A new approach for energy efficiency in MANET based on the OLSR protocol

Sofiane Hamrioui*
Department of Computer Science,
Houari Boumediene University (USTHB),
Algiers, Algeria
and
Laboratoire de Recherche en Informatique (LARI),
Mouloud Mammeri University (UMMTO),
Tizi Ouzou, Algeria
Email: s.hamrioui@gmail.com
*Corresponding author

Mustapha Lalam
Laboratoire de Recherche en Informatique (LARI),
Mouloud Mammeri University (UMMTO),
Tizi Ouzou, Algeria
Email: lalamustapha@yahoo.fr

Pascal Lorenz
GRTC, University of Haute Alsace (UHA),
Colmar, France
Email: Lorenz@ieee.org

Abstract: One of the critical issues in Mobile Ad hoc Network (MANET) is the energy efficiency. The challenge is how to extend the limited lifetime of energy in mobile nodes. We proposed a new approach to minimise the energy consumption called EM-OLSR (Energy Efficiency in MANET by improving OLSR protocol). EM-OLSR is based on the OLSR routing protocol and adds a new energy fairness parameter to the Multi-Point Relay (MPR) technique. This new parameter is used by our approach and allows fairness energy consumption in the same set of MPR. In this mechanism, nodes with low power are prevented in the routing process in order to maintain similar power values for all the mobile nodes. The simulation results showed that our proposed EM-OLSR approach allow significant power saving up to 14% and an increase in average lifetime of a mobile node as high as 22%.

Keywords: MANET; OLSR protocol; EM-OLSR; energy efficient; performance.


Biographical notes: Sofiane Hamrioui since 2008 is a teacher in the Department of Computer Science, University of Science and Technology Houari Boumediene, Algiers, Algeria. He is enrolled in doctoral thesis since 2008 and looks as part of its research issues in mobile and ad hoc wireless networks as like interactions between protocols, performance protocols, quality of services and saving energy. He received the engineering degree in computer science option parallel and distributed systems in 2004 and the magister degree in computer science in 2007 from the Mouloud Mammeri University of Tizi Ouzou, Algeria.

Mustapha Lalam joined the University of Tizi Ouzou, Algeria in 1993, where he is currently a Professor at the Computer Science Department in the University of Tizi Ouzou. He received the Masters degree in Computer Architecture from the High School of Computer Science, Algiers, Algeria, in 1980 and the PhD degree in Computer Science from University of Toulouse, France, in 1990. He has been involved in research and Development of Computer Architecture, Distributed Systems and Mobility management for Wireless Mobile Computing and Communications.
1 Introduction

In Mobile Ad hoc Network (MANET), the main objective of routing protocols is the routing of the data towards any point in the network. The obvious solution is the routing towards the destination by using the minimum possible number of the hops. It was the default choice in the IP networks and recently in the MANET. This approach is interesting since it is well studied and allows minimising routing time. But currently one of the principal concerns of the MANET is the energy efficiency to get better performance. Then, it is very important to integrate this functionality in the proposed routing protocols.

Minimising power consumption is very important issue in MANET (Ahmad, 2005). Significant progress was made in the design of least expensive solutions in energy consumption for MANET (Jones et al., 2001; Kubisch et al., 2003; Zheng and Kravets, 2003). Several of them aim at protocols different levels of OSI model such and routing protocols (Mohapa and Krishnamurthy, 2005). We exploit this policy in order to propose a new approach for better energy consumption in the MANET.

The proposed approach is called Energy Efficient for MANET by improving OLSR (EM-OLSR) which is an improvement of the Optimised Link State Routing (OLSR) protocol (Clausen et al., 2001; Tonnesen, 2011), for better energy conservation in MANET. This new approach is essentially based on the parameters of the communication environment especially the communication distance of the mobile nodes and their mobility. We added another parameter to the MPR technique used by this protocol. This new parameter allows fair energy consumption in the same set of Multi-Point Relay (MPR). With this adaptation, nodes with low power are prevented in the routing process in order to maintain similar power values for all the mobile nodes.

In what follows, after a short presentation of the context, we give the most significant approaches proposed for energy saving in MANET and oriented network level. Then we turn to the presentation of our EM-OLSR approach and it implementation in NS-2. We conclude our paper by studying the impacts of EM-OLSR on the MANET performance, particularly on the network reliability and the energy consumption.

2 Presentation of the context

A MANET (Ahmad, 2005) is a particular case of wireless network where each node communicates over the radio interface, directly communicate each other without any centralised administration. Every node acts as a router for establishing the connection between node and a host from source to destination. The protocol communication will offer an autonomous network conceived and formed by the set of the participant nodes.

The most significant functionality of MANET is routing. The routing gathers a set of procedures which start and maintain communications between two nodes. In MANET, it is necessary to create new protocols which guarantee the new needs of applications with taking into account the new parameters of the network (like mobility, asymmetrical links, hidden nodes, etc). It is the objective of MANET routing protocols which can be classified according to several criteria in various families, the most used in MANET are: the link state/distance vector classification and Proactive/Reactive classification.

The complexity of MANET makes it difficult to design protocols that are able to handle all the problems, particularly to ensure Quality of Services (QoS) due to the model of architectures. The different QoS solutions (Fouial, 2004; Li, 2006) for such networks can be classified in several sub-groups according to the concerned layer. Difficult to guarantee of an appropriate QoS in MANET because in such context it is necessary to take many aspects such as the medium unpredictable properties, the nodes mobility, the hidden and exposed terminals problems, the security and the energy consumption.

To offer efficient energy consumption in MANET, it is possible to use communications protocols stack. The suggested solutions (Li and Halpern, 2001; Singh et al., 2010; Hwang et al., 2011) are roughly classified in three families: energy control protocols, routing protocols with energy efficiency and energy management protocols. All these suggested approaches for MANET aim to an efficient energy consumption.

In the following section, some suggested approaches for better energy consumption in MANET are given. In our work, we are interested only on the approaches aiming for routing level.

3 Related work

The Connected Dominating Set (CDS) approaches (Wu and Li, 1999; Cardei et al., 2002) use vicinity or topology information to determine the set of nodes which form a CDS for the network, where any node is either a CDS member or a direct neighbour of at least one of the members. Nodes in the CDS are regarded as routing pivots and are constantly
The Geographic Adaptive Fidelity (GAF) (Xu et al., 2001) is another technique that exploits the knowledge of nodes geographical positions to choose coordinators. Nodes geographical positions are used to divide the complete topology into fixed size zones (fixed geographical sector). The zones are created so that any two nodes in two adjacent zones can communicate. The nodes radio range, assumed fixed, dictates the size of a zone. Only one node in each zone must be awake and can be the coordinator. Thus, by exploiting the knowledge of geographical positions, GAF simplifies the coordinator selection procedure. Nodes in the network still commute between themselves for the work of the coordinator. The performance of GAF is biased (partial) because of the way with the zones are created and can lead to more load on some nodes than on others.

SPAN (Chen et al., 2001) is a distributed and random algorithm for coordinators choice. Each node decides to be a coordinator or not. The transition between the two states is based on probabilities. The equity is ensured in making the node with highest energy the most probable to be a coordinator. The other criterion employed in coordinators choice is the value which a node adds to the total connectivity of the network. A node connecting more nodes will have more chances to be elected coordinator. The random concept is employed to avoid simultaneous multiple coordinators. For efficiency, these emissions are integrated in the control messages of the routing protocol (piggy-backed).

Transmission power control approach is based on transmission power control approach. Flow argumentation Routing (FAR) (Chang and Tassiulas, 2000) which assumes a static network and finds the optimal routing path for a given source-destination pair that minimises the sum of link costs along the path. Online Max-Min (OMM) (Li et al., 2001) which achieves the same goal without knowing the data generation rate in advance. Power aware Localised Routing (PLR) (Stojmenovic and Lin, 2001) is a localised, fully distributed energy aware routing algorithm but it assumes that a source node has the location information of its neighbours and the destination and Minimum Energy Routing (MER) (Doshi and Brown, 2002) addresses issues like obtaining accurate power information, associated overheads, maintenance of the minimum energy routes in the presence of mobility and implements the transmission power control mechanism in DSR and IEEE 802.11 MAC protocol.

Localised Energy Aware Routing (LEAR) protocol (Woo et al., 2001) is based on DSR but modifies the route discovery procedure for balanced energy consumption. In LEAR, a node determines whether to forward the route-request message or not depending on its residual battery power (Er). Conditional Max-Min Battery Capacity Routing (CMMBCR) protocol (Toh, 2001) uses the concept of a threshold to maximise the lifetime of each node and to use the battery fairly.

In the work of Sumathi and Thanamani (2011) a new version of AODV for energy efficient is proposed to reduce energy expenditure due to overhearing. The proposed algorithm controls the level of overhearing. It reduces energy consumption without affecting quality of route information. This algorithm enables the sender to select no overhearing, unconditional overhearing or probability based overhearing for its neighbours. It is specified in the ATIM frame’s sub type field and made it available to its neighbours during ATIM window. Number of overhearing nodes is controlled by probability based overhearing method.

EOLSR (Mahfoudh and Minet, 2008) is a variant of OLSR, where MPR selection and path calculation is determined by both a node’s residual energy level and its number of neighbours. The key insight here is that sending data to a node also forces all its neighbours to consume energy in overhearing the data packet. The simulation results reported show that combining the new path calculation with the modified MPR selection yields the best performance. EOLSR suggests that a node’s residual energy level is propagated by extending the protocol control messages, but does not discuss how accurate this information is.

De Rango et al. (2008) propose two novel mechanisms for the OLSR routing protocol, aiming to improve its energy performance in MANET. They propose a modification in the MPR selection mechanism of OLSR protocol, based on the willingness concept, in order to prolong the network lifetime without losses of performance (in terms of throughput, end-to-end delay or overhead). Additionally, we prove that the exclusion of the energy consumption due to the overhearing can extend the lifetime of the nodes without compromising the OLSR functioning at all. A comparison of an Energy-Efficient OLSR (EE-OLSR) and the classical OLSR protocol is performed, testing some different well-known energy aware metrics such as MTPR, CMMBCR and MDR.

In conclusion, none of the previous approaches has addressed all or even some of the parameters of the environment communication involved in the rapid consumption of the energy. Some works have only studied the parameters related to the network traffic. In fact, modelling of these parameters and their behaviour in an approach to energy conservation will be a great contribution for MANET performance. Our work focuses precisely on these parameters in order to provide an efficient and fairness energy solution in terms of energy consumption enabling longer life of the network. By improving the OLSR routing protocol with adding a new threshold to it MPR technique, we show that it is possible to ensure greater and fairness energy between nodes, then we get a longer lifetime of nodes in the MANET.

4 Presentation of EM-OLSR

Our EM-OLSR improvement uses the network layer by adapting the OLSR protocol. In link state protocols, each node declares the direct links with its neighbours to the whole network. In case of OLSR, nodes declare only a sub-part of their neighbouring using the MPR technique.
They primarily consist that each node must ignore a set of links and direct neighbours, which are redundant for the calculation of the routes with shorter path. More precisely, in the set of neighbours node, only one subset of these neighbours is considered as relevant. This subset is selected in order to be able to reach all the neighbouring with two hops (all neighbours of the neighbours). This subset is called the set of MPR. An algorithm for MPR calculation is given by Qayyum et al. (2002).

Our solution takes the strengths of the OLSR protocol. In addition to the MPR technique used by this protocol, we decided to use another parameter that allows fair energy consumption in the same set of MPR. This new parameter get its value according to the parameters of the communication environment used such as the nodes number, the distance of the communication, the mobility of nodes, the type of application, the rate of interference, etc. With this new parameter, the energy consumption could be optimised to all nodes of the same multi point. The modelling of our solution and the pseudo programme is given below.

For each mobile node $i$, the most important parameters in the communication environment which can really influence mostly the energy consumption are the speed of the mobility $M_i$ and the distance of communication $D_i$. We take into account these two parameters to get the first part of our fairness threshold as follows:

$$ F(D_i, M_i) = \frac{M_i + D_i}{\alpha \sum_{j=1}^{N-1} D_{ij} + \beta \sum_{j=1}^{N-1} M_{ij}} $$

(1)

where:

$M_i$: the speed mobility of the node $i$

$D_{ij}$: is the average distance between the node $i$ and $t$ nodes.

It is calculated with the following function:

$$ D_i = \frac{\sum_{j=1}^{N-1} d_{ij}}{N} $$

(2)

$N$: the nodes number in the network;

$d_{ij}$: the distance between the nodes $i$ and $j$.

$\alpha$ and $\beta$: used to make the mobility and the distance parameters more or less important.

Equation (1) gives, for the node $i$, the ratio between the energy dissipated locally and that dissipated other ways.

In a MANET, we know that there are not only the distance between the nodes and their mobility which is leading to high energy consumption, but there are also others parameters that affect this consumption. For these reason, our proposed fairness threshold take into account also the maximum of these parameters. Note by:

$L$: the number of parameters which influences the communication environment;

$P_i$: parameter number $i$ in the communication environment;

$E$: the set of the parameters $P_i$ defined as follows:

$$ E = \{P_1, \ldots, P_L\} $$

(3)

$V_i$: the numerical value associated to $P_i$, it is calculated as follows:

$$ V_i = \begin{cases} +1 & \text{if } P_i \text{ participates in the rapid} \\ 0 & \text{dissipation of the energy} \end{cases} $$

(4)

The average value of the influences of all the $P_i$ auxiliary parameters is noted by $G$ and calculated as follows:

$$ G = \frac{\sum_{i=1}^{L} V_i}{L} $$

(5)

Form equations (1) and (5), the fairness threshold $S_i$ for each node $i$ is obtained as follows:

$$ S_i = F(D_i, M_i) + G $$

(6)

We give in what follows a pseudo algorithm which shows how our new fairness parameter $S$ is used by the EM-OLSR protocol. We assume also that

$S_{RM}$: the Set of all the Multipoint Relay;

$C_{S_{RM}}$: the Cardinal of the $S_{RM}$;

$node_i$: the node number $i$;

$Pwr_i$: the residual energy (current) of node $i$.

If a change is detected in the two hops vicinity then

(1) Calculate $S_{RM}$/the set of multipoint relays/

$$ C_{S_{RM}} := \sum i \{\text{nodes number in the } S_{RM}\} $$

While ($C_{S_{RM}} > 0$) do

For $i := 1$ to $C_{S_{RM}}$

Calculate $S_i$ [see the formula (6)]

$Pwr_i$: energy remaining of node $i$;

If ($(Pwr_i - S_i) < 0$) then

$S_{RM} := S_{RM} - node_i$;

$C_{S_{RM}} := C_{S_{RM}} - 1$;

End

End for

End While

Go To (1);

End If

[The following code of EM-OLSR]

5 Incidences of EM-OLSR on MANET performance

The main goal of our experiments is to study the performances of EM-OLSR and show its impacts on the
reliability and the energy consumption in MANET. We evaluate our proposed approach in term of packet lost, energy consumption and the life time of nodes in the network. First, we need to put $\alpha$ and $\beta$ to 1 and the set $E$ is empty. This is to validate our fairness threshold $S$ with the basic parameters which are the communication distance and the mobility at the first time.

### 5.1 Simulation environment

We used the Network Simulator (NS-2; http://www.isi.edu/nsnam/ns/) from Lawrence Berkeley National Laboratory (LBNL). The extension includes a set of routing protocols for MANET network and includes the 802.11 MAC protocol. The link layer of the simulator implements the IEEE 802.11 MAC protocol standard with the Distributed Coordination Function (DCF). All nodes communicate through wireless links in half-duplex with an identical band bandwidth of 1 Mb/s. For our simulations, the effective transmission range is 250 m. We have also assumed an interference range of 550 m, and all nodes in the area of this distance of a transmitting node will find the medium busy. Each node has a queue buffer link layer of 50 packets managed with a mode droptail (Floyd and Jacobson, 1993). The technique of scheduling packet transmissions is FIFO type. The propagation model used is the two-ray ground model (Bullington, 1957).

Traffic sources are Continuous Bit-Rate (CBR) and the number of source – destination pairs and the packet sending rate in each pair are varied to change the offered load in the network. All traffic sessions are established at random times near the beginning of the simulation run and they stay active until the end.

The mobility model uses the random waypoint model (Hyytiä and Virtamo, 2005) in a rectangular field. The nodes move in an area of 2200 m $\times$ 600 m field. Here, each node starts its communication from a random location to a random destination. Once the destination is reached, another random destination is targeted after a pause. To change mobility, we vary the pause time which affects the relative speeds of the mobiles.

Simulations are run for 1000 s; each data point represents an average of three runs with identical traffic models, but different randomly generated mobility scenarios. For fairness, identical mobility and traffic scenarios are used across protocol variations when comparisons are made.

We will evaluate three key performance metrics: protocol reliability, power consumption and network life time.

### 5.2 Protocols reliability

#### 5.2.1 Speed variation

For this simulation a pause Time = 50 s and a network load = 20 sources.

For weak mobility of nodes, the network presents a rather high stability; links failure is less frequent than in the case of a high mobility. Consequently, the fraction of data loss is smaller when nodes move with low speeds, and grows with the increase of this mobility. We note that packets loss rates for the two protocols (OLSR and EM-OLSR) are almost similar. Based on these results, we deduce that the reliability of EM-OLSR is influenced by the speed of the nodes mobility with the same way that OLSR. Then our solution, although it aims to improve the energy consumption in the network, it does not decrease the reliability of the OLSR protocol.

#### 5.2.2 Pause time variation

Figure 2 shows the data loss rate when the pause time varies using nodes with speed = 2 m/s and a network load = 20 sources set.
reliability of OLSR but it doesn’t degrade it too. Indeed, the essential objective of our solution is the energy consumption in the network.

5.2.3 Variation of the sources CBR number

Figure 3 gives rate of lost packets when the number of sources varies, using: speed = 2 m/s and time of pause = 20 s.

Figure 3 shows that the rate of loss relatively increases with the increase of CBR sources number. Indeed the increase in the number of links leads to an overloaded network, which favours packets collisions, and thus increases data loss rate. As in the two previous cases, the rate of packets loss for the both protocol (OLSR and EM-OLSR) is almost the same. We conclude that our solution EM-OLSR is influenced by the network overload as like OLSR. Where the network has more overloads, EM-OLSR does not improve the reliability but it does not degrade it too.

5.3 Energy Consumption

According to the results from the preceding study, we build the following scenario for the study of the power consumption.

Number of nodes = 10 nodes, number of CBR sources = 3 sources, maximum speed = 2 m/s, pause time = 50 s, simulation duration = 1000 s, initial power = 20 J.

5.3.1 Total energy of the network

On this graph, the total energy of the network before improvement decreases faster than after improvement during the time interval (0,600 s). The difference in consumption during this interval is due to the intelligent management of this energy with the addition of our equity parameter to the MPR technique, and then it will extend the energy consumption of nodes in time. During the interval (600 s, 1000 s), we notice that the energy level of the network before improvement stabilises because of its loss of connectivity.

This loss of connectivity is the fact that the energy of nodes is used with unfair way, leading to depletion of the total energy of nodes the most solicited by the protocol OLSR. This explains the failure of network connectivity, which stops the activity in the network. Indeed, when t = 600 s, the number of working nodes in the network before improvement is 4, and these nodes probably do not communicate because of their distance. During the same time interval, the energy in the network with our EM-OLSR improvement continues to decrease, which proves that the nodes are communicating.

We conclude from the energy evolution in the interval (0,600) that our approach EM-OLSR allows to save about 14% of the total energy in the network.

5.3.2 Network’s Life time

Figure 5 depicts the lifetime of the network. It shows that the number of working nodes in the network before improvement decreases starting from t = 350 s and stabilises at t = 700 s with only three nodes because of connectivity loss. This number of nodes start to decreases again at about t = 900 s. On the other hand, for our proposed protocol, the number of working nodes in the network remains constant until t = 750 s, then it starts to decrease rapidly.

Due to the utilisation of our fairness threshold, our proposed approach EM-OLSR favours nodes with a higher residual power and carries out its equitable use. The results of the simulations showed that our approach allows an increase of 22 % in average lifetime of a node, and consequently allows increasing the lifetime of the whole network.
6 Conclusion and future works

In this paper, we proposed a new approach called Energy Efficiency for MANET by improving OLSR (EM-OLSR) which is an improvement for the OLSR protocol for better energy conservation in MANET. This new approach is essentially based on energy quality of the mobile nodes and their mobility. We added another parameter to the MPR technique used by this protocol. This new parameter allows fair energy consumption in the same set of MPR. With this adaptation, nodes with low power are prevented in the routing process in order to maintain similar power values for all the mobile nodes. After implementation and simulation of this improvement, we studied its incidences on a MANET performance, more particularly on power consumption in the network. Obtained results are very conclusive and satisfactory: reduced data loss rates, significant power saving up to 14% and an increase in an average lifetime of a mobile node as high as 22%.

As perspectives, we will continue our work with the modelling of the maximum number of communication environment parameters. We will try to reflect as much as possible the communication environment with a more realistic set. Also, we plan to conduct a study on the communication environment of MANET to better assign meaningful values to the two constants $\alpha$ and $\beta$. In fact, these values must be deduced mainly depending on the complexity of the MANET and the type of the application covered by the network. Finally, our EM-OLSR protocol will be tested on a real platform; in this case, we really need to produce all the phenomena supposed exist in a real MANET.

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