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# Energy Aware MPR Selection Mechanism in OLSR-based Mobile Ad Hoc Networks

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**Abstract**

OLSR is a proactive routing protocol for mobile ad hoc networks (MANETs). OLSR uses the concept of MPR selection mechanism to reduce broadcast packets. Because mobile nodes in MANETs are powered by batteries, MPR nodes often run out of energy. This paper introduces a residual energy-based OLSR (REOLSR) protocol. REOLSR selects MPR nodes based on residual energy of their symmetric 1-hop neighbor nodes. The aim is to avoid selecting nodes with lower residual energy as MPR nodes in order that the protocol minimizes the MPR nodes run out of their energy faster. The simulation results show that REOLSR increases network throughput efficiently.

**Keywords**: MANET, OLSR, MPR selection.

## Mechanizm selekcji węzłów z ograniczeniami energii w sieciach mobilnych Ad hoc oparty na protokole OLSR

**Streszczenie**

OLSR jest proaktywnym protokołem routingu dla mobilnych sieci ad hoc (MANETs). Wykorzystuje on ideę mechanizmu selekcji węzłów do transmisji wielopunktowej (MPR) w celu zredukowania liczby transmitowanych pakietów. Węzły MPR są bardzo obciążone, a więc ich źródła energii powinny być oszczędzane. Ponieważ węzły mobilne w sieci MANET są zasilane z baterii, zatem węzły MPR często rozładowują swoje źródła zasilania. W artykule zaproponowano modyfikację protokołu OLSR (REOLSR) opartą na analizie energii resztkowej. Protokół REOLSR wybiera węzły MPR w oparciu o kryterium ich energii resztkowej ich symetrycznych sąsiednich węzłów typu 1-hop. Protokół uwzględnia także liczbę węzłów będących w zasięgu i stopień każdego węzła. Celem jest minimalizacja wyboru węzłów zużywających szybciej swoje źródło energii. Protokół ma zminimalizować używanie węzłów o wyładowanych źródłach zasilania. Wyniki symulacji pokazują, że REOLSR zwiększa wydajność osiągów sieci.

**Słowa kluczowe**: MANET, OLSR, wybór węzłów MPR.

## 1. Introduction

Mobile ad hoc networks (MANETs) enable mobile nodes to communicate with each other over wireless links without any centralized controllers or base stations (BS). Each node acts 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 protocol.

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, 9]. In OLSR, the limited resources, namely battery life for mobile hosts, are a very critical issue that can affect to the overall network performance. Packets are distributed only by nodes which are chosen as Multipoint Relay (MPR) nodes [10]. Because mobile nodes in MANETs are powered by batteries, the MPR nodes often run out of their energy. Thus, we have to select MPR nodes carefully.

In this paper we propose a residual energy-based OLSR (REOLSR) protocol. REOLSR selects MPR nodes based on residual energy of their symmetric 1-hop neighbor nodes. The scheme also considers the number of reachable nodes and the degree of each node. The aim is to avoid selecting nodes with lower residual energy as MPR nodes in order that the protocol minimizes the MPR nodes run out of their energy faster.

The rest of this paper is organized as follows. Section 2 describes the OLSR routing protocol. Section 3 reviews papers related to this work. In Section 4, we provides the classical and modification of MPR selection mechanisms. Section 5 discusses performance of REOLSR with the results of simulation results. We conclude the paper in Section 6.

## 2. Optimized Link State Routing (OLSR) Protocol

OLSR is a proactive routing protocol. The protocol has paths available immediately to all destinations in the networks because it periodically updates routing table before they are needed. OLSR optimizes the classical link state algorithm based on the idea of MPR. The concept of MPR [10] is to reduce the number of control traffic by selecting only some of 1-hop neighbor nodes instead of all nodes in the same coverage area. To control its traffic, OLSR generates periodically HELLO messages and Traffic Control (TC) messages [3].

### 2.1. 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 broadcast a hello message according to the hello-interval time. The message contains information on its 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.

### 2.2. Traffic Control (TC) Message

A TC message is diffused by each node for advertising its own topological information. Each node generate a TC message periodically at every refreshing period TC-interval except there are changes detected in 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 MPR 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.

### 2.3. MPR Selection

An MPR node is a subset of symmetric 1-hop neighbor node 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 neighbors instead of all nodes which covers the same network area [10]. Thus, the duplicate retransmission in the same coverage area can be reduced when diffusing a broadcast packet in the network. Even though non-MPR neighbors of a node can receive and process a broadcast packet, they do not retransmit it. The terminology and heuristic to calculate MPR nodes are described in [3].

## 3. Related Works

Energy efficiency is an important issue in mobile ad hoc network environments. In [11], Mahfoudh and Minet divide the energy efficient routing protocol into three groups: the strategy transmitting data with the lowest amount of energy consuming, the strategy to select the intermediate nodes with the highest remains energy, and the combination of the two strategies. Furthermore, the research studied three variants energy efficient of OLSR: E, M1E, and M2E. The MPR selections of the variants are calculated based on minimum residual energy of the sending node, the 1-hop nodes, and 2-hop nodes.

In particular, the energy efficient routing based on modification to the MPR selection mechanism for OLSR has been proposed by several researchers in the literatures [12, 13, 14]. Ghanem et al. point out the two new mechanisms to the MPR calculation [12]. The mechanisms to select MPR nodes depend on the discriminating 1-hop neighbor nodes. The discriminating is according to the three metrics: the cost regarding the residual energy on a node, the cost to the end to end transmitting, and the shortest path. Their research showed that the number of active node in the networks is increased. Rango et al. modified the energy aware based on the energy drain rate of battery capacity, and the predicted lifetime [13]. The battery capacity is divided into three levels: low, medium, and high while the predicted lifetime consists of short, medium, and long. Furthermore, the pair metrics (battery, lifetime) is associated to willingness value (default, low, and high) for MPR selection mechanism. In [14], Verbree et al. analyzed the lifetime of an OLSR network and focused on the network structure on the MPR selection. The authors introduced the metric 'maximum forcedness ratio' to some MPR calculation mechanisms to illustrate the variation lifetime in the network. The simulation results of all the researches showed that respecting to the limited energy resource of the nodes for MPR selection mechanism can increase OLSR routing performance.

## 4. MPR Selection Mechanism

This section describes MPR selection heuristic. We first describe mechanism for standard MPR selection. Then we explain an MPR selection mechanism of REOLSR.

### 4.1. MPR Selection Standard [3]

The heuristic for standard MPR computation is as follows:

a) Select nodes in N1h, the set of 1-hop neighbor node, as members of an MPR set which have N_willingness equal to WILL_ALWAYS.

b) Compute the degree D(y) of all 1-hope neighbor nodes where $\forall$ nodes y $\in$N1h.

c) Put nodes of N1h to the MPR set where only those nodes that provides links to a node in N2h (the set of 2-hop neighbor node). Delete nodes in N2h which have link to nodes in the MPR set.

d) If not all nodes in N2h are covered by nodes in MPR set:

d-1) For each node in N1h which is not an MPR node, calculate the number of nodes in N2h which are covered by each node in N1h.

d-2) Choose nodes from N1h with maximum N_willingness and non-zero reachability as an MPR node. If there are more than one node in N1h selected, choose the nodes with highest reachability. If some nodes have the same number to reach uncovered nodes in N2h, find the value of having a larger degree D(y) and put the node in the MPR set. Next, delete nodes in N2h which have link to node in the MPR set.

e) For optimization, the nodes can be deleted 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 Figure 1. According to above procedure, the MPR nodes are selected as shown in Table 1.

As shown in Figure 2, we now add energy constraints to the nodes in Figure 1. In Figure 2, when node 0 (N0) is creating its routing table to destination node 15 (N15), using the MPR standard criteria, it will select a route N0 → N3 → N15. The energy of the MPR node (N3) is 6 joule. As we can see from Figure 2, the optimal path based on energy constrains between N0 and N15 is N0 → N4 → N15 where the residual energy of its relay node (N4) is 8 joule. From the illustration above, in the MPR selection mechanism, the nodes which have higher residual energy should be considered.

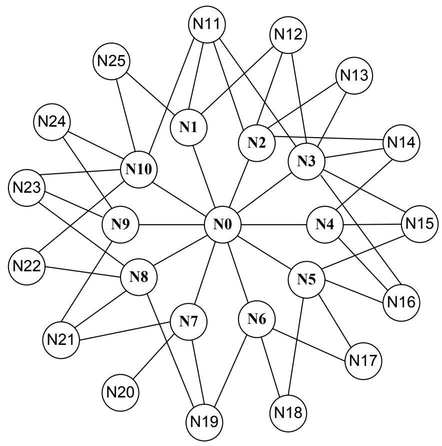


Fig. 1. N0 as an MPR Selector
Rys. 1. N0 jako selektor MPR

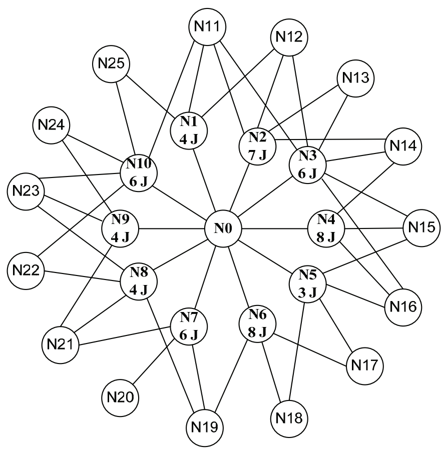


Fig. 2. Nodes with energy constraint
Rys. 2. Węzły z ograniczeniem energii

## 4.2. Modification of MPR Selection

We present a heuristic for the MPR selection in REOLSR with respect to the power constraint of 1-hop neighbor nodes. The heuristic prioritizes the maximum residual energy of 1-hop nodes rather than the willingness, reachability or the degree. When all nodes in 2-hop nodes are not covered yet by at least one node in an MPR set, this mechanism will select a symmetric 1-hop node (not MPRs member and non zero reachability) as an MPR node with the highest residual energy instead of the willingness of the nodes. The proposed heuristic also considers the number of reachability of each node if there is a tie in selecting the highest residual energy of the nodes. After that, if there is more than one node with the same maximum reachability, the node with the highest degree will be chosen as an MPR node. Therefore, the heuristic of REOLSR modifies the Step d-2) of the standard MPR selection in such a way that a node with the highest residual energy is preferentially selected as an MPR node. From Figure 2, based on REOLSR, the calculation for MPR selection can be seen in Table 2.

Applying this heuristic, when N0 is creating its routing table to destination N15, it will select the route N0 → N4 → N15. It can be seen that this algorithm selected N4 as an intermediate node from N0 to N15, compare to classical MPR selection selected N3 (section 4.1). From the energy point of view, N4 is better than N3 where their residual energy is 8 Joule and 6 Joule respectively. Furthermore, this heuristic avoids the nodes with a lower residual energy selected as MPR in order the protocol minimize a node runs out its energy faster.

Tab. 1. MPR Computation of OLSR Standard
Tab. 1 Obliczenie MPR według standardu OLSR

| Selector Node | 1-hop neighbor | 2-hop neighbor | MPR |
|---|---|---|---|
| N0 | N1, N2, N3, N4, N5,N6, N7, N8, N9, N10 | N11, N12, N13, N14, N15, N16, N17, N18, N19, N20, N21, N22, N23, N24, N25 | N7, N3, N10, N5 |

Tab. 2. MPR selected in the REOLSR
Tab. 2. Wybór MPR według REOLSR

| Node | MPR |
|---|---|
| N0 | N7, N4, N6, N2, N10 |

Tab. 3. Simulation parameters
Tab. 3. Parametry symulacji

| Simulation Parameter | |
|---|---|
| Propagation model | TwoRayGroud |
| Network type | IEEE 802.11 |
| Mobility model | Random waypoint |
| Queue Length | 50 |
| Interface Queue | DropTail/PriQueue |
| Topology Area | 800x800 m$^2$ |
| Number of Nodes | 50 |
| Simulation Time | 150 s |
| Transmission Power | 1.2 Watt |
| Receiving Power | 0.6 Watt |

## 5. Performance Evaluation

To evaluate the modified MPR heuristic of REOLSR, 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.

Figure 3 shows the throughput as a function of the initial energy of each node. We observe that when the initial energy is less than 15 joule, the throughput difference between REOLSR and OLSR is negligible. This is because at low energies, observation time is very short due to all the nodes run out of their energy before the end of simulation time. In the case where initial energy is more than 15 joules, the figure shows the advantage of the proposed REOLSR. The throughput increases about 7% compared with classical OLSR. When the initial energy is 35 joule, the number of throughput remains stable and improves the throughput approximately 4% for REOLSR.

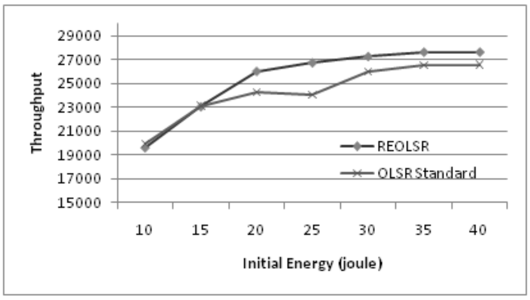


Fig. 3. Network throughput
Rys. 3. Osiągi sieci

Figure 4 shows the throughput as a function of the simulation time, where the initial energy of each node is set to be 35 joule. This figure clearly shows that the amount of throughput remains the same until 100s. The differences of the number of throughput begin to appear in line with increasing simulation time. As illustrated in section 4.2, the REOLSR selects its MPR with higher residual energy as first metric instead of willingness in classical OLSR. It minimizes the MPRs run out their energy faster during forwarding packets. As the result, the throughput of the REOLSR outperforms OLSR standard.

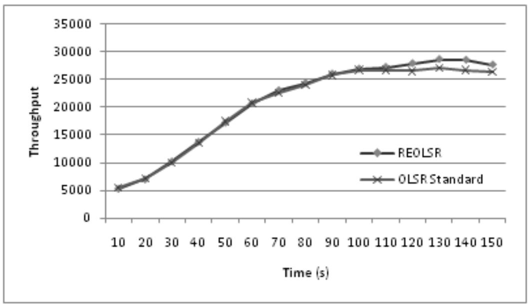


Fig. 4. Network Throughput
Rys. 4. Osiągi sieci

## 6. Conlusions

In this paper, we presented REOLSR, a modification MPR selection mechanism of OLSR protocol. The REOLSR allows a node to create MPR set considering the maximum residual energy of each symmetric 1-hop neighbor node. Thus, the nodes with higher remaining energy are considered. The performance of the REOLSR was examined through NS2.34 with UM-OLSR. The simulation results show that REOLSR achieve better throughput when compared with the MPR selection standard. In the future work, we will analyze a combination between energy, reachability, and degree of each node as a parameter for metric level in selecting MPR criteria.

## 7. References


[1] Albolhasan M., Wysocki T., Dutkiewicz E.: A Review of Routing Protocols for Mobile Ad Hoc Networks. Ad Hoc Network 2, pp 1-22, 2004.
[2] Liu C., Kaiser J.: A Survey of Mobile Ad Hoc Network Routing Protocols. University of Magdeburg, 2005.
[3] Clausen T., Jacquet P.: Optimized Link State Routing Protocol (OLSR), IETF RFC 3626, 2003.
[4] Perkins C.E., Bhagwat P.: Highly Dynamic Destination-Sequenced Distance-Vector Routing (DSDV) for mobile computers. SIGSOMM. pp. 234-244, 1994.
[5] Perkins C.E., Royer E.B.: Ad hoc On-Demand Distance Vector (AODV) Routing. IETF RFC 3561, 2003.
[6] Johnson D., Hu y., Maltz D.: The Dynamic Source Routing Protocol (DSR) for Mobile Ad hoc Networks for IPv4. IETF RFC 4728, 2007.
[7] Park V,. Corson S.: Temporally Ordered Routing Algorithm (TORA). Internet Draft, draft-ietf-manet-tora-spec-04.txt., 2001.
[8] Haas Z.J., Pearlman M.R., Samar P.: The Zone Routing Protocol (ZRP) for Ad Hoc Networks. Internet Draft, draft-ietf-manet-zone-zrp-04.txt., 2001.
[9] Internet Engineering Task Force (IETF), http://datatracker.ietf.org /wg/manet/charter.
[10] Qayyum A., Viennot L., Laouiti A.: Multipoint Relaying for Flooding Broadcast message in Mobile Wireless Networks. In IEEE Proc. of the 35th Annual Hawaii Int. Conf. on System Science (HICSS), pp 3866-3875, 2002.
[11] Mahfoudh S., Minet P.: An Energy Efficient Routing Based on OLSR in Wireless Ad Hoc and Sensor Networks. In IEEE 22nd Int. Conf. on Advance Information Networking and Applications Workshops (AINAW), pp 1253-1259, 2008.
[12] Ghanem N., Boumerdassi S., Renauls E.: New Energy Saving Mechanism for Mobile Ad Hoc Networks using OLSR. ACM on PE-WASUN, pp 273-274, 2005.
[13] Rango F.D., Fotino M., Marano S.: EE-OLSR: Energy Efficient OLSR Routing Protocol for Mobile Ad Hoc Networks. In Military Communication Conference (MILCOM), pp 1-7, 2008.
[14] Verbree J.M., Graaf M.D., Hurink J.: An Analysis of the Lifetime of OLSR Networks. Ad Hoc Networks 8(4), pp 391-399, 2010.
[15] The Network Simulator NS2, http://www.isi.edu/nsnam/ns.
[16] Ros F. J., Ruiz P.: M. UM-OLSR, MANET Simulation and Implementation at the University of Murcia (MASIUM), http://masimum.dif.um.es.


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