A New Energy Efficient Mechanism to Enhance MPR Selection in OLSR: EEM-OLSR

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Abstract

Mobile Ad Hoc Networks (MANET) enables mobile nodes to communicate with each other through wireless connections without any centralized controller or base station. Each mobile node is powered by a battery. The efficient use of battery energy is therefore a key factor in MANET. Optimized Link State Routing Protocol (OLSR) uses a Multipoint Relay (MPR) selection method to reduce transmitted packets during the flooding process. In the OLSR protocol, nodes are chosen as MPRs based on the WILLINGNESS and REACHIBILITY, where the willingness is related to the residual energy of the node. MPR nodes consume more energy than non-MPR nodes. As a result, we have focused on reducing energy consumption. This paper introduces a new mechanism for selecting the MPR in the OLSR protocol, in order to enhance energy management and prolong the network lifetime based on the willingness without losses of performances (such as MPRs count, The Number of Dead Nodes, end-to-end delay, control overhead, packet loss). Simulation results using Ns-3 with varying numbers of nodes show that our proposed EEM-OLSR protocol outperforms the classic OLSR by significantly improving the network lifetime.

Keywords
EEM-OLSR, MPRs, WILLINGNESS, REACHIBILITY

1. Introduction
The wide range of applications supported by ad hoc mobile networks explains the popularity of this form of network. These applications cover different domains, such as environmental monitoring, wildlife protection, emergency rescue, home monitoring, target tracking, bridge structural health, military activities. Mobile nodes are characterized by small size, advanced communication technologies, but also a limited amount of energy. This energy may be very costly to regenerate. In order to optimize network lifetime, energy-efficient strategies are needed in such networks (Yetgin et al. 2017), (Gupta et al. 2015).
Solutions to maximize network lifetime can be classified into four categories (Mohamed et al. 2018), (Elshrkawey et al. 2018), (Selvakumar and Sankaranarayanan, 2018) Some change the transmitting capacity of wireless nodes, others reduce the amount of information transmitted by aggregation, others allow nodes sleep to spare energy, and finally, the last ones use energy-efficient routing. In this paper, we have concentrated on this last category, for several reasons

- A multi-hop transmission consumes energy. Reducing the energy expended on transmitting a packet from its source to its destination will increase the lifetime of the network (Kgotlaetsile et al. 2018).
- Avoiding low-residual energy nodes will help prolong the lifetime of the network.

• Optimizing the flooding of the network will also minimize the number of transmissions required to reach all network nodes and thus spare node energy.

A number of routing protocols have been proposed in the literature designed for mobile ad-hoc, taking into account the energy constraints of a network, to improve performance in terms of efficient data transmission and to ensure the optimal level of service quality (QoS) (Modieginyane et al. 2018).

Optimized Link State Routing (OLSR) is a proactive protocol that uses the multipoint relay (MPR) concept to reduce transmitted packets during the flooding process (Chowdhury and Hossain 2020). When the residual energy of the node in OLSR exceeds a fixed lower threshold, this node cannot be chosen as an MPR. No MPR is present in the entire network after a certain time. This improves the overhead control and degrades the network's QoS. We concentrated on improving the energy and the lifetime of the network in this paper by giving all the nodes the opportunity to be MPRs, which Improves the reactivity of mobile nodes within the network, especially when their residual energy decreases.

This paper is structured as follows. After the introduction, we provided an explanation of the Optimized Link State Routing Protocol (OLSR) in the second section, followed by a description of the proposed EEM-OLSR routing protocol in the third section. We also provided an analysis of the simulation results in the fourth section. We gave concluding comments in the last section.

2. Optimized Link State Routing Protocol (OLSR)

Optimized Link State Routing (OLSR) is a proactive link state-based routing protocol for Ad-Hoc wireless networks. This protocol was chosen by the MANET working group of the Internet Engineering Task Force (IETF) as one of the main routing protocols for Ad-Hoc networks (Sultan Mahmood and Ashraf, 2020). The advantage of OLSR is that it uses a technique called MultiPoint Relays (MPR) to minimize the traffic load in the network when broadcasting control messages. Multi-point relays are chosen after the phase of discovery of the neighbors of all the nodes in the network using HELLO messages. These messages allow each node to have a list of their direct neighbors and 2-hop neighbors. The choice of MPRs is then made based on the information exchanged with the HELLO messages. Another type of TC (Topology Control) message allows the MPR to transmit the list of its neighbors who have chosen it as MPR and also serves to establish the routing table.

2.1 Hello Message

HELLO messages are used for selecting the MPRs nodes. Each node broadcasts HELLO messages containing neighborhood information and their link status. A HELLO message includes the list of all nodes known to the sender, HELLO messages are also used to discover a link break figure 1 shows the HELLO Packet format of OLSR. The discovering node sends a Route Reply (RREP) response with an infinite metric and an incremented destination sequence number to all its neighbors who used that link. This response will then be relayed from node to node to inform all the nodes using the link in a route. If a source node receives such an RREP response, it may decide to reinitiate a route discovery in the event that it still has traffic to send (Dohyung et al. 2016).

<table>
<tr><td colspan="2">Reserved</td><td>Htime</td><td>Willingness</td></tr>
<tr><td>Link Code</td><td>Reserved</td><td colspan="2">Link Message Size</td></tr>
<tr><td colspan="4">Neighbor Interface Address</td></tr>
<tr><td colspan="4">Neighbor Interface Address</td></tr>
</table>

Figure 1. OLSR HELLO Packet Format

2.2 Topology Control (TC)

Each node regularly sends a Topology Control (TC) message to the network in order to declare all of its multi relay selectors. The use of multipoint relays for flooding such a message makes it possible to limit the number of unnecessary retransmissions of the message, while ensuring that all the nodes of the network receive the message (Dohyung et al. 2016), (Laqtib et al. 2019).

3. Description of Proposed EEM-OLSR Routing Protocol

In this section, we introduce a new mechanism for selecting the MPR in the OLSR routing protocol, in order to improve energy management and prolong the network lifetime, an MPR set is selected based on reachability and degree. It fails to consider the energy constraints that result in a limited lifetime of the network. The OLSR was improved by setting a residual energy threshold to increase both network lifetime and energy efficiency. This modified protocol called EEM-OLSR. The EEM-OLSR optimizes the energy consumption of the network as well as distribute the load over the whole network, and relieves nodes that have long been selected as MPRs. In our approach, we propose to give an opportunity for a node not chosen as MPR to be so and to reduce overall power consumption by avoiding nodes with minimum battery life to be MPR, as well as increasing the network lifetime.

A node that has not been selected as an MPR consumes less energy than another node that has long been chosen as an MPR. So, in order to allow all nodes to become an MPR, we gradually reduce the dynamic threshold in the willingness which based on the power-status of the node. This new approach has the advantage that it is consistent with the standard OLSR and needs no further control traffic or modifications of the core functioning of OLSR.

3.1 New Process of the Hello Message

The "Willingness" field is defined by an integer ranging from 0 to 7 and indicates the capacity of the node to be an MPR. Thus, nodes can notify their neighbors about their capacities by using the "Willingness" field in the HELLO packets (see figure 1). The willingness of a node is set to be 0 (WILL_NEVER), 1 (WILL_LOW), 3 (WILL_DEFAULT), 6 (WILL_HIGH), or 7 (WILL_ALWAYS), WILL_DEFAULT is the default node willingness. While WILL_NEVER implies that nodes are not selected as MPR nodes, WILL_ALWAYS shows that nodes are always selected as MPR nodes.

First, we initialize the node's willingness of our proposed protocol EEM-OLSR that directly depends on its residual energy as described below:

```
dynamic_threshold = 10.0
Energy_level = (energy/init_energy)*100;
if (energy_level<=dynamic_threshold)
 willingness()=OLSR_WILL_NEVER;
   else if (energy_level<=30.0)
     willingness()=OLSR_WILL_LOW;
       else if (energy-level<=60.0)
         willingness()=OLSR_WILL_DEFAULT;
  else willingness()=OLSR_WILL_HIGH;
```

3.2 Modification of MPR Selection Mechanism

We have described below the algorithm of the proposed EEM-OLSR using the new mechanism for selecting the nodes based on the "willingness" . In this algorithm, we note that:

N_{1-hop}: *is the set of direct neighbors of x.*
N_{2-hop}: *is the set of neighbors of the second level.*
R(y): reachability of each node
D(y): degree of each node
MPRset: is the set of multi-point relays of x.
1. Start with an empty multipoint relay set.
2. Calculate the degree D(y) of each node in N_{1-hop}.
3. Add to the MPR set the nodes in N_{1-hop} *,which are the only nodes to provide reachability to a node in* N_{2-hop}. *Then remove nodes from* N_{2-hop} *that are covered by nodes in the MPRset.*
4. While (N_{2-hop} *is not empty) Do*
a. Calculate reachability R(y) of each node in N_{1-hop}
b. Select as a MPR the node with highest Willingness and non-zero reachability R(y), R(y) >0.

- *In case of multiple choice select the node, which provides reachability R(y) to the maximum number of nodes in N_{2-hop} .*
- *In case of multiple nodes providing the same amount of reachability, select the node as MPR whose D(y) is greater.*

5. Remove all nodes from N_{2-hop} which are covered by a node in the MPR set

4. Analysis of The Simulation Results

We have evaluated the network performances by increasing the number of nodes. Additional information has been added to the Hello message to allow a selection of energy-aware multipoint relays. To show the effectiveness of the EEM-OLSR protocol we use the Ns-3 simulation tool to compare the EEM-OLSR protocol with the standard OLSR [13].

4.1 Performance Metrics

In our simulation, five performance metrics are chosen to evaluate the effectiveness of the EEM-OLSR protocol as follows:

MPRs count: This metric shows the number of MPRs in the network (Laqtib et al. 2020).

The Number of Dead Nodes: This metric gives the total number of dead nodes at the end of simulation time (Machado et al. 2020).

Control overhead: The percentage of the number of control packets (i.e., HELLO and TC messages) to all packets (including user data packets and control packets) during the simulation (Dyabi et al. 2015).

End-to-End delay: End-to-End delay is the average time between transmission of a packet and its reception, the time it takes the packet to achieve the destination after it leaves the source. The deadline for the end-to-end delay includes the routing and other various delays (Ayad and Bouabana-Tebibel 2012), (Jha and Kharga 2012).

Packet Loss: It is the ratio of the data lost at destination to those generated by the CBR sources. The packets are dropped when the node is not able to find the valid route to the node specified as an intermediate node in the route to reach the destination node (Gadekar and Kadam 2017).

4.2 Simulation Parameters

We used the Ns-3 (Purnama et al. 2018), (Laqtib et al. 2018) network and ECLIPSE LUNA simulator under UBUNTU 14.04 to evaluate the EEM-OLSR protocol. Network area of 640 m x 640 m with 100 nodes moving, the mobility model used in the simulation is the RWP (Random WayPoint) with a speed of mobility varied between 0 and 20 m/s for each node (see table 1).

Table 1. Simulation Parameters

Parameter	**Value**
Area size	640 x 640 m
Traffic Type	CBR
Mac Layer	802.11
Time of simulation	1000 s
Mobility Model	Random Waypoint
Initial energy	10.0 J
Simulation Time	300s
Number of Nodes	100

4.3 Simulation Results

MPRs calculation: The EEM-OLSR protocol elects the MPRs nodes based on their residual energy. EEM-OLSR provides better results than standard OLSR. The Figure 2 shows that the number of MPRs in the case of OLSR is significantly less than in the case of EEM-OLSR protocol. This proves that the EEM-OLSR protocol elects the most stable MPRs nodes compared to the OLSR protocol. We can conclude that maintaining a sufficient number of MPRs will reduce the broadcast of the Hello messages over the entire network. This will increase significantly its lifetime.

Number of Dead Nodes: Figure 3 shows that EEM-OLSR has decreased the number of dead nodes in the network relative to OLSR even though the number of nodes increased.

Average End to End delay: As can be seen from figure 4, with an increase in the number of nodes the packets are forwarded to their destination within a very short period of time using EEM-OLSR. Average end to end delay allowing nodes to choose the best paths for transmitting data. This will increase the QoS of the network.

Control overhead: Figure 5 shows that our proposed protocol reduces the overhead generated by redundant control messages, in contrast to the OLSR standard, and we can conclude that EEM-OLSR avoids an overhead flood of information.

Packet Loss: Figure 6 Shows that EEM-OLSR outperforms OLSR by considering the impact of the number of packet losses. This is due to the option of more efficient routes in EEM-OLSR compared with the OLSR protocol. We may conclude that our approach has a beneficial impact on the reduction of packet losses.

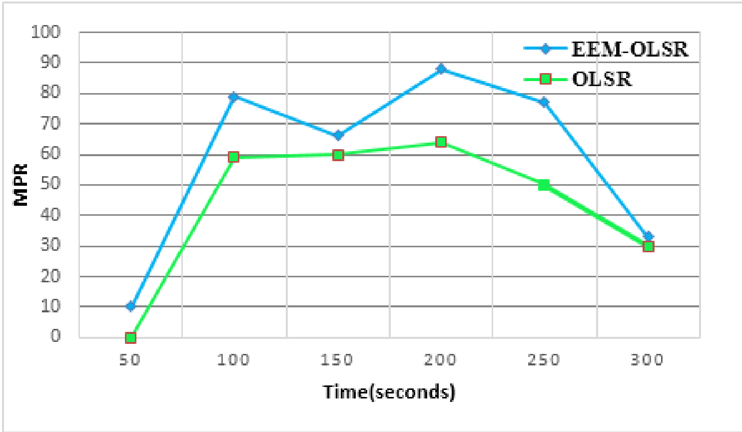

Figure 2. Impact of MPRs on network lifetime.

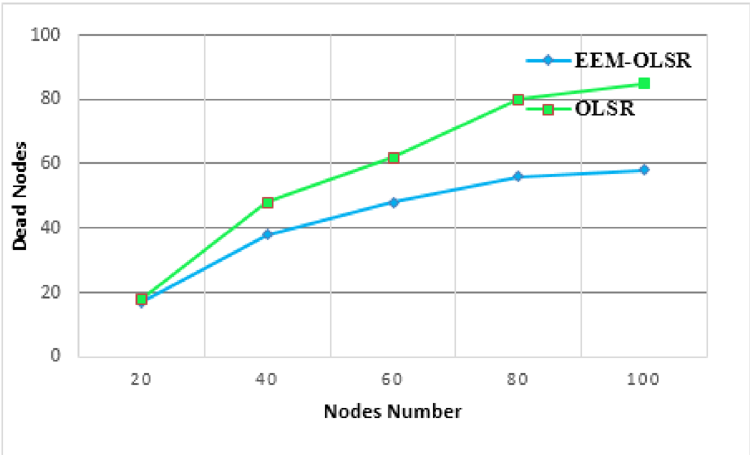

Figure 3. Number of Dead Nodes vs Number of Nodes.

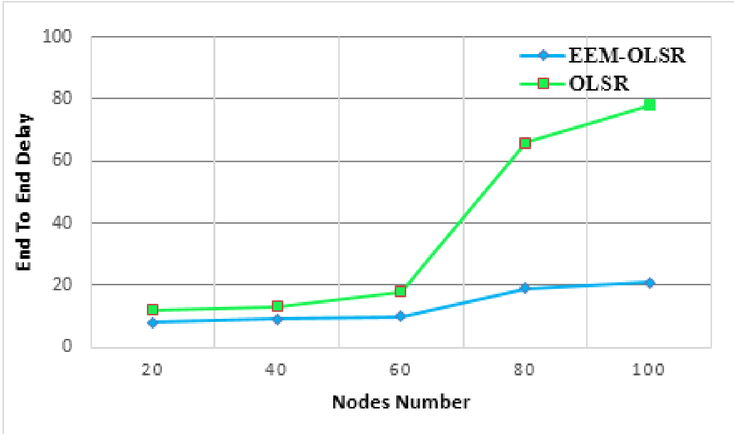

Figure 4. Average end to end delay vs Number of Nodes.

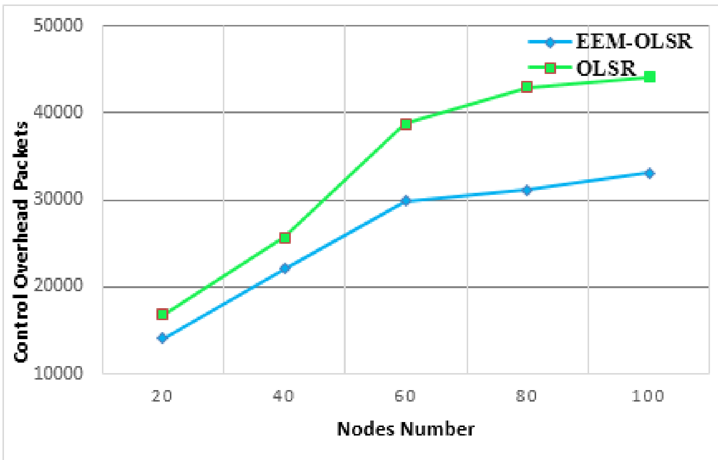

Figure 5. Control overhead vs Number of Nodes

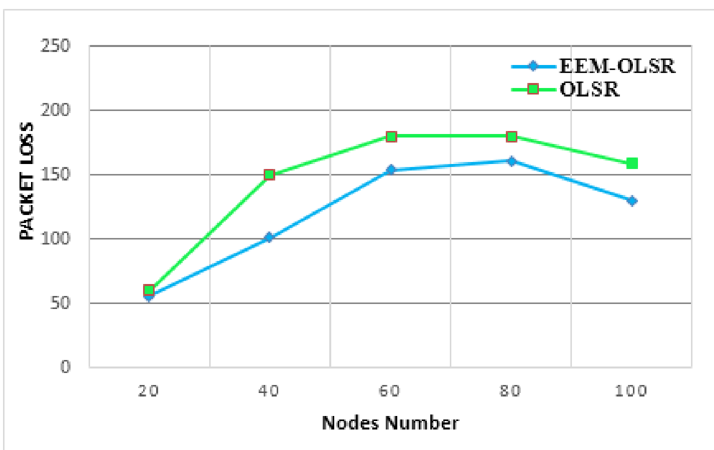

Figure 6. Packet Loss vs Number of Nodes

5. Conclusion

Our aim is to make OLSR energy efficient, in order to prolong the lifetime of Mobile ad hoc MANET. Our contribution demonstrates that the QoS parameters used in EEM-OLSR are outperformed the standard OLSR, especially when a number of nodes increases or the network becomes so mobile. EEM-OLSR is highly appropriate for mobility and considerably decreases the number of packets loss. The descent in routing overhead demonstrates that the total energy consumed is well optimized. So, the EEM-OLSR protocol provides a low overhead routing for dense networks It seems that EEM-OLSR is very suitable for dense mobile ad-hoc networks. The simulation results have confirmed the effectiveness of our proposed protocol EEM-OLSR in terms of the QoS metrics used. As a piece of future work, it can compare our proposed routing protocol EEM-OLSR by using other protocols with the help of other different parameters in wide network size with different mobility models and check its performance.

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