and 3, respectively. Next, RE-OLSR finds the node yh with the highest residual energy. In this case, yh is N2 whose residual energy is equal to 8 joules. RE-OLSR then calculates E (yh) –E(y) for each node. Because α is set to be 3, N3 does not satisfy E(yh) – E(y) < α. On the other hand, N4 satisfies it. Thus RE-OLSR compares R(N2) with R(N4). R(N2) is smaller than R(N4) which is 3. Therefore, RE-OLSR selects node N4 as an MPR node. As a result, all two-hop neighbor nodes are covered by MPR nodes, i.e., N1 and N4. Thus, the procedure stops. Table 2 shows the relationship between MPR nodes and the value of α in this situation.

IV. PERFORMANCE EVALUATION

A. Model

To evaluate the performance of RE-OLSR, we conduct simulation experiments with NS2.34 network simulator [16] with UM-OLSR implementation provides by [17]. System parameters are listed in Table 3. There are 50 mobile nodes in an area of 800 m × 800 m. Each node randomly moves in this area. The maximum speed of mobile nodes is 10 m/s. There are 20 randomly selected pairs which send CBR traffic over UDP. Each source node continuously transmits 8 packets/s where the size of each packet is 512 bytes. The queue length of each mobile node is set to be 50. The N_willingness of each node is set to be 3, i.e., WILL_DEFAULT. The transmission power, the receiving power, and the idle power are set to be 1.2, 0.6, and 0 W, respectively. We collect 10 independent samples from simulation experiments, and the duration of each simulation is 200 seconds.

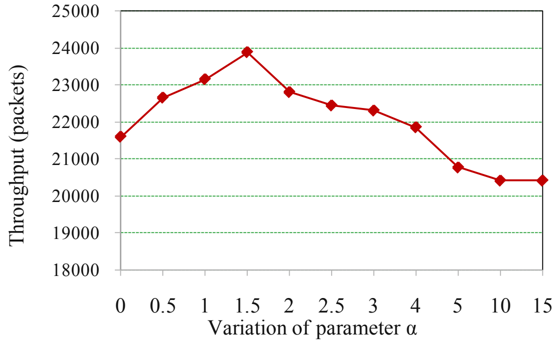

Figure5. Network throughput

B. Simulation Results

First, we examine the optimal value of α for RE-OLSR in our experimental scenario. Fig. 5 shows the total throughput, namely the number of delivered packets, as a function of parameter α, where the initial energy of each node is set to be 100 joules. Note that when α = 0, each node selects a node with highest residual energy in Step 4.3) in the algorithm of RE-OLSR. On the other hand, when α is large, RE-OLSR tends to select MPR nodes based on reachability. We observe that the throughput is about 21,500 when α = 0. We also observe that the throughput increases with the value of α when α≤ 1.5. When α> 1.5, the throughput decreases with the increase in α.

Fig.6 shows the total throughput of each protocol, where initial energy of each node is set to be 100 joules. We observe that throughput of RE-OLSR with α =10 is almost the same as that of OLSR. As mentioned above, when α is large, RE-OLSR tends to choose a node with largest reachability as an MPR node, regardless of residual energy. Specifically, RE-OLSR with large α is similar to OLSR. We also observe that the proposed scheme with appropriate values of α enhances the throughput because it improves energy consumption.

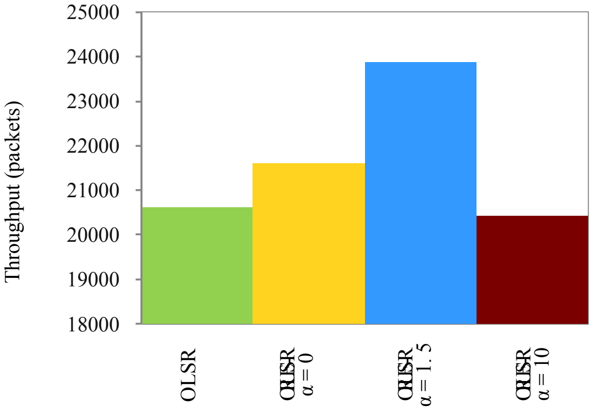

Figure.6 Throughput comparison

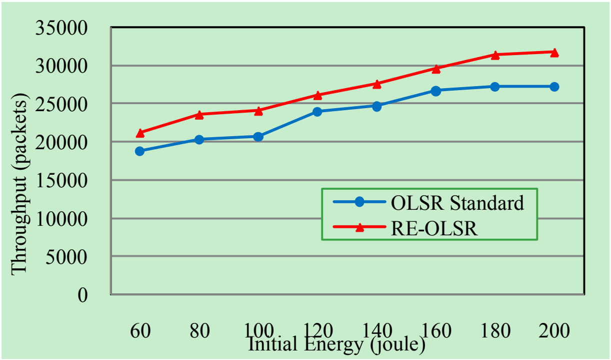

Figure.7 Network throughput

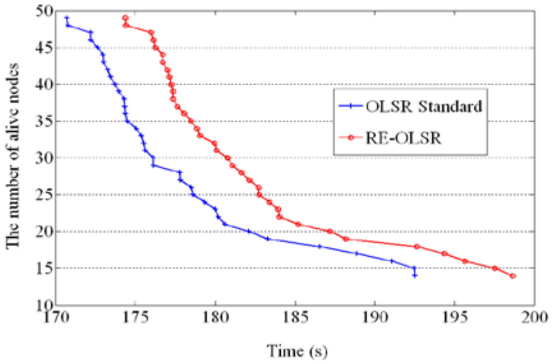

Figure.8 The number of active nodes

Fig. 7 shows the throughput as a function of the initial energy of each mobile node. As we can see from this figure, RE-OLSR enhances the throughput efficiently. This result implies that RE-OLSR improves energy efficiency of mobile nodes.

Fig. 8shows the number of active nodes as a function of time in the simulation, where initial energy of each node is set to be 150 joules and α = 1.5 in RE-OLSR. We observe that the number of active nodes in RE-OLSR is larger than that of OLSR. This is because that RE-OLSR avoids selecting MPR nodes which have small residual energy. Thus, the mobile nodes are still alive for a longer time during broadcasting messages in the network.

V. CONCLUSION

In this paper, we proposed residual energy-based OLSR protocol named RE-OLSR in MANETs. The RE-OLSR allows the mobile nodes to create MPR sets with considering the combination of the residual energy, the reachability and the degree of their symmetric one-hop neighbor nodes .Comparing to the conventional OLSR, the simulation results showed that RE-OLSR improves energy efficiency and enhances the network throughput performance efficiently.

REFERENCES

[1] M. Albolhasan, T. Wysocki, and E. Dutkiewicz, “A Review of Routing Protocols for Mobile Ad Hoc Networks,”Ad Hoc Network, vol. 2, no. 1, pp 1-22, January 2004.

[2] T. Clausenand P. Jacquet, “Optimized Link State Routing Protocol (OLSR),” RFC 3626, IETF, October 2003.

[3] C. E. Perkinsand P. Bhagwat. “Highly Dynamic Destination-Sequenced Distance-Vector Routing (DSDV) for mobile computers,”ACM SIGSOMM Computer Communication, vol. 24. no. 4, pp. 234-244, October 1994.

[4] C. E. Perkinsand E. B. Royer, “Ad hoc On-Demand Distance Vector (AODV) Routing,” RFC 3561, IETF, July 2003.

[5] D. Johnson, Y. Hu, and D. Maltz, “The Dynamic Source Routing Protocol (DSR) for Mobile Ad hoc Networks for IPv4,” RFC 4728, IETF,February 2007.

[6] V. Parkand S. Corson, “Temporally Ordered Routing Algorithm (TORA),” tora-spec-04, IETF,July 2001.

[7] Z. J. Haas, M. R. Pearlman, and P. Samar, “The Zone Routing Protocol (ZRP) for Ad Hoc Networks,” zrp-04, IETF, July 2002.

[8] A. Qayyum, L. Viennot, and A. Laouiti, ”Multipoint Relaying for Flooding Broadcast message in Mobile Wireless Networks,” in Proc. The 35th Annual Hawaii International Conference on System Science (HICSS), Hawaii, USA, 2002, pp 3866-3875.

[9] Z. Guo and B.Malakooti, “Energy Aware Proative MANET Routing with Prediction on Energy Consumption,” in Proc. International Conference on Wireless Algorithm, Systems and Applications (WASA), Chicago, IL, 2007, pp. 287 – 293.

[10] A. Benslimane, R. E. Khoury, R. E. Azouzi, and A. Pierre, “Energy Power-Aware Routing in OLSR Protocol,” in Proc. 1st Mobile Computing and Wireless Communication International Conference (MCWC), Amman, 2006, pp. 14-19.

[11] S. Mahfoudhand P. Minet, “An Energy Efficient Routing Based on OLSR in Wireless Ad Hoc and Sensor Networks,” in Proc. The 22nd Internation Conference on Advance Information Networking and Applications - Workshops (AINAW), Okinawa, Japan, 2008, pp. 1253-1259.

[12] X. Zhang, T. Kunz, L. Li,and O. Yang, “An Energy-efficient Broadcast Protocol in MANETs: Design and Evaluation,“ in Proc. The 8th Annual Communication Networks and Services Research Conference (CNSR), Montreal, Canada, 2010, pp. 199-206.

[13] N. Ghanem, S. Boumerdassi, and E. Renauls, ”New Energy Saving Mechanism for Mobile Ad Hoc Networks using OLSR,” in Proc. 2nd ACM Int. Workshop on PE-WASUN,New York, NY, 2005, pp. 273-274.

[14] T. Kunz. “Energy-Efficient Variations of OLSR,” in Proc. International Wireless Communiction and Mobile Computing Conference (IWCMC), Crete Island, 2008, pp. 517-522.

[15] F. D. Rango, M. Fotino, and S. Marano, “EE-OLSR: Energy Efficient OLSR Routing Protocol for Mobile Ad Hoc Networks,” in Proc. Military Communication Conference (MILCOM), San Diego, CA, 2008, pp. 1-7.

[16] (2009) The Network Simulator NS2 website. [Online]. Available: http://www.isi.edu/nsnam/ns

[17] F. J. Rosand P. M. Ruiz, “UM-OLSR,” MANET Simulation and Implementation at the University of Murcia (MASIUM), Available on line at http://masimum.dif.um.es.