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Increasing network lifetime by energy-efficient routing scheme for OLSR protocol

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***Abstract*—One of the main considerations in designing routing protocols for Mobile Ad -Hoc Network (MANET) is to increase network lifetime by minimizing nodes' energy consumption, since nodes are typically battery powered. Many proposals have been addressed to this problem; however, few papers consider a proactive protocol like Optimized Link State Routing Protocol (OLSR) to better manage the energy consumption. Some of them have explored modifications to the MPRs selection mechanism, whereas others have investigated multiple cross layer parameters to increase the network lifetime. In this paper, we explored both modification to MPR selection and integrating appropriate routing metrics in the routing decision scheme to lessen effects of reason that lead to more energy consumption. Our power-aware version of OLSR is proven by simulations in NS3 under a range of different mobile scenarios. Significant performance gains of 20% are obtained in network lifetime for our modified OLSR and little to no performance gains in term of Packet Delivery Ratio (PDR).**

I. INTRODUCTION

MANET is a self-configured, infrastructure-less, network of mobile devices connected by wireless links, MANET can also be defined as, a collection of mobile wireless nodes that intercommunicate on share wireless channels. Individual devices in a mobile ad hoc network are free to move in any direction and frequently devices links changes occur. Since MANETs are highly suitable for applications involving special outdoor events, communications in regions with no wireless infrastructure, emergencies and natural disasters, and military operations. Routing is one of the key issues in MANETs due to their highly dynamic and distributed nature, in recent years, many routing protocols have been proposed for MANETs. These protocols can be classified into three different groups: proactive, reactive and hybrid. In proactive routing protocols such as DSDV and OLSR, the routes to all the destination (or parts of the network) are determined at the start up, and maintained by using a periodic route update process. In reactive protocols such as AODV, DSR, routes are determined when they are required by the source using a route discovery process. Hybrid routing protocols combines the basic properties of the first two classes of protocols into one.

In particular, energy efficient routing may be the most important design criteria for MANETs, since mobile nodes will be powered by batteries with limited capacity. Power failure of a mobile node not only affects the node itself but also its ability to forward packets on behalf of others and thus the overall network lifetime. For this reason, many research efforts have been devoted to developing energy-aware routing protocols to increase network lifetime. Most existing energy-aware MANET routing schemes are reactive. In this paper we investigate an energy-aware mechanism suitable to be integrated with a proactive routing protocol. While proactive routing is known to be inefficient to scale to large-size mobile network, it has the advantage of handling heavier traffic without extra routing control overhead, which could be significant in reactive routing. There is still substantial room of enhancing MANET proactive routing in various aspects, including energy- aware routing approaches. Specifically, our system is built as an energy-aware extension to OLSR. The energy behavior of OLSR protocol has been evaluated and many energy-efficient designing schemes for it have been presented to optimize energy consumption, some of these approaches have based on exploring the suitability of the protocol for QoS routing, to achieve the best results, these QoS protocol variants typically modify both the MPR selection criteria and the path determination algorithm. While other approach have investigated a combination of multiple network parameters that indicate energy depletion and enable effective prediction of low energy paths, by identify the reasons that lead to energy depletion in different parts of network and then choose metrics to reduce their effect.

In this paper, we are exploring modifications to OLSR protocol; we evaluate the impact of these modifications on the network performance under a wide range of scenarios. Unlike previous work, we are interested in whether changing both MPR selection and investigating cross layer parameters that effect the network lifetime. The performance of this work has been evaluated using mobility enhancements made to NS-3 simulator in terms of Network lifetime and PDR.

The rest of this paper is structured as follows. In section 2 we describe the core operation of OLSR briefly. In section 3 we shortly describe the related work. Section 4 discusses our proposed routing scheme. The performance of the extended version of OLSR is evaluated by extensive simulation; which is presented in Section 5. Finally the conclusion remarks are given in Section 6.

II. BRIEF REVIEW OF OLSR

The Optimized Link State Routing Protocol (OLSR) is table-driven protocol, developed for mobile ad hoc networks. Nodes exchange topology information with other nodes of the network regularly. Nodes determine their one-hop neighbors by transmitting Hello messages and then selects a set of them as "multipoint relays" (MPR). In OLSR, only these nodes forward topological information, providing every other node with partial information about the network. Furthermore, only these MPRs will generate link state information to be forwarded throughout the network. MPRs provide an efficient mechanism for flooding control traffic by reducing the number of transmissions required.

Nodes, selected as MPRs, also have a special responsibility when declaring link state information in the network. Indeed, the only requirement for OLSR to provide shortest path routes to all destinations is that MPR nodes declare link-state information for their MPR selectors. Additional available link-state information may be utilized, e.g., for redundancy.

Nodes which have been selected as multipoint relays by some neighbor node(s) announce this information periodically in their control messages. Thereby a node announces to the network, that it has reachability to the nodes which have selected it as an MPR. In route calculation, the MPRs are used to form the route from a given node to any destination in the network. Furthermore, the protocol uses the MPRs to facilitate efficient flooding of control messages in the network.

By these optimizations, the amount of retransmission is minimized, thereby reducing overhead as compared to link state routing protocols. Each node will then use this topological information, along with the collected Hello messages, to compute optimal routes to all nodes in the network. The protocol is particularly suitable for large and dense networks, since the MPRs technique works well in such as context.

III. RELATED WORK

In routing protocols for mobile networks, the need of energy efficiency is a problem concerning with the constraints imposed by battery capacity and heat dissipation, hence many energy- efficient routing protocols proposed, which modify the routing design to take energy costs in consideration. We are more interested in investigating the MANET protocol: OLSR, many works have been conducted on modifying both the MPR selection mechanism and the path determination algorithm have proposed a novel energy aware Multipoint Relay selection mechanism by modification in this mechanism to pick out MPRs based on their residual energy values. While some others modify the route determination algorithm by selecting paths based on the sum of residual energy values of their nodes. However and have been interested in whether changing both MPR selection and path determination algorithm for best performance.

Recently some researches have focused on exploring multiple metrics routing schemes especially for proactive protocols, as OLSR such as in where the authors, for increasing the network lifetime without loss of performance, take into account cross layer parameters which contain residual energy of nodes, network congestion and network topology parameters, and then modify OLSR in order to make routing decisions according to these parameters. They use a weight-based routing scheme, when a weight is assigned at each node dynamically. While routing tables of nodes are updating according to the path costs computed using the weights of nodes received at each time period. The metrics contribute additively to the node’s weight computation, with some multiplicative factors to change the importance of the routing metrics by varying their values, as shown in Equation 1.

$$wi = \alpha 1 \frac{Li}{Lmax} + \alpha 2 \left(1 - \frac{Ei}{Emax}\right) + \alpha 3 \frac{Di}{Dmax} \quad (1)$$

Where $\sum_{i=1}^{3} \alpha 1 = 1$,Li is the number of packets in the MAC queue,Ei is the residual energy at each time and Di is the node degree. Lmax is the maximum considerd MAC queue size, Emax is the initial energy of a node and Dmax is the number of nodes in the network minus one.

In order to not increasing network overhead, they embed nodes weights to the TC packet that are periodically generated by each node. So TC packet is extended to include the field for the updated weights, which is locally computed using equation (1) of the originator node. And the Topology tuples are also extended to take a new field for the weight of the originator node.

In the last step, based on the path costs computed from the nodes weights, routing tables should be updated rather than on number of hops. And should also include path costs to the destination address instead of the number of hops, where path cost is define as the sum of the intermediate nodes’ weights along the path.

IV. IMPROVEMENT NETWORK LIFETIME BY MODIFICATIONS TO OLSR

We made essentially two modifications to OLSR: similar to we take into account these cross layer parameters which contain residual energy of nodes, network congestion and network topology parameters, and then we added modifications to the MPR criteria.

Based on we have modified routing tables updating relying on the path costs computed from the nodes weights which have been computed as shown in Equation 1, hence a new algorithm have been proposed that assigns cost equal to 1 to paths towards the 1- hope neighbours. Next is examines the topology tuples given by the topology table and three cases are considered to update the routing table. The first one occurs when there is an entry in the routing table for the originator node of the topology tuple. In this case, a new entry is added to the routing table for the destination node of TC with cost equal to the sum of the cost corresponding to route to the originator node and the originator node’s weight. The second case, occurs when there are entries for both the originator and the destination node of the topology tuple. Then, the algorithm chooses greedily the new path detected through the originator ode or it maintains the old path, by comparing their costs. Finally, in the case where there aren't entries neither for the originator node nor the destination node, no new entry is created.

Our contribution on this work is at MPR selection level. According to OLSR standard each node has a parameter called 'willingness', indicates its availability to carry traffic on behalf of other nodes, the value of a node's willingness parameter is an integer between 0 and 7, A node with willingness equal to 0 must never be selected as MPR by any node. A node with willingness equal to 7 must always be selected as MPR. But by default in OLSR standard all willingness values are set to a default value equal to 3, and it is still constant along the simulation. We put in the willingness variable the available residual energy of the node which be taken each time the HELLO packet is generated, using the Equation 2.

$$Willingness = round\left(\frac{Ei}{Emax} * 7\right) \qquad (2)$$

Where Ei is the residual energy at each time and Emax is the intial energy of the node.

V. SIMULATION RESULTS

As mentioned before we used NS3 network simulator to evaluate our modified version of OLSR. We considered three performance metrics to evaluate this proposition, which are:

- Average Node Residual Energy : total residual energy[J]/number of nodes
- Packet Delivery Ratio (PDR): the ratio of the number of packets delivered to the destination nodes over the number of packets sent by the source nodes.
- Network Lifetime: the time until the battery of a mobile node depletes.

We simulated a MANET with 30 nodes in a dense 1500 x 1500 meter square area. There are 5 UDP sources generating packets of 512 bytes with different data rates. We executed the simulations to evaluate the performance of our modified routing scheme compared to the standard OLSR and the precedent work (without modification in MPR selection). The common simulation parameters of the two variations are summarized in Table 1 below.

TABLE I. SIMULATION PARAMETERS

Area	1500 x 1500
Nodes	30
Traffic sources	5
Traffic Type	CBR / UDP
Packet Size	512 bytes
Start of Traffic	50 sec
Transmission Power	7.5 dbm
Link bandwidth	2 Mb/s
Initial Node Energy	0.4 Joules

In the first setup, and in order to evaluate the change of the average residual energy over time, we consider a mobile scenario where mobile nodes move in the area based on a Random Waypoint Mobility model with a speed of 20 m/s, with the parameters described in Table 1, in addition the source nodes send 10 packets/sec, and the simulation time is set to 300 sec.

We present the results in Figure 1. It's obvious that our modified scheme get the most average residual energy. we notice that at the end of the simulation, by our modified OLSR there are about 20% energy savings compared to the standard OLSR, and about 7% energy savings compared to the precedent work (without modification in MPR selection), as mentioned in Table 2 below.

TABLE II. FINAL AVERAGE RESIDUAL ENERGY

Protocol	Final average residual energy
Standard OLSR	0.0344893 J
modified OLSR [8]	0.0390780 J
our modified OLSR	0.0429491 J

In the second setup, and in order to evaluate the increase of the network lifetime, but at the same time without loss of performance in terms of PDR, we consider three different scenarios in terms of mobility: low, medium and high mobility. In the low mobility scenario, mobile nodes move based on a Random Waypoint Mobility model with a speed of 5 m/sec. In the medium mobility scenario, nodes move with a speed of 15 m/sec. And in the high mobility scenario, nodes move with a speed of 30 m/sec. These scenarios have common parameters described in Table 1. The simulations are done with 3 different traffic rates, which are: 10 packets/sec, 15 packets/sec and 20 packets/sec, to study the effect of traffic rate. For network lifetime measurement, we execute the simulations until a node is completely depleted.

In Figure 2b we observe that our modified OLSR outperform the others in network lifetime, in the case of low mobility scenario, thus we obtain a gain that achieves over 23% compared to the standard OLSR, this is explained by the selection of alternative paths, and preferring the more residual energy node value when selecting the MPR nodes in our modified OLSR, although the chosen path maybe longer that another which have less sum residual energy of their nodes. In term of PDR we have also a bit little improvement that may reach to 7% as observed in Figure 2a, due to the fact that the concept of the network congestion which was taken on consideration when we make the weight of node through the MAC queue utilization, thus larger weight was assigned to nodes with high MAC queue utilization, which means the congested nodes, we know how the congested network participates in loss of packets. In the medium mobility scenario case (Figure 3) we attain closely the same results as in the low mobility speed, with a bit little decrease in both gain in network lifetime and PDR due to the fact that the nodes move faster. In the high mobility scenario (Figure 4) is obviously expected that the performance be lower in comparison with the precedent cases, when the mobility force dynamic change of MPR node selected, especially in our modified OLSR, because it can't learn the weight and the residual energy in nodes fast enough to take the routing decisions in high mobility conditions, therefore we have more packet losses.

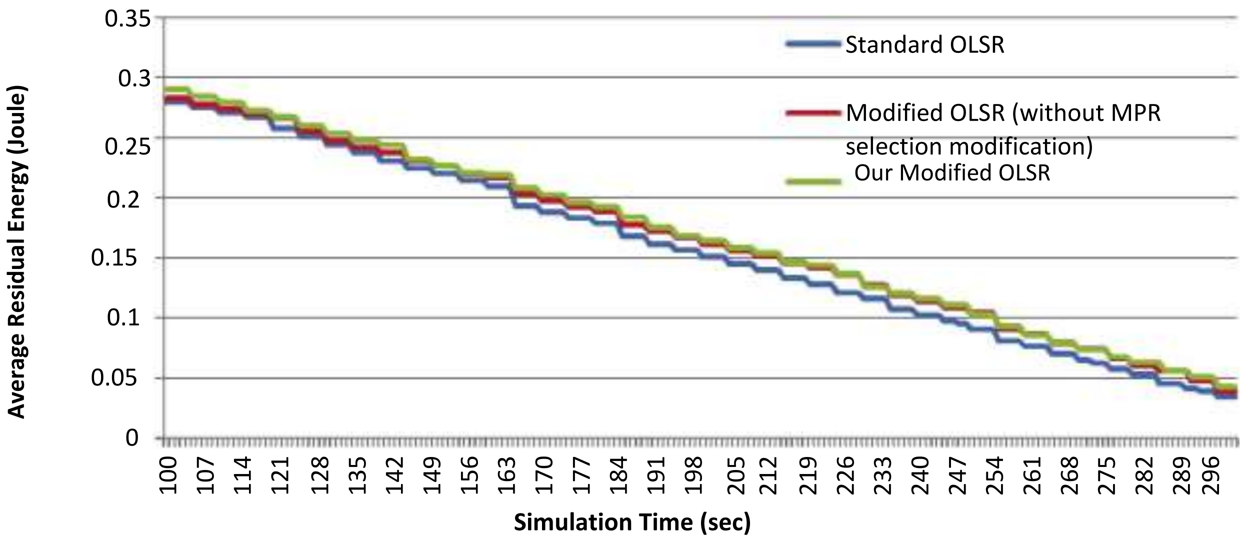
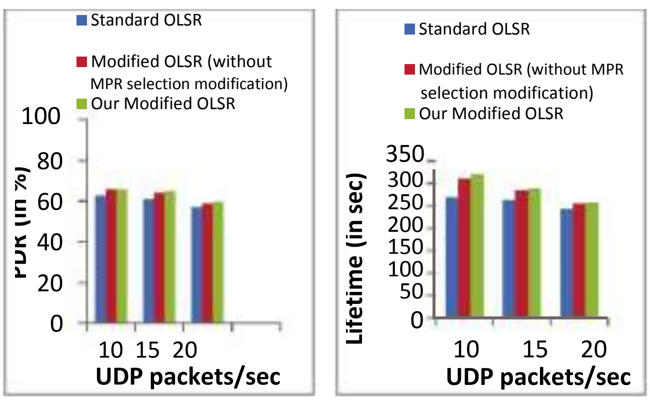


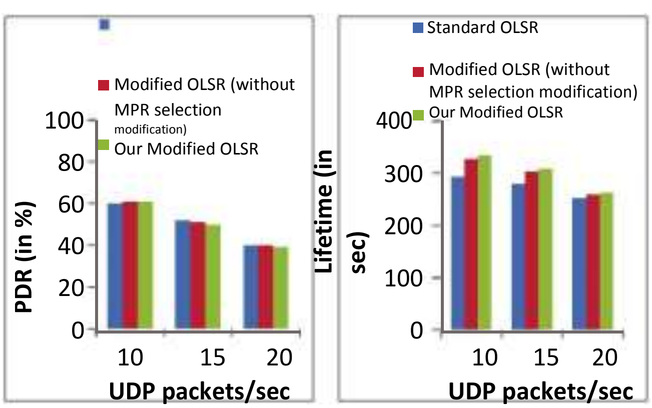
Fig. 1. Average Residual Energy



(a)PDR for various traffic rate

(b)Network Lifetime for various traffic rate

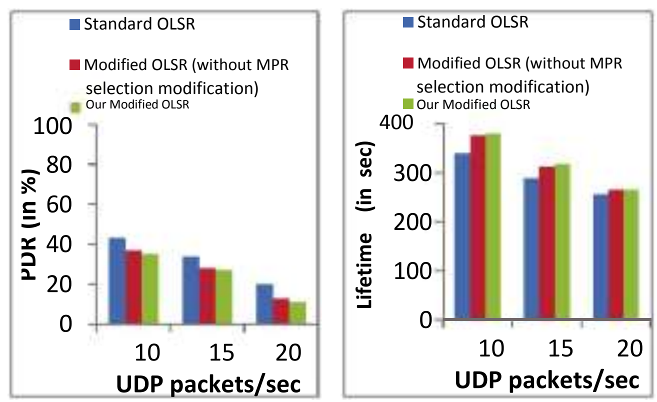
Fig. 2 . Low Mobility Scenario



(a)PDR for various traffic rate

(b)Network Lifetime for various traffic rate

Fig. 3 . Medium Mobility Scenario



(a)PDR for various traffic rate

(b)Network Lifetime for various traffic rate

Fig. 4 .High Mobility Scenario

VI. CONCLUSIONS

In this paper we demonstrated an effective and efficient energy-aware the proactive MANET routing protocol OLSR, by a mechanism that aim to increase network lifetime and enhance performance, we are interested in integrating appropriate routing metrics in the routing decision scheme to reduce effects of reason that lead to more energy consumption, via adopting three salient parameters which are: residual energy, network congestion and network topology. Then we proposed a novel MPR selection policy that allows network lifetime to be preserved for longer time, by involve the residual energy in MPR selection criteria through the willingness variable. We evaluated the modified OLSR under a range of different scenarios, varying traffic load and mobility pattern, we compared our modified OLSR, in terms of network lifetime and PDR, with the standard

OLSR and the precedent work (without modification in MPR selection). Our simulation showed that our modified OLSR is able to prolong network lifetime pretty more than precedent work without significant loss of PDR. We are currently extending our OLSR modifications to investigate more cross layer parameters that allow to prevent the energy depletion and increase the network lifetime.

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