

Residual energy-based OLSR in mobile ad hoc networks

Wardi[†], Kouji Hirata[‡], Yoshinobu Higami[‡], Shin-ya Kobayashi[‡]

^{†‡}Graduate School of Science and Engineering
Ehime University
Matsuyama, Japan

[†]wardi@koblab.cs.ehime-u.ac.jp, [‡]{hirata, higami, kob}@cs.ehime-u.ac.jp

Abstract— OLSR is a proactive routing protocol for mobile ad hoc networks (MANETs). OLSR uses a concept of MPR selection mechanism to reduce broadcast packets during a flooding process. MPR nodes use more energy than nonMPR nodes. Thus they easily run out their energy since mobile nodes in MANETs are powered by battery with limited energy. This paper proposes a residual energy-based OLSR protocol named REOLSR2. The REOLSR2 selects MPR nodes based on not only reachability and degree but also residual energy of 1-hop neighbors. The aim is to avoid selecting MPR nodes which has small residual energy and concentrating energy consumption in specific nodes. Simulation results show that the proposed scheme reduces energy consumption and enhances network throughput efficiently.

Keywords—MANET; OLSR; MPR selection; throughput

I. INTRODUCTION

Mobile ad hoc networks (MANETs) enable mobile nodes to communicate with each other over wireless links without any centralized controllers or base stations. Each node in MANETs acts not only as a host but also as a router to forward packets to further nodes. The rapidly deployable and self-configuring makes MANETs very interesting research issues. In addition, the randomly moving and limited resources are very challenging studies in designing an efficient and reliable routing performance [1].

Routing protocols in MANETs can be classified into three major categories: proactive, reactive, and hybrid [1, 2]. The proactive routing protocols (table-driven protocol), such as OLSR (optimized link state routing protocol) [3] and DSDV (Destination-Sequenced Distance-Vector) [4], periodically exchange information on each node to maintain the routes for all nodes throughout a network. On the other hand, the reactive routing protocols (on demand protocol), such as AODV (Ad hoc On-Demand Distance Vector) [5] and DSR (Dynamic Source Routing) [6], establish routing information for a path to the destination only when they are required. The hybrid routing protocols, such as TORA (Temporally Ordered Routing Algorithm) [7] and ZRP (Zone Routing Protocol) [8], combine some properties of the both reactive and proactive routing protocols.

OLSR is one of well-known proactive routing protocols for MANETs. The protocol have been developed at INRIA and

standardized by the IETF MANET working group in the draft Request for Comment RFC3626 [3]. The most important concept used in OLSR is the idea of multipoint relays (MPRs) where only MPR nodes can distribute broadcast messages. Therefore, the nodes which are selected as MPRs will forward more messages than nonMPR nodes, and thus consume more energy. In OLSR, the limited energy resources, namely battery, in mobile hosts are a very critical issue that affects the overall network performance. Thus, we have to select MPR nodes carefully.

In the past, energy aware routing protocols for OLSR have been proposed in the literatures [9, 10, 11, 12, 13]. In [9], an energy aware MPR selection mechanism called REOLSR for MANETs is proposed. The REOLSR selects MPR nodes based on only residual energy of their symmetric 1-hop neighbor nodes. However, the REOLSR tends to select more nodes as MPR nodes because it does not consider reachability and degree. To enhance the performance of MANETS, in this paper, we propose a residual energy-based OLSR protocol called REOLSR2, which is based on REOLSR [9]. Unlike REOLSR, the REOLSR2 selects MPR nodes based on not only the residual energy of 1-hop neighbors as main parameter but also their reachability and degree. The aim is to avoid selecting MPR nodes which has small residual energy and concentrating energy consumption in specific nodes.

The rest of this paper is organized as follows. Section 2 describes the OLSR routing protocol. In Section 3, we explain REOLSR2. Section 4 discusses performance of REOLSR2 with the results of simulation experiments. We conclude the paper in Section 5.

II. OPTIMIZED LINK STATE ROUTING (OLSR) PROTOCOL

OLSR is a proactive routing protocol. The protocol has paths available immediately to all destinations because it periodically updates routing tables. OLSR optimizes a classical link state algorithm based on the idea of MPR. The concept of MPR [14] is to reduce the number of control traffic by selecting only some of 1-hop neighbor nodes as an MPR set instead of all nodes in the same coverage area. To control its traffic, OLSR generates periodically HELLO messages and Traffic Control (TC) messages [3].

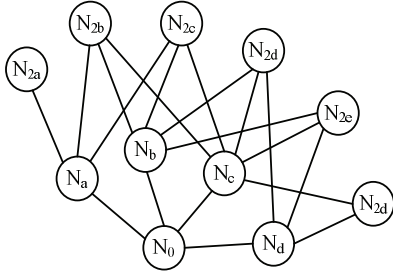


Figure 1. N_0 as an MPR selector

A. HELLO Message

Hello messages are periodically sent by each node to its 1-hop neighbors and not forwarded to the further nodes. Each node periodically broadcasts a HELLO message according to the hello-interval time. The message contains information on their neighbors and their link status. Thus, this mechanism enables each node to detect not only their 1-hop neighbors but also their 2-hop neighbors. This information will then be used by each node to independently select its own MPR among its symmetric 1-hop neighbor nodes.

B. Traffic Control (TC) Messages

A TC message is distributed by each node for advertising its own topological information. Each node generates a TC message periodically at every refreshing period called TC-interval except there are changes detected in an MPR selector set before TC-interval. The TC message contains information on its MPR selector set and includes the sequence number associated to the message. Only the nodes which are selected as an MPR node can disseminate the TC message, so that the number of control messages is reduced. Based on the information diffused by the TC message, each node creates its own topology table.

C. MPR Selection

An MPR node is a subset of symmetric 1-hop neighbor nodes which is selected independently to relay its messages to 2-hop neighbor nodes. A set of selected nodes as MPR nodes is called an MPR set which covers all 2-hop neighbor nodes. The idea is to minimize the number of control packets by selecting only a small part of 1-hop neighbors as MPR nodes instead of all 1-hop neighbor nodes [10]. The 1-hop neighbors that are not a member of the MPR set receive and process the broadcast packets but they do not retransmit them to the further nodes. Thus, the duplicate retransmission in the same coverage area can be reduced. The terminology and heuristic to calculate MPR nodes are describe in [3].

Each node has a parameter named $N_willingness$. 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 of the willingness of nodes is WILL_DEFAULT. Whereas WILL_NEVER indicates that a node is not selected as an MPR node, WILL_ALWAYS indicates that a node is always chosen as an MPR node.

III. MPR SELECTION MECHANISM

This section describes MPR selection heuristic. We first describe a mechanism for standard MPR selection in OLSR. Then we explain an MPR selection mechanism of REOLSR2.

A. MPR Selection Standard [3]

The heuristic for standard MPR computation for each node is as follows:

- a. Select nodes in the set N_1 of 1-hop neighbor nodes whose $N_willingness$ is WILL_ALWAYS, as members of an MPR set.
- b. Calculate the degree $D(y)$, which is defined as the number of symmetric neighbors, for each node y in N_1 .
- c. Add nodes of N_1 , which are the only nodes to provide reachability to a node in N_2 , to the MPR set, where N_2 denotes the set of 2-hop neighbor nodes. Then remove the nodes from N_2 which are covered by nodes in the MPR set.
- d. Until all nodes in N_2 are covered by nodes in the MPR set, the following steps d.1 and d.2 are repeated:
 - d.1. For each node y in N_1 , calculate the reachability $R(y)$, where the reachability denotes the number of nodes in N_2 which are not yet covered by nodes in the MPR set and which are reachable through this 1-hop neighbor.
 - d.2. Select node y with the highest $N_willingness$ and $R(y) > 0$. 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 selected nodes to the MPR set, and remove the node from N_2 which are covered by the selected node.
- e. For optimization, the nodes can be removed from the MPR set if the remaining nodes in the MPR set still cover all 2-hop neighbor nodes.

We show an example of MPR selection with Fig. 1. According to the above procedure, the MPR nodes are selected as shown in Table 1.

B. Modification of MPR Selection

In standard OLSR, an MPR set is selected based on reachability and degree. It does not consider residual energy of each node. As shown in Fig. 2, we now add energy constraints

TABLE I. MPR COMPUTATION OF OLSR STANDARD

Selector Node	1-Hop Neighbor	2-Hop Neighbor	MPR Node
N_0	N_a, N_b, N_c, N_d	$N_{2a}, N_{2b}, N_{2c}, N_{2d}, N_{2e}, N_{2f}$	N_a, N_c

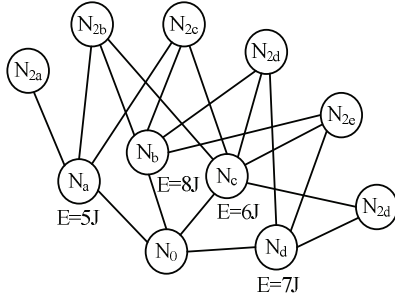


Figure 2. Nodes with energy constraint

TABLE II. MPR SELECTED BY REOLSR2

Selector Node	MPR		
	$\alpha = 1$	$\alpha = 2$	$\alpha = 3$
N_0	N_a, N_b, N_d	N_a, N_d	N_a, N_c

to the nodes in Fig. 1. In Fig. 2, when node N_0 is creating its routing table to destination node N_{2d} , using the MPR standard criteria, it will select a route $N_0 \rightarrow N_c \rightarrow N_{2d}$. The path from N_0 to N_{2d} can be reached through N_b (8 joules), N_c (6 joules), or N_d (7 joules). However, N_c has the smallest residual energy. Thus, it is not efficient in terms of energy consumption. As a result, energy of specific nodes may run out quickly. To resolve this problem, the REOLSR2 selects MPR sets based on not only reachability and degree but also the residual energy of 1-hop neighbors. The reachability and degree of the nodes are considered according to residual energy of nodes. To do so, the heuristic of REOLSR2 modifies the step d of the standard MPR selection as follows:

- d. Until all nodes in N_2 are covered by nodes in the MPR set, the following steps d.1, d.2, and d.3 are repeated:
 - d.1. For each node y in N_1 , calculate the reachability $R(y)$.
 - d.2. For each node y in N_1 , calculate the residual energy $E(y)$. Let y_h denotes the node with the highest residual energy whose reachability more than 0, i.e., $R(y_h) > 0$.
 - d.3. If $E(y_h) - E(y) \geq \alpha$ for each node y in N_1 , 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 whose residual energy $E(y)$ is bigger than $(E(y_h) - \alpha)$ in N_1 . If there are multiple nodes with highest reachability, select one with largest $D(y)$ from those nodes. Then add selected nodes to the MPR set, and remove the node from N_2 which are covered by the selected node.

In Fig. 2, from the energy point of view, N_b is better than N_c or N_d where the residual energy of N_b is 8 joules compared with 6 joules and 7 joules for N_c and N_d , respectively. However, when N_a has been selected as a MPR node, the number of reachability of N_b is 2 nodes. It is smaller than N_c or N_d which has 3 nodes each. N_c has the highest number of degree (5 nodes) compare to N_b (4 nodes) and N_d (3 nodes). Thus, applying this heuristic, when N_0 is creating its routing table to destination N_{2d} , it will select whether N_b , N_c , or N_d for

TABLE III. SIMULATION PARAMETERS

Simulation Parameters	
Propagation Model	TwoRayGround
Network Type	IEEE 802.11
Mobility Model	Random Waypoint
Queue Length	50
Topology Area	800 x 800 m2
Number of Nodes	50
Willingness	3
Simulation Time	200s
Transmission Power	1.2 Watt
Receiving Power	0.6 Watt

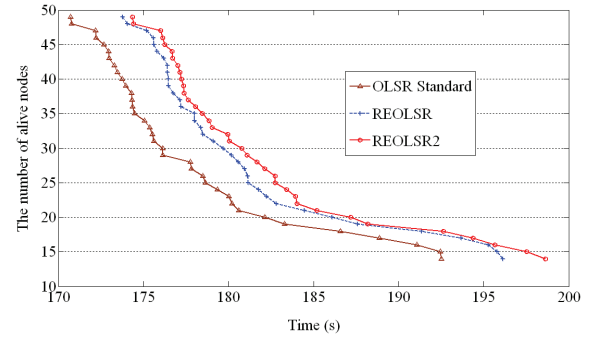


Figure 3. The number of active nodes

its intermediate node depend on the value of α as shown in Table 2.

IV. PERFORMANCE EVALUATION

To evaluate the performance of REOLSR2, we conduct simulation experiments with NS2.34 network simulator [15] with UM-OLSR implementation provided by [16]. The simulation parameters are listed in Table 3.

Fig. 3 shows the number of active nodes as a function of simulation time, where initial energy of each node is set to be 150 joules and $\alpha = 1.5$ in the proposed scheme. For the sake of comparison, we plot the results of OLSR standard and REOLSR. We observe that the number of active nodes of the proposed scheme (REOLSR2) is larger than those of OLSR standard and REOLSR. This is because if an MPR node has small residual energy, the MPR node easily runs out of its energy during broadcasting messages.

Fig. 4 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. This figure illustrates that the number of throughput approximately 21,730 when $\alpha = 0$. Then, the performance of throughput generally improves with the value of α until it reaches its peak about 23,870 at $\alpha = 1.5$. When $\alpha > 1.5$, the throughput decreases with the increase in α .

Fig. 5 represents the total throughput of each protocol, where initial energy of each node is set to be 100 joules. We

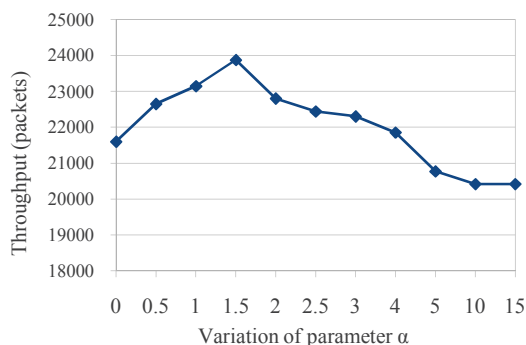


Figure 4. Throughput

observe that throughput of REOLSR2 with $\alpha = 0$ almost the same as that of REOLSR. This is because at $\alpha = 0$, this mechanism will select the highest amount of residual energy among the 1-hop neighbors as MPR. However, when the value of α is big, from $\alpha = 10$, REOLSR2 protocol tends to choose the node of 1-hop neighbor as MPR which has the highest number of reachability. Therefore, the throughput approaches the OLSR protocol standard. We also observe that the proposed scheme with appropriate values of α enhances the throughput because it improves energy consumption.

In Fig. 6, the throughput is described as a function of the initial energy, where the time observation for the three protocols is set to be 200 seconds. This figure shows that for small initial energy until about 55 joules, the classical OLSR performs the best throughput due to the OLSR protocol has smaller size of Hello messages than the two protocols. However, for initial energy bigger than 55 joules, the REOLSR2 lead in number of throughput. The number of throughput starts to stable when initial energy 180 joules.

V. CONCLUSION

In this paper, we proposed REOLSR2. The REOLSR2 allows a node to create MPR set considering to not only the reachability and degree but also residual energy of each symmetric 1-hop neighbor node. The simulation results showed that REOLSR2 improves energy consumption and throughput performance.

REFERENCES

- [1] M. Albolhasan, T. Wysocki, and E. Dutkiewicz, "A Review of Routing Protocols for Mobile Ad Hoc Networks," *Ad Hoc Network*, vol. 2, pp 1-22, January 2004.
- [2] C. Liu and J. Kaiser, "A Survey of Mobile Ad Hoc Network Routing Protocols," University of Magdeburg, 2005.
- [3] T. Clausen and P. Jacquet, "Optimized Link State Routing Protocol (OLSR)," RFC 3626, IETF, October 2003.
- [4] C. E. Perkins and P. Bhagwat. "Highly Dynamic Destination-Sequenced Distance-Vector Routing (DSDV) for mobile computers," *ACM SIGSOCC Computer Communication*, vol. 24. no. 4, pp. 234-244, October 1994.
- [5] C. E. Perkins and E. B. Royer, "Ad hoc On-Demand Distance Vector (AODV) Routing," RFC 3561, IETF, July 2003.
- [6] 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.
- [7] V. Park and S. Corson, "Temporally Ordered Routing Algorithm (TORA)," tora-spec-04, IETF, July 2001.

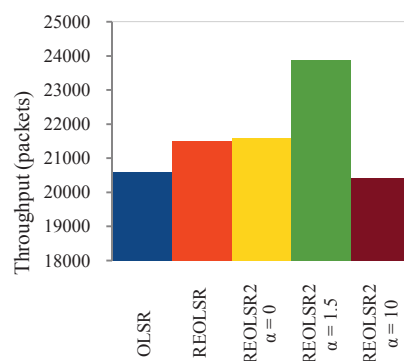


Figure 5. Throughput comparison

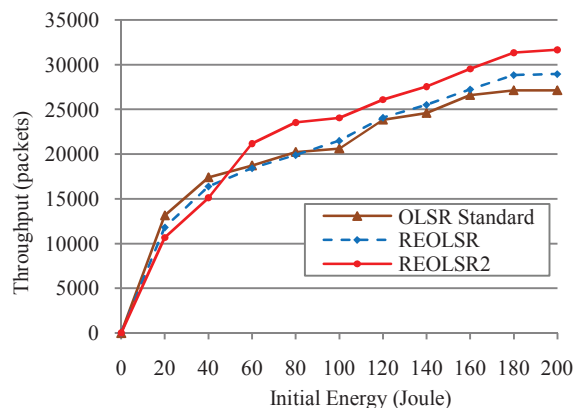


Figure 6. Network throughput

- [8] Z. J. Haas, M. R. Pearlman, and P. Samar, "The Zone Routing Protocol (ZRP) for Ad Hoc Networks," zrp-04, IETF, July 2002.
- [9] Wardi, K. Hirata, Y. Higami, and K. Shinya, "Energy Aware MPR Selection Mechanism in OLSR-based Mobile Ad Hoc Networks," in *Proc. The 17th International Multi-Conference on Advanced Computer Systems (ACS-AIBIS)*, Miedzyzrodzie, Poland, October 2010.
- [10] S. Mahfoudh and P. Minet, "An Energy Efficient Routing Based on OLSR in Wireless Ad Hoc and Sensor Networks," in *Proc. The 22nd International Conference on Advance Information Networking and Applications - Workshops (AINAW)*, Okinawa, Japan, pp. 1253-1259, April 2008.
- [11] 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, pp. 199-206, June 2010.
- [12] N. Ghanem, S. Boumerdassi, and E. Renauds, "New Energy Saving Mechanism for Mobile Ad Hoc Networks using OLSR," in *Proc. 2nd ACM Int. Workshop on PE-WASUN*, New York, NY, pp. 273-274, October 2005.
- [13] 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, pp. 1-7, November 2008.
- [14] 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, pp 3866-3875, January 2002.
- [15] The Network Simulator NS2, Available on line at <http://www.isi.edu/nsnam/ns>.
- [16] F. J. Ros and P. M. Ruiz, "UM-OLSR," MANET Simulation and Implementation at the University of Murcia (MASIUM), Available on line at <http://masimum.dif.um.es>.